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EDEXCEL INTERNATIONAL A LEVEL MATHS: QUESTIONS BY TOPIC

Work, Energy & Power (M2.3)

International A Level Mathematics · M2: Mechanics 2 (WME02)

25 questions · 229 marks · Mark schemes included

Past papers January 2020 - June 2025 · 1 sub-topic

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HOW TO USE THIS BOOKLET

Questions are grouped by sub-topic and run from the lowest to the highest mark tariff, then oldest paper first.

Click any row below to jump straight to that sub-topic or question.

On every question page, click ANSWER in the top-right corner to jump to its mark scheme; < QUESTION brings you back.

A gold bar in the left margin marks exactly where the question sits on the original page.

Diagrams, graphs, grids and tables are printed exactly as they appear in the original papers.

Each question is filed under its main topic; longer questions may also test skills from other topics.

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QUESTIONS

25 questions · 229 marks · 1 sub-topic

SUB-TOPIC M2.3a

WORK, ENERGY & POWER

Sub-topic M2.3a · 25 questions · 229 marks · lowest tariff first



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1. A cyclist and his bicycle have a total mass of 75 kg. The cyclist is moving down a straight road that is inclined at an angle α to the horizontal, where $\sin \alpha = \frac{1}{15}$

The cyclist is working at a constant rate of 56 W. The magnitude of the resistance to motion is modelled as a constant force of magnitude 40 N. At the instant when the speed of the cyclist is $V \text{ m s}^{-1}$, his acceleration is $\frac{1}{3} \text{ m s}^{-2}$

Find the value of V .

(5)

Question 1 continued

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(Total 5 marks)

Q1



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1. A motorcyclist and his motorcycle have a combined mass of 480 kg.

The motorcyclist drives down a straight road that is inclined at an angle θ to the horizontal, where $\sin \theta = \frac{1}{12}$, with the engine of the motorcycle working at 3.5 kW. The motorcycle is moving at a constant speed of $V \text{ m s}^{-1}$. The resistance to the motion of the motorcycle is modelled as a constant force with magnitude $20V$ newtons.

Find the value of V .

(5)

Question 1 continued

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(Total 5 marks)

Q1



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2. A car of mass 900 kg is moving down a straight road which is inclined at an angle α to the horizontal, where $\sin \alpha = \frac{1}{12}$

The engine of the car is working at a constant rate of 15kW.

The resistance to the motion of the car is modelled as a constant force of magnitude 400 N.

Find the acceleration of the car at the instant when it is moving at 16 m s^{-1}

(5)

Question 2 continued

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(Total 5 marks)

Q2



(Total for Question 1 is 5 marks)

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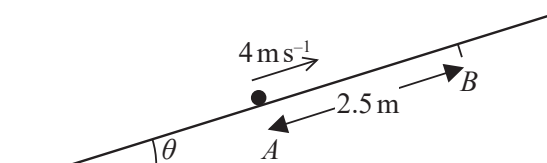


Figure 1

A rough straight ramp is fixed to horizontal ground. The ramp is inclined at an angle θ to the horizontal, where $\sin \theta = \frac{1}{7}$. The points A and B are on a line of greatest slope of the ramp with $AB = 2.5$ m and B above A , as shown in Figure 1. A package of mass 2 kg is projected up the ramp from A with speed 4 m s^{-1} and first comes to instantaneous rest at B . The coefficient of friction between the package and the ramp is μ . The package is modelled as a particle.

Use the work-energy principle to find the value of μ .

(6)

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Q2

Question 1 continued

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(Total 7 marks)

Q1



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Question 3 continuedLeave
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Q3

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Question 2 continued

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(Total 8 marks)

Q2



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Question 4 continued

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(Total 8 marks)

Q4

Grading box for Q4.



1. A truck of mass 1500 kg is moving on a straight horizontal road.
The engine of the truck is working at a constant rate of 30 kW.
The resistance to the motion of the truck is modelled as a constant force of magnitude R newtons.
At the instant when the truck is moving at a speed of 20 ms^{-1} , the acceleration of the truck is 0.6 ms^{-2}

Question 1 continued

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(Total for Question 1 is 8 marks)



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Question 2 continuedLeave
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Question 2 continued

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(Total 9 marks)

Q2



Question 2 continued

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Question 2 continued

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Question 2 continued

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(Total 9 marks)

Q2







Question 3 continued

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(Total for Question 3 is 9 marks)



Question 5 continued

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Question 5 continued

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(Total for Question 3 is 7 marks)



Question 3 continued

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(Total for Question 3 is 9 marks)

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Question 6 continued

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(Total 10 marks)

Q6

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Question 5 continued

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Question 5 continued

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(Total for Question 5 is 10 marks)



Question 4 continued

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Question 4 continued

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Question 4 continued

(Total for Question 4 is 10 marks)



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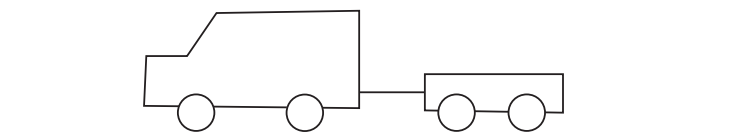


Figure 2

A van of mass 900 kg is moving along a straight horizontal road.

The van is towing a trailer of mass 300 kg.

The trailer is attached to the van by a rigid towbar which is parallel to the direction of motion of the van and the trailer, as shown in Figure 2.

The resistance to the motion of the van is modelled as a constant force of magnitude 500 N.

The resistance to the motion of the trailer is modelled as a constant force of magnitude 200 N.

The towbar is modelled as a light rod.

The engine of the van is working at a constant rate of 18 kW.

At the instant when the speed of the van is 12 ms^{-1} , the tension in the towbar has magnitude T newtons.

(a) Find the value of T

(7)

Later, the van is towing the trailer up a straight road inclined at an angle α to the horizontal, where $\sin \alpha = \frac{1}{15}$

The towbar is still parallel to the direction of motion of the van and the trailer.

The resistance to the motion of the van from non-gravitational forces is modelled as a constant force of magnitude 500 N.

The resistance to the motion of the trailer from non-gravitational forces is modelled as a constant force of magnitude 200 N.

The towbar is again modelled as a light rod.

When the van is travelling with a constant speed of $v \text{ ms}^{-1}$, the engine of the van is working at a constant rate of 18 kW.

(b) Find the value of v

(4)



Question 2 continued

Lined area for writing the answer to Question 2.



(Total for Question 2 is 11 marks)



6. A van of mass 900 kg is moving along a straight horizontal road.

The resistance to the motion of the van is modelled as a constant force of magnitude 600 N.

The engine of the van is working at a constant rate of 24 kW.

At the instant when the speed of the van is $V \text{ ms}^{-1}$, the acceleration of the van is 2 ms^{-2}

- (a) Find the value of V

(4)

Later on, the van is towing a trailer of mass 700 kg up a straight road inclined at an angle θ to the horizontal, where $\sin \theta = \frac{1}{14}$

The trailer is attached to the van by a towbar, as shown in Figure 3.

The towbar is parallel to the direction of motion of the van and the trailer.

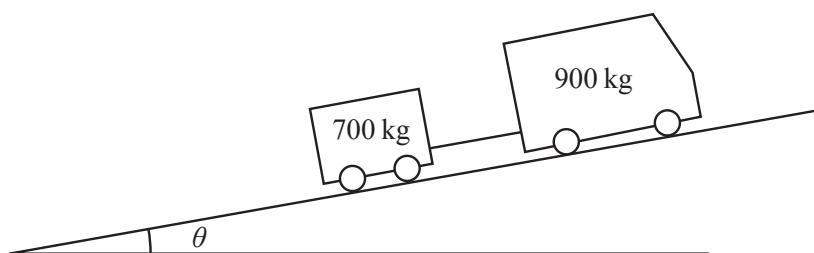


Figure 3

The resistance to the motion of the van from non-gravitational forces is modelled as a constant force of magnitude 600 N.

The resistance to the motion of the trailer from non-gravitational forces is modelled as a constant force of magnitude 550 N.

The towbar is modelled as a light rod.

The engine of the van is working at a constant rate of 24 kW.

- (b) Find the acceleration of the van at the instant when the van and the trailer are moving with speed 8 ms^{-1}

(4)

At the instant when the van and the trailer are moving up the road at 9 ms^{-1} , the towbar breaks. The trailer continues to move in a straight line up the road until it comes to instantaneous rest.

The distance moved by the trailer as it slows from a speed of 9 ms^{-1} to instantaneous rest is d metres.

- (c) Use the work-energy principle to find the value of d .

(4)

Question 6 continued

Lined area for writing the answer to Question 6 continued.



Question 6 continued

Lined area for writing the answer to Question 6 continued.



(Total for Question 6 = 12 marks)



4. The combined mass of a cyclist and her cycle is 70 kg.

The cyclist travels on a straight horizontal road with constant acceleration 0.4 ms^{-2}

The resistance to the motion is modelled as a constant force of magnitude 30 N.

- (a) Using this model, find the rate at which the cyclist is working, at the instant when her speed is 5 m s^{-1}

(4)

The cyclist travels in a straight line **down** a hill from a point A to a point B , where $AB = 250\text{ m}$

- at the instant she passes A , her speed is 5 m s^{-1} and she **stops** pedalling
- at the instant she passes B , her speed is 8 m s^{-1}
- the resistance to the motion is modelled as a constant force of magnitude 30 N

- at the instant she passes B , her speed is 8 m s^{-1}

- the resistance to the motion is modelled as a constant force of magnitude 30 N

- (b) Use this model with the work-energy principle to find the change in vertical height from A to B .

(5)

The cyclist travels **up** a hill from a point C to a point D , where $CD = 200$ m.

- she travels from C to D with constant speed, 8 m s^{-1}
- she travels in a straight line at 5° to the horizontal
- the resistance to the motion from non-gravitational forces is modelled as a constant force of magnitude 30 N

- she travels in a straight line at 5° to the horizontal

- the resistance to the motion from non-gravitational forces is modelled as a constant force of magnitude 30 N

- (c) Use this model to find the total work done by the cyclist as she moves from C to D .

(3)

Question 4 continued

Lined area for writing the answer to Question 4 continued.



Question 4 continued

Lined area for writing the answer to Question 4 continued.



Question 4 continued

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(Total for Question 4 is 12 marks)



Question 4 continued

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Question 4 continued

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Question 4 continued

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(Total for Question 4 is 12 marks)





Question 5 continued

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Question 5 continued

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(Total for Question 5 is 13 marks)



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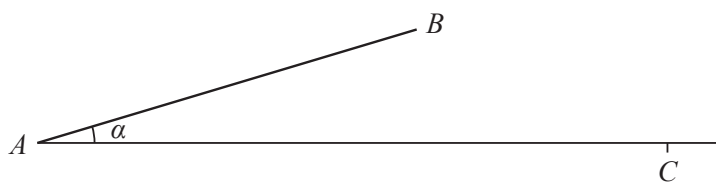


Figure 4

Figure 4 shows a rough ramp fixed to horizontal ground.

The ramp is inclined at angle α to the ground, where $\tan \alpha = \frac{1}{6}$

The point A is on the ground at the bottom of the ramp.

The point B is at the top of the ramp.

The line AB is a line of greatest slope of the ramp and $AB = 4$ m.

A particle P of mass 3 kg is projected with speed $U\text{ ms}^{-1}$ from A directly towards B .

The coefficient of friction between the particle and the ramp is $\frac{3}{4}$

(a) Find the work done against friction as P moves from A to B . (4)

Given that at the instant P reaches the point B , the speed of P is 5 m s^{-1}

(b) use the work-energy principle to find the value of U . (4)

The particle leaves the ramp at B , and moves freely under gravity until it hits the ground at the point C .

(c) Find the horizontal distance from B to C . (6)

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Question 8 continued

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Question 8 continued

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Question 8 continued

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Q8

(Total 14 marks)

TOTAL FOR PAPER IS 75 MARKS

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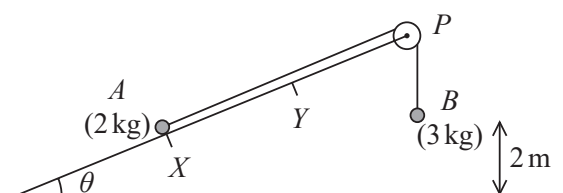
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Figure 4

Two particles, A and B , of mass 2 kg and 3 kg respectively, are connected by a light inextensible string. Particle A is held at rest at the point X on a fixed rough ramp that is inclined at an angle θ to the horizontal, where $\tan \theta = \frac{5}{12}$. The string passes over a small smooth pulley P that is fixed at the top of the ramp. Particle B hangs vertically below P , 2 m above the ground, as shown in Figure 4.

The particles are released from rest with the string taut so that A moves up the ramp and the section of the string from A to P is parallel to a line of greatest slope of the ramp.

The coefficient of friction between A and the ramp is $\frac{3}{8}$.

Air resistance is ignored.

(a) Find the potential energy lost by the system as A moves 2 m up the ramp. (3)

(b) Find the work done against friction as A moves 2 m up the ramp. (4)

When B hits the ground, B is brought to rest by the impact and does not rebound and A continues to move up the ramp.

(c) Use the work-energy principle to find the speed of B at the instant before it hits the ground. (4)

Particle A comes to instantaneous rest at the point Y on the ramp, where $XY = (2 + d)\text{ m}$.

(d) Use the work-energy principle to find the value of d . (4)

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Q6

MARK SCHEMES

official mark schemes, in the same order as the questions



Question Number	Scheme	Marks
1.	Use of $56 = FV$ Equation of motion $F + 75g \sin \alpha - 40 = 75 \times \frac{1}{3}$ $\left(\frac{56}{V} = 65 - 49 = 16 \right)$ $V = \frac{56}{16} = 3.5$ Notes	B1 M1 A1 A1 A1 [5]
B1 M1 A1 A1 A1	Require all terms. Dimensionally correct. (Omission of g is an accuracy error.) Condone sine / cosine confusion and sign errors Unsimplified equation with at most one error. In F or in V. Two signs inconsistent is 2 errors. Correct unsimplified equation. In F or in V. Max 3 s.f.. Not $\frac{7}{2}$ Not $3\frac{1}{2}$	

PEARSON EDEXCEL IAL MATHEMATICS

General Instructions for Marking

1. The total number of marks for the paper is 75
2. The Edexcel Mathematics mark schemes use the following types of marks:
 - **M** marks: Method marks are awarded for ‘knowing a method and attempting to apply it’, unless otherwise indicated.
 - **A** marks: Accuracy marks can only be awarded if the relevant method (M) marks have been earned.
 - **B** marks are unconditional accuracy marks (independent of M marks)
 - Marks should not be subdivided.

3. Abbreviations

These are some of the traditional marking abbreviations that will appear in the mark schemes.

- bod – benefit of doubt
 - ft – follow through
 - the symbol $\surd$ will be used for correct ft
 - cao – correct answer only
 - cso - correct solution only. There must be no errors in this part of the question to obtain this mark
 - isw – ignore subsequent working
 - awrt – answers which round to
 - SC: special case
 - oe – or equivalent (and appropriate)
 - d... or dep – dependent
 - indep – independent
 - dp decimal places
 - sf significant figures
 - * The answer is printed on the paper or ag- answer given
 - $\square$ or d... The second mark is dependent on gaining the first mark
4. All A marks are ‘correct answer only’ (cao.), unless shown, for example, as A1 ft to indicate that previous wrong working is to be followed through. After a misread however, the subsequent A marks affected are treated as A ft, but manifestly absurd answers should never be awarded A marks.

Q	Mark Scheme	Marks	Marking guidance
1 (a)	M(x axis)	M1	Need all terms. Dimensionally consistent. Condone if m missing throughout. Accept as part of a vector equation
	$2m \times (-2) + 3m \times 2 + 4m \times 3k = 9m \times \bar{x}$ $\bar{x} = \frac{2+12k}{9}$ *	A1*	Obtain given result
		2	
(b)	M(y axis)	M1	Need all terms. Dimensionally consistent. Might be seen as part of a vector equation in (a). It does not score any marks until referred to in part (b). Condone if m missing throughout.
	$2m \times 5 + 3m \times (-3) + 4m \times k = 9m \times \bar{y}$ $\left(\bar{y} = \frac{1+4k}{9} \right)$	A1	Correct unsimplified equation. Allow if m missing throughout.
	Form and solve equation in k ($2+12k+2+8k=27$)	DM1	Use their $\bar{y}$ and $\bar{x}+2\bar{y}=3$ Dependent on the two preceding M marks
	$k = \frac{23}{20}$ (1.15)	A1	Correct answer only
		4	
		(6)	

Q	Mark Scheme	Marks	Marking guidance
2	Use of $P = Fv$	M1	Seen or implied e.g. $F = \frac{15000}{16} (= 937.5)$ Condone 15 in place of 15000 or extra zeros on 15000
	Equation of motion	M1	Need all terms. Condone sign errors and sin / cos confusion. Dimensionally consistent.
	$F + 900g \sin \theta - 400 = 900a$	A1	Unsimplified equation in P or their F with at most one error
	$\frac{15000}{16} + 900g \times \frac{1}{12} - 400 = 900a$	A1	Correct unsimplified equation with F and $\sin \theta$ substituted
	$a = 1.41 \quad (1.4) \quad (\text{m s}^{-2})$	A1	3sf or 2sf
		(5)	



1.	Gain in GPE $= 2.6g \times 20 \sin \alpha \left(= 2.6g \times 20 \times \frac{5}{13} \right)$	M1	Or equivalent. Condone sine / cosine confusion
	$F_{\max} = \frac{1}{5} \times 2.6g \cos \alpha \left(= \frac{1}{5} \times 2.6g \times \frac{12}{13} \right)$	M1	Or equivalent. Condone sine / cosine confusion
	Work done against friction $= 20F_{\max}$	M1	Follow their $F_{\max}$. Must have an expression for $F_{\max}$. Independent of the preceding M1
	Total work done $= 2.6g \times 20 \sin \alpha + 4 \times 2.6g \cos \alpha$	DM1	Dependent on preceding M marks Must be adding the two relevant expressions
	$= 290(\text{J})$	A1	2 sf or 3 sf Do not ISW
			NB: Omission of g should be marked as an accuracy error
		[5]	
		(5)	

Question Number	Scheme	Marks
2	Work energy equation KE lost = WD + PE gain $\frac{1}{2} \times 2 \times 16 = \text{WD} + 2g \times 2.5 \sin \theta$ (WD = 9) Use of $F = \mu \times 2g \cos \theta$ Use of Work done = $2.5F$ $9 = 2.5 \times \mu \times 2g \cos \theta \Rightarrow \mu = 0.19$	M1 A1 A1 B1 B1 A1 (6) [6]
M1	Must be using work-energy. Require all terms. Dimensionally correct. Allow their WD, but must be WD, not F Condone sine/cosine confusion and sign errors	
A1	Unsimplified equation with at most one error	
A1	Correct unsimplified equation NB: $16 = \text{WD} + 7$ seen scores 3 marks	
B1	$(F = \mu \times 19.398...)$ Allow $\pm$ This mark is available if they use a <i>suvat</i> approach	
B1	Allow $\pm$	
A1	Or 0.186. Max 3 sf. Not $\frac{3\sqrt{3}}{28}$	



Q	Solution	Mark	Guidance
1a	$F = \mu R = \frac{1}{5}mg \cos \alpha$	B1	Seen or implied
	Work done = force x distance	M1	Correct method for work done against friction
	$= \frac{1}{5}mg \times \frac{12}{13} \times d = \frac{12}{65}mgd$ *	A1*	Obtain given answer from correct working.
		(3)	
1b	Work-energy equation	M1	All terms required and dimensionally correct. Condone sign errors and sin/cos confusion
	$\frac{1}{2}mv^2 = mg \times d \times \frac{5}{13} - \frac{12}{65}mgd \left(= \frac{13}{65}mgd \right)$	A1	Unsimplified equation with at most one error
		A1	Correct unsimplified equation
	$v = \sqrt{\frac{2gd}{5}}$	A1	Or exact equivalent e.g. $\sqrt{\frac{26}{65}gd}$, $\frac{1}{5}\sqrt{10gd}$ Accept $0.63\sqrt{gd}$ or better
		(4)	
		[7]	
2	Equation of motion down the slope	M1	First equation (either direction). Condone sign errors and sin/cos confusion
	$F_1 + 450g \times \frac{1}{15} - R = 450 \times 0.5$	A1	Unsimplified equation with at most one error.
	$\left(\frac{P}{12} + 30g - R = 225 \right) \left(\frac{P}{12} - R = -69 \right)$	A1	Correct unsimplified equation in P or F_1
	Equation of motion up the slope	M1	Second equation. Condone sin/cos confusion. Signs consistent with first equation and change in direction of motion
	$F_2 - 450g \times \frac{1}{15} - R = 450 \times -0.5$	A1	Correct unsimplified equation in P or F_2
	$\left(\frac{P}{6} - 30g - R = -225 \right) \left(\frac{P}{6} - R = 69 \right)$		
	$F_1 = \frac{P}{12}$ or $F_2 = \frac{P}{6} \left(= \frac{2P}{12} \right)$	M1	Use of $P = Fv$ at least once
	Solve for P	DM1	Dependent on all previous M marks
	$\left(R = \frac{P}{8} \right) P = 1660$ or $P = 1700$	A1	3 sf or 2 sf (follows use of 9.8) Allow 1.66 kW but not 1.66
		(8)	
		[8]	

Question Number	Scheme	Marks	Notes
3.	Use of $P = 15F_1$ or $P = 10F_2$	M1	Seen or implied
	$F_1 - R = 600 \times 0.2$	M1	Equation of motion. Needs all terms. Condone sign errors. Inclusion of g is an accuracy error
	$\frac{P}{15} - R = 120$	A1	Correct equation in P and their R
	Up the slope: $F_2 - R - 600g \sin \theta = 0$	M1	Equation of motion. Needs all terms and $F_2 \neq F_1$. Condone sign errors. Condone sin/cos confusion. Omission of g is an accuracy error
		A1	Unsimplified equation in P or F_2 with at most 1 error
	$\frac{P}{10} - R - 30g = 0$	A1	Correct equation in P and their same R
	$\frac{P}{15} - \frac{P}{10} + 30g = 120$	DM1	Solve for P . Dependent on the 2 preceding M marks
	$P = 5220 \quad (5200)$	A1	Correct max 3 s.f.
		[8]	

3			Allow column vectors
	Use of $\mathbf{I} = m\mathbf{v} - m\mathbf{u}$	M1	Must be subtracting
	$(\mathbf{I} =) \pm 0.5((4 - \lambda)\mathbf{i} + (-\lambda)\mathbf{j})$	A1	Accept $\pm$ correct unsimplified expression on right hand side. (Ignore the left hand side) Allow $2\mathbf{i} - \frac{\lambda}{2}(\mathbf{i} + \mathbf{j})$ or equivalent
	Use of magnitude to form an equation in one variable	M1	Correct use of Pythagoras
	$\frac{5}{2} = \frac{1}{4}((4 - \lambda)^2 + (-\lambda)^2)$	A1ft	Follow their $\mathbf{I}$
	$0 = 2\lambda^2 - 8\lambda + 6 \quad (= (2\lambda - 6)(\lambda - 1))$	DM1	Form a 3 term quadratic (seen or implied). Not necessarily stated “= 0” From $\mathbf{I} = a\mathbf{i} + b\mathbf{j}$ can obtain $4a^2 - 8a + 3 = 0$ or $4b^2 + 8b + 3 = 0$ Dependent on the preceding M1 Solving not required for the M1.
	$\lambda = 3$ and $\lambda = 1$	A1cso	From correct solution only. Do not need to see method of solution.
		[6]	
3alt	Use of $\mathbf{I} = m\mathbf{v} - m\mathbf{u}$ to form a vector triangle	M1	
	Triangle with sides of length $\sqrt{\frac{5}{2}}, 2\mathbf{i} $ and $\left \frac{\lambda}{2}(\mathbf{i} + \mathbf{j})\right $	A1	
	Use of cosine rule with $45^\circ \left(\frac{\pi}{4}\right)$	M1	
	$\frac{5}{2} = 2^2 + \left(\frac{\lambda}{2}\right)^2 \times 2 - 2 \times 2 \times \frac{\lambda}{2} \sqrt{2} \cos 45^\circ$	A1ft	Correct unsimplified equation Follow their magnitudes
	$0 = \lambda^2 - 4\lambda + 3 \quad (= (\lambda - 3)(\lambda - 1))$	DM1	Form a 3 term quadratic (seen or implied) Dependent on the preceding M1
	$\lambda = 3$ and $\lambda = 1$	A1	Correct solution only
		[6]	
		(6)	

1a	Equation of motion	M1	Dimensionally correct. Condone sign error.
	$F - R = 1500a$	A1	Correct unsimplified equation in F or P
	Use of $P = Fv : \left(\frac{30000}{20} - R = 1500 \times 0.6 \right)$	M1	Must be trying to use 30 kW but condone error in zeros
	$R = 600$	A1	Correct answer only
		4	
1b	Equation of motion	M1	Dimensionally correct. Need all relevant terms. Condone sign errors and sin/cos confusion. Allow with F .
	$\frac{30000}{V} - 1500g \times \frac{1}{8} - 500 = -1500 \times 0.2$	A1 A1	Unsimplified equation with F substituted and at most one error Correct unsimplified equation with F substituted. If F is never substituted, A0A0
	$V = 14.7 \quad (15)$	A1	3 sf or 2 sf
		4	
		(8)	
2	1 st equation e.g. Equation for change in KE	M1	Dimensionally correct. Must be subtracting but condone sign error.
	$\frac{1}{2} \times 0.5(x^2 + y^2 - (5^2 + 3^2)) = 22$ $(x^2 + y^2 = 122) \quad (1^2 + (2\lambda + 3)^2 = 122)$	A1	Correct unsimplified equation seen or implied (They might have used impulse-momentum first and done some work before substituting x and y .)
	2 nd equation e.g. Impulse-momentum equation	M1	Dimensionally correct. Must be subtracting but condone sign error.
	$0.5(\mathbf{x}\mathbf{i} + \mathbf{y}\mathbf{j}) - 0.5(5\mathbf{i} + 3\mathbf{j}) = (-2\mathbf{i} + \lambda\mathbf{j})$ $((x-5)\mathbf{i} + (y-3)\mathbf{j} = -4\mathbf{i} + 2\lambda\mathbf{j})$	A1	Correct unsimplified equation
NB: open has M1A1A1 for the final 3 marks but this should be marked DM1DM1A1			
	Form a quadratic equation in λ	DM1	e.g. $1^2 + (3 + 2\lambda)^2 = 122$ Dependent on the 2 preceding M marks
	Solve for 2 values of λ	DM1	e.g. solve $4\lambda^2 + 12\lambda - 112 = 0$ or $(3 + 2\lambda)^2 = 121$ Dependent on the preceding M1
	$\Rightarrow \lambda = 4 \quad \text{or} \quad \lambda = -7$	A1	Correct only and no errors seen (watch out for $x = -1$ used)
alt	Form a quadratic in y	DM1	e.g. $1 + y^2 = 122 \quad (y^2 = 121)$ Dependent on the 2 preceding M marks
	Solve for 2 values of y and use these to obtain 2 values of λ	DM1	Dependent on the preceding M1
	$\Rightarrow \lambda = 4 \quad \text{or} \quad \lambda = -7$	A1	
		7	

Question Number	Solution	Marks	Notes
1.	$\mathbf{I} = 2[\lambda \mathbf{i} + \lambda \mathbf{j} - 5\mathbf{i} - 3\mathbf{j}]$	M1	Use of $\mathbf{I} = m(\mathbf{v} - \mathbf{u})$
	$= 2(\lambda - 5)\mathbf{i} + 2(\lambda - 3)\mathbf{j}$	A1	Any equivalent form
	$ \mathbf{I} = \sqrt{40} \Rightarrow (\lambda - 5)^2 + (\lambda - 3)^2 = 10$	M1	Correct use of Pythagoras and their impulse to form an equation in λ
	$\lambda^2 - 8\lambda + 12 = 0 \Rightarrow \lambda = 2 \text{ or } \lambda = 6$	DM1	Solve to find both values for λ . Dependent on the 2 preceding M marks
	$\mathbf{I} = -6\mathbf{i} - 2\mathbf{j}$ or $\mathbf{I} = 2\mathbf{i} + 6\mathbf{j}$ ($a = -6, b = -2$ or $a = 2, b = 6$)	A1	And no others
		(5)	
	Alternative working:		
	$\mathbf{I}(= a\mathbf{i} + b\mathbf{j}) = 2(\mathbf{v} - (5\mathbf{i} + 3\mathbf{j}))$	M1A1	
	$\mathbf{v} = \frac{a+10}{2}\mathbf{i} + \frac{b+6}{2}\mathbf{j} \Rightarrow (\Rightarrow a+10 = b+6)$		
	$a^2 + b^2 = 40 \Rightarrow b^2 - 4b - 12 = 0$ or $a^2 + 4a - 12 = 0$	M1	Correct use of Pythagoras and impulse to form an equation in a or b Any equivalent form
	$b^2 - 4b - 12 = 0 \Rightarrow b = 6 \text{ or } b = -2$	DM1	
	$\mathbf{I} = -6\mathbf{i} - 2\mathbf{j}$ or $\mathbf{I} = 2\mathbf{i} + 6\mathbf{j}$	A1	Or simplified equivalent
		[5]	

Question Number	Solution	Marks	Notes
2	Driving force = $\frac{3P}{12}$	B1	Use of $P = Fv$ Allow for $\frac{P}{12}$ in second equation if not awarded here
	Motion up the hill $F - R - W \sin \theta = 0$	M1	Need all terms. Condone sign errors and sin/cos confusion.
	$\frac{3P}{12} - R - \frac{9000}{15} = 0$ $\left(\frac{3P}{12} - R = 600 \right)$	A1	Correct substituted equation Any equivalent form
	Motion down the hill $F + W \sin \theta - R = \frac{9000}{9.8} \times \frac{9.8}{20}$	M1	Need all terms. Condone sign errors and sin/cos confusion.
	$\frac{P}{12} + \frac{9000}{15} - R = 450$ $\left(\frac{P}{12} - R = -150 \right)$	A1 A1	Substituted equation with at most one error. Any equivalent form. Correct substituted equation. Any equivalent form.
	Solve for P or R	DM1	Dependent on both preceding M marks
	$\left(\frac{2P}{12} = 750 \right) \Rightarrow P = 4500$	A1	One correct
	$R = 525$ (530)	A1	Both correct
		(9)	
SC1	Misread mass = 9000kg Gives equations $\frac{P}{4} = R + 5880$ $\frac{P}{12} = R - 1470$ Solutions: $P = 44100$, $R = 5145$		B1 M1A0 M1A1ftA0 M1A1ftA1ft Total 7/9
SC2	Use of mass = weight = 9000 Gives equations $\frac{P}{4} = R + 600$ $\frac{P}{12} = R + 3810$ Solutions: $P = -19260$, $R = -5415$		B1 M1A1 M1A1A0 M1A0A0 Total 6/9
		[9]	

2.a	Equation of motion for car and trailer	M1	Need all terms. Dimensionally correct. Condone sin/cos confusion and sign errors.
	$F - 300 - 150 - \frac{200g}{20} - \frac{600g}{20} = 0$ $(F - 842 = 0)$	A1 A1	Unsimplified equation in P or F with at most one error Correct unsimplified equation in P or F Missing g is one accuracy error
	$\frac{1000P}{15}(-450 - 98 - 294 = 0)$	M1	Use of $P = Fv$ Allow with P or $1000P$
	$P = 12.6$ or $P = 13$	A1	3 s.f. or 2 s.f. only A final answer of 12600 (13000) scores 4/5 Condone $12600 = 12.6$ (correct thinking without stating the units)
		[5]	
2b	KE lost = gain in GPE + WD against resistance	M1	Must be using work-energy principle for trailer only. Dimensionally correct. Correct terms and no extras. Condone sign errors and sin / cos confusion.
	$\frac{1}{2} \times 200 \times 400 = \frac{200}{20}gd + 300d (= 398d)$	A1 A1	Correct unsimplified equation in one variable with at most one error Correct unsimplified equation in one variable.
	$XY = d = 101 \text{ (100) (m)}$	A1	3 s.f. or 2 s.f. only
		[4]	
		(9)	



Q	Scheme	Mark	Notes
3a	$F_{\max} = \frac{1}{3} \times 2g \cos \alpha (= 5.90\dots)$	M1	Use of $F = \mu R$ Seen or implied. Condone sine / cosine confusion Condone g missing
	WD against friction $= 6 \times \text{their } F_{\max}$	M1	$(= 35.4\dots(\text{J}))$ Seen or implied as part of the 4 th M mark
	PE gain $= 2g \times 6 \times \sin \alpha$ $(= 6 \times \frac{42}{5} = 50.4)$	M1	dimensionally correct. Condone sine / cosine confusion
	Total WD = WD against friction + WD against gravity (gain in PE)	DM1	Dependent on the 3 preceding M marks. Require both terms and no extras
	Total WD $= 85.8 (\text{J})$ or $86 (\text{J})$	A1	3 sf or 2 sf only $(8\sqrt{10} + 36) \frac{g}{7}$ is A0 (incorrect units)
	NB a candidate who resolves parallel to the slope but never multiplies either component by 6 will score the first M1 only		
		[5]	
3b	Work-energy equation (KE gained = loss in GPE - WD against friction)	M1	Must be using work-energy. Need all terms, no extras and dimensionally correct. Condone sign errors Condone sine / cosine confusion.
	$\frac{1}{2} \times 2v^2 = 2g \times 6 \sin \alpha - 6 \times \frac{2}{3} g \cos \alpha$	A1 A1	Unsimplified equation with at most one error Correct unsimplified equation. They must have started with correct expressions, but follow through on any calculation errors
	$v = 3.87 (\text{ms}^{-1})$ or $3.9 (\text{ms}^{-1})$	A1	3 sf or 2 sf only
		[4]	
		(9)	

Q	Scheme	Mark	Notes																											
4a	If the division of the shape involves non-standard shapes (e.g. a trapezium) the centres of mass must be quoted correctly or a correct method used to find the position to score any marks.																													
	<table><tr><td>rectangle</td><td>-triangle</td><td>+triangle</td></tr><tr><td>$20a^2$</td><td>$-\frac{9}{2}a^2$</td><td>$\frac{9}{2}a^2$</td></tr><tr><td>$2a$</td><td>$3a$</td><td>$2a$</td></tr></table> or <table><tr><td>rectangle</td><td>rectangle</td><td>Double triangle</td></tr><tr><td>$3a^2$</td><td>$8a^2$</td><td>$9a^2$</td></tr><tr><td>$\frac{1}{2}a$</td><td>$2a$</td><td>$2a$</td></tr></table> or <table><tr><td>rectangle</td><td>trapezium</td><td>triangle</td></tr><tr><td>$5a^2$</td><td>$\frac{21}{2}a^2$</td><td>$\frac{9}{2}a^2$</td></tr><tr><td>$\frac{1}{2}a$</td><td>$\frac{48}{21}a$</td><td>$2a$</td></tr></table>	rectangle	-triangle	+triangle	$20a^2$	$-\frac{9}{2}a^2$	$\frac{9}{2}a^2$	$2a$	$3a$	$2a$	rectangle	rectangle	Double triangle	$3a^2$	$8a^2$	$9a^2$	$\frac{1}{2}a$	$2a$	$2a$	rectangle	trapezium	triangle	$5a^2$	$\frac{21}{2}a^2$	$\frac{9}{2}a^2$	$\frac{1}{2}a$	$\frac{48}{21}a$	$2a$	B1 B1	Correct mass ratios for a correct division of the folded template and correct total of $20a^2$ Correct distances from AD seen or implied. B0B1 is possible if they have incorrect masses but a full set of correct distances. e.g. if they use the second alternative but have not doubled the triangle. Or they might have a correct split with an error in one of the areas or an incorrect (or missing) total or equivalent
rectangle	-triangle	+triangle																												
$20a^2$	$-\frac{9}{2}a^2$	$\frac{9}{2}a^2$																												
$2a$	$3a$	$2a$																												
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$\frac{1}{2}a$	$2a$	$2a$																												
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$\frac{1}{2}a$	$\frac{48}{21}a$	$2a$																												
	Moments about AD or a parallel axis.	M1	Dimensionally consistent. All terms for a correct division of L and no extras. Accept as part of a vector equation																											
	$40a^3 - \frac{27}{2}a^3 + 9a^3 = 20a^2d$ or $\frac{3}{2}a^3 + 16a^3 + 18a^3 = 20a^2d$ or $\frac{2}{2}a^3 + \frac{48}{2}a^3 + 9a^3 = 20a^2d$	A1	Correct unsimplified equation for their axis. Allow for correct component in a vector equation.																											
	$d = \frac{71}{40}a$ *	A1*	Obtain given answer from correct working. Need at least one line of working to collect like terms e.g. $20d = \frac{71}{2}a$ Final answer must be as printed i.e. $d = \dots$																											
		[5]																												
4b	Moments about S	M1	A complete method to get an equation in W and F only. Need all terms and no extras. Dimensionally consistent.																											
NB If they start by finding the centre of mass for the system they do not score marks until they form the moments equation. If they are clearly using moments about A (e.g. d and $4a$ used as distances in their equation) this is M0 unless they include the reaction at S and resolve to form the required equation. If they say they are using moments about S and have just one incorrect distance allow M1A1A0A0																														
	$4W \times \frac{31}{40}a + W \times 3a = F \times 5a$ or $(4W + W)(2.22a - a) = 5aF$	A1 A1	Unsimplified equation with at most one error Correct unsimplified equation																											
	$F = \frac{61}{50}W$	A1	Accept 1.22W or 1.2W																											
		[4]																												
		(9)																												

Q	Scheme	Mark	Notes
5a	Use of $P = Fv$	M1	$\frac{10000}{16} (= 625)$ o.e. seen or implied in the working. Allow for $\frac{10}{16}$
	Equation of motion for the system	M1	Dimensionally correct. Need all terms and no extras. Condone sign errors and sine/cosine confusion If they start with separate equations for the van and trailer, just mark the combined equation.
	$F - 400 - 800g \sin \alpha = 800a$	A1 A1	Unsimplified equation in P or F with a most one error Correct unsimplified equation in P or F Use of cosine in place of sine for both vehicles counts as a repeated error and only loses 1 mark
	Obtain deceleration $0.419(\text{ms}^{-2})$ or $0.42(\text{ms}^{-2})$	A1	3 sf or 2 sf only Answer must be positive.
		[5]	
5b	Equation of motion for the van or the trailer	M1	Dimensionally correct. Need all terms and no extras. Condone sign errors and sine/cosine confusion Use the mass in the ma term to decide which part of the system they are using.
	$T - 150 - 200g \sin \alpha = 200a$ or $F - T - 250 - 600g \sin \alpha = 600a$	A1 A1	Unsimplified equation with at most one error Correct unsimplified equation
	Obtain tension $206(\text{N})$ or $210(\text{N})$	A1	3 sf or 2 sf only
		[4]	
		(9)	

Question	Scheme	Marks
2	Use of Impulse momentum equation	M1
	$\mathbf{I} = 3(\mathbf{x}\mathbf{i} + \mathbf{y}\mathbf{j}) - 3 \times 5\mathbf{i}$ $= 3(x-5)\mathbf{i} + 3y\mathbf{j}$	A1
	$ I ^2 = 9((x-5)^2 + y^2) = 9 \times 82 (=738)$	M1
	Equation for change in KE	M1
	$\frac{1}{2} \times 3(x^2 + y^2 - 25) = 138$ $(x^2 + y^2 - 25 = 92)$	A1
	$(x-5)^2 + y^2 = 82$ $x^2 + y^2 = 117 \Rightarrow 10x = 60$	DM1
	$\mathbf{v} = 6\mathbf{i} + 9\mathbf{j} (\text{ms}^{-1})$	A1
		(7)
ALT	Use of $I = \begin{pmatrix} 3\sqrt{82} \cos \theta \\ 3\sqrt{82} \sin \theta \end{pmatrix}$ $I = \begin{pmatrix} 3\sqrt{82} \cos \theta \\ 3\sqrt{82} \sin \theta \end{pmatrix} = 3 \begin{pmatrix} x \\ y \end{pmatrix} - 3 \begin{pmatrix} 5 \\ 0 \end{pmatrix}$	M1 A1
	$ I ^2 = 9((x-5)^2 + y^2) = 9 \times 82$	M1
	Equation for change in KE $\frac{1}{2} \times 3(x^2 + y^2 - 25) = 138$	M1 A1
	Leads to $\theta = 83.66\dots$ $x = 5 + 3\sqrt{82} \cos \theta = 6$ $y = 3\sqrt{82} \sin \theta = 9$ $\mathbf{v} = 6\mathbf{i} + 9\mathbf{j} (\text{ms}^{-1})$	DM1 A1
	Notes	
M1	Find the difference in momenta. Dimensionally correct. Condone subtraction in wrong order. Must use both components. (Ignore $3\sqrt{82}$ if it appears on LHS)	
A1	Correct unsimplified expression for difference in momentum. Condone subtraction the wrong way round.	
M1	Correct use of Pythagoras with $3\sqrt{82}$ and both components of impulse. Ignore poor $\mathbf{i}\cdot\mathbf{j}$ notation, eg $\mathbf{i}^2$ for this mark, if recovered by correct subsequent working.	
M1	Use change in KE to produce an equation in terms of x and y. Dimensionally correct, requires 2 KE terms of correct structure. Condone subtraction in wrong order. Ignore poor $\mathbf{i}\cdot\mathbf{j}$ notation eg $(\mathbf{x}\mathbf{i})^2 + (\mathbf{y}\mathbf{j})^2$ for this mark, if recovered by correct subsequent working.	

	M0 For use of velocity.	
A1	Correct unsimplified equation A0 for incorrect notation. A0 for subtraction the wrong way round.	
DM1	Dependent on all preceding M marks. Solve for x or y	
A1	Correct velocity only. Accept column vector. ISW if continue to find speed.	



Question	Scheme	Marks
3(a)	Equation of motion for whole system.	M1
	$F - 640 - 1100g \sin \alpha = 1100a$	A1 A1
	Use of $P = Fv$ $F = \frac{15000}{12} (=1250)$	M1
	$a = 0.16(\text{ms}^{-2})$ or $a = 0.163(\text{ms}^{-2})$	A1
		(5)
3(b)	Work-energy equation for the trailer.	M1
	$\frac{1}{2} \times 200 \times 14^2 = 240d + 200g \times \frac{1}{25}d$	A1 A1
	$(AB =) 62(\text{m})$ or $(AB =) 61.6(\text{m})$	A1
		(4)
		(9)
	Notes	
3(a)		
	Over-accuracy or under-accuracy is penalised max once per complete question. Penalise final A mark in the appropriate part. Use of $g = 9.81$ or 10 is penalised max once per complete question. Penalise final A mark in the appropriate part. If both errors occur, could lose the final two A marks.	
M1	Equation of motion for whole system. All terms required. Dimensionally correct. Condone sign errors and sin/cos confusion. May form two equations of motion (van and trailer) and combine to eliminate T . Condone slip with zeroes for M mark. The forces on the LHS must be consistent with the mass in the ' ma '. Note that $\sin\left(\frac{1}{25}\right)$ is an accuracy error, not a method error.	
A1	Unsimplified equation in F or P with at most one error. Missing g from both weight terms counts as 1 error.	
A1	Correct unsimplified equation in F or P	
M1	Use of $P = Fv$. Condone slip with zeroes for M mark.	
A1	Correct answer, 2 sf or 3 sf.	
3(b)		
M1	Work-energy equation. Condone slip with zeroes for M mark. Dimensionally correct, all terms required and with correct structure: KE, GPE, WD. No repeats. Must use mass of trailer only. Condone sign errors and sin / cos confusion. M0 for <i>suvat</i> . Note that $\sin\left(\frac{1}{25}\right)$ is an accuracy error, not a method error.	
A1	Unsimplified equation with at most one error.	
A1	Correct unsimplified equation with mass replaced.	
A1	Correct answer, 2 sf or 3 sf No need for $AB =$	

	Take moments about the centre of $ABCD$	M1	
	$M \times \frac{2\sqrt{2}}{11}a = kM \times 4\sqrt{2}a$	A1	Correct unsimplified equation in k Allow with a not seen
	$\Rightarrow k = \frac{1}{22}$	A1	Allow with a not seen
		[9]	
Question Number	Solution	Marks	Notes
5a	$\mathbf{a} = \frac{d\mathbf{v}}{dt}$	M1	Differentiate to obtain $\mathbf{a}$ – powers going down
	$= (6t - 9)\mathbf{i} + (2t + 1)\mathbf{j}$	A1	differentiation correct
	$= 9\mathbf{i} + 7\mathbf{j} \text{ (m s}^{-2}\text{)}$	A1	ISW if go on to find $ \mathbf{a} $
		(3)	
5b	Instantaneous rest $\Rightarrow \mathbf{v} = 0\mathbf{i} + 0\mathbf{j}$ $\Rightarrow 3(t - 1)(t - 2) = 0$ and $(t - 2)(t + 3) = 0$	M1	Set $\mathbf{v} = 0$ and solve for t (Need both components equal to zero)
	$\Rightarrow t = 2$	A1	
	$\mathbf{r} = \int \mathbf{v} dt$	M1	Integrate to obtain $\mathbf{r}$ – powers going up. Condone if no constant of integration seen.
	$= \left(t^3 - \frac{9}{2}t^2 + 6t\right)\mathbf{i} + \left(\frac{1}{3}t^3 + \frac{1}{2}t^2 - 6t\right)\mathbf{j}$	A1 A1	At most one error Correct integration Allow column vector. Allow A1A0 for correct integration and non-zero constants(s) of integration
	$= 2\mathbf{i} - \frac{22}{3}\mathbf{j}$, distance $= \sqrt{2^2 + \left(\frac{22}{3}\right)^2}$	DM1	Correct strategy to find the distance, i.e. substitute their value for t and use Pythagoras Dependent on the two preceding M marks
	$= \frac{2\sqrt{130}}{3} = 7.60 \text{ (m)}$	A1	7.6 or better from correct work
		(7)	
		[10]	

Question Number	Solution	Marks	Notes
6a	$R = 6g \cos \alpha$	B1	Correct normal reaction
	Work done $= 15 \times 0.25 \times R$	M1	Correct method with their R
	$= 204(\text{J})$	A1	Or 200(J) Accept 21g or better. (20.7692...g) Not $\frac{2646}{13}$
		(3)	
6b	NB The question specifies that the work-energy principle should be used, so solutions based on <i>suvat</i> equations are not accepted.		
	Initial KE – GPE lost – WD = final KE	M1	Use of work-energy to form equation in v . Dimensionally correct. Ignore sign errors. Allow WD or their WD
	$\frac{1}{2} \times 6 \times 14^2 - 6g \times 15 \times \frac{5}{13} - 6g \times 15 \times \frac{3}{13}$ $= \frac{1}{2} \times 6v^2$ $\left(3 \times 196 - \frac{450g}{13} - \frac{270g}{13} = 3v^2 \right)$	A1ft A1ft	Unsimplified equation with at most one error Correct unsimplified equation Follow their WD
	$v = 3.88 \quad (3.9)$	A1	Max 3 sf
	Work-energy equation	M1	Complete method using work-energy to form equation in w . Dimensionally correct. Ignore sign errors.
	$\frac{1}{2} \times 6 \times 14^2 - 6g \times 15 \times \frac{3}{13} = \frac{1}{2} \times 6w^2$ or $\frac{1}{2}mw^2 = \frac{1}{2}mv^2 + mg \times \frac{15 \times 5}{13}$	A1ft	Correct unsimplified equation Follow their WD or their v
	$w = 11.3 \quad (11)$	A1	Max 3 sf
		(7)	
		[10]	

5a	Use of $F_{\max} = \mu R : F_{\max} = \frac{2}{7} \times 1.5g \cos \theta$	M1	(3.87...) Condone trig confusion. Trig substitution not required. Allow M1 if there is a clear statement for $F_{\max}$ “correct” and then used in a calculation including the gain in GPE
	Use of $WD = 2.5 F_{\max}$	M1	Trig substitution not required. M0 if they have included the gain in GPE
			If the method for F is incorrect but involves the use of μ to obtain F and then they use the “work done” formula correctly allow M0M1
	$WD = 9.69 \quad (9.7)(J)$	A1	3 sf or 2 sf not $\frac{126}{13}$
		3	
5b	Work-energy equation	M1	The Q asks for work-energy. Need all terms and dimensionally correct. Condone sign errors and sin / cos confusion
	If their answer to (a) included the GPE then it must be used for the total work done here to score the M1		
	$\frac{1}{2} \times 1.5U^2 = WD + 1.5 \times 9.8 \times 2.5 \times \sin \theta$	A1ft A1ft	Unsimplified equation with at most one error. Correct unsimplified equation Follow their WD against friction
	$U = 5.64 \quad (5.6)$	A1	3 sf or 2 sf
		4	
5c	Work-energy equation for A to A	M1	The Q asks for work-energy. Need all terms and dimensionally correct.
	$\frac{1}{2} \times 1.5v^2 = \frac{1}{2} \times 1.5U^2 - 2WD$	A1ft	Correct unsimplified equation. Follow their WD against friction and their U
	$v = 2.43 \quad (2.4) \quad (ms^{-1})$	A1	3 sf or 2 sf
		3	
5c alt	Work-energy equation for B to A	M1	The Q asks for work-energy. Need all terms and dimensionally correct.
	$\frac{1}{2} \times 1.5v^2 = 1.5 \times 9.8 \times 2.5 \times \sin \theta - WD$	A1ft	Correct unsimplified equation. Follow their WD
	$v = 2.43 \quad (2.4) \quad (ms^{-1})$	A1	3 sf or 2 sf
		3	
		(10)	

Q	Scheme	Marks	Notes
2(a)	$\frac{3}{4}t = \sqrt{2t+1}$	M1	Equate the two expressions Allow M1 only if they verify that it works for $k = 4$
	$9t^2 - 32t - 16 = 0$	A1	Correct 3 term quadratic In t or in k . Any equivalent form without the root
	$t = 4$ or $-\frac{4}{9}$, so $k = 4$ $k \geq 0$ *	A1*	Given answer for k correctly explained The Q asks for an explanation, so they must explain why they reject the negative root.
		(3)	
2(b)	Differentiate v to obtain a	M1	power decreasing by 1, condone incorrect chain rule
	$a = \frac{dv}{dt} = \frac{1}{2}(2t+1)^{-\frac{1}{2}} \times 2$	A1	Correct derivative (any equivalent form)
	When $t = 1.5$, $a = 0.5$ (m s^{-2})	A1	cao
		SC	Allow M1A1A0 for correct differentiation seen as part of a vector approach
		(3)	
2(c)	$x = \int \sqrt{2t+1} dt$	M1	Attempt to integrate: power increasing by 1 Must see working – the question excludes calculators for this step
	$= \frac{2}{3}(2t+1)^{\frac{3}{2}} \times \frac{1}{2} (+C)$	A1	Correct indefinite integral
	Correct use of correct limits	M1	Use of $t = 0$, $x = 0$ and $t = 4$ as limits in a definite integral or to obtain the constant of integration and hence x when $t = 4$ ($C = -\frac{1}{3}$) “Correct use” means (value when 4 substituted) – (value when 0 substituted)
	$x = \frac{26}{3}$	A1	Accept 8.7 or better
	$\int \frac{3}{4}t dt$	M1	Attempt to integrate: power increasing by 1 Must see working – the question excludes calculators for this step NB It is correct to use <i>suvat</i> in place of this second interval, but if they do then M1 includes use of the correct initial speed (3 ms^{-1})
	$= \left[\frac{3}{8}t^2 \right]_4^8$	A1	Correct definite integral. Accept $\frac{3 \times 64}{8} - \frac{3 \times 16}{8}$ or equivalent unsimplified expression
	Total = $\frac{80}{3}$ (m) (=18 (m))	A1	Accept 27 or better ($26.\dot{6}$)
		SC	Correct integration seen as part of a vector approach can score M1A1M0A0M1A0A0
		(7)	
		(13)	

Q	Scheme			Marks	Notes
3(a)	Large disc	Small disc	Template	B1	correct area ratios and distances seen or implied Allow + kr or $-kr$
	πR^2	πr^2	$\pi R^2 - \pi r^2$		
	0	$R - r$	$\pm kr$		
	Moments about axis through X			M1	Or moments about a parallel axis. Need all terms but condone sign errors Do not need to see the zero term Dimensionally consistent Could be part of a vector equation
	$(0 \times \pi R^2) - \pi r^2 \times (R - r) = (\pi R^2 - \pi r^2) \times (-kr)$ Moments about the left-hand end of the diameter through X and Y gives: $\pi R^2 \cdot R - \pi r^2 (2R - r) = \pi (R^2 - r^2) (R - kr)$			A1	Correct unsimplified equation Do not need to see the zero term Must be using $-kr$ (unless they have changed the sign on the left-hand side)
	$r = \frac{k}{1-k} R$ *			A1*	Obtain given answer from correct working e.g. via $\frac{r}{R+r} = k$
					If they use $\bar{x}$ in place of $\pm kr$ and never substitute $\pm kr$ they can score B0M1A0A0
				(4)	
3(b)	$0 < \frac{k}{1-k} R < R$			M1	use of correct inequality
	$(0 <) k < (1 - k) \Rightarrow (0 <) k < \frac{1}{2}$			A1	Correct only Only need the right-hand value. A0 with an incorrect left hand value
				(2)	
3(c)	$k = \frac{4}{9} \Rightarrow r = \frac{4}{5} R$			B1	Seen or implied (this mark could be implied by the correct expression for $\tan \alpha$ in terms of k)
	$\tan \alpha = \frac{R}{kr} \left(= \frac{R}{\frac{4}{9} \times \frac{4}{5} R} = \frac{45}{16} \right)$ $\left(\tan \alpha = \frac{1-k}{k^2} \right)$			M1	Correct use of trig in a correct triangle Available for finding $90 - \alpha$
	$\alpha = 70^\circ$			A1	or better (70.426...) Accept 109.6, 250.4 and 289.6
				(3)	

Q	Scheme	Marks	Notes
3(d)	Moments about an axis through P	M1	dimensionally consistent, condone sign errors and missing g throughout The equation should be of the form $M_1gR = Mg \times \text{a distance (in } r \text{ or } R)$ Moments about any other axis requires use of the forces acting at P
	$M(P), M_1gR = Mg \times \frac{4}{9}r$ Or $M_1gR = Mg \times \frac{16}{45}R$	A1	correct unsimplified equation in r and / or R
	$M_1 = \frac{16}{45}M$	A1	Accept $0.36 M$ or better
		(3)	
		(12)	

Q	Scheme	Marks	Notes
4(a)	$F = \frac{1}{7} \times mg \cos \alpha \quad \left(= \frac{1}{7} \times mg \times \frac{4}{5} \right)$	M1	condone sin/cos confusion
	$= \frac{4mg}{35} *$	A1*	obtain given answer from correct working Correct trig value must be seen as it is a given answer – could be against the Q
		(2)	
4(b)	Energy equation: PE gain + WD against Fr = KE lost or equivalent	M1	NB: The question tells them to use work-energy. Need all terms, dimensionally correct but condone sign errors. Condone sine / cosine confusion
	$\frac{4mgd}{35} + mgd \sin \alpha = \frac{1}{2} m \times 10ag$	A1	unsimplified equation with at most one error
	Or $\frac{4mgd}{35} + mgd \times \frac{3}{5} = \frac{1}{2} m \times 10ag$	A1	correct unsimplified equation
	$d (= AB) = 7a$	A1	cao
		(4)	
4(c)	Energy equation	M1	NB: The question tells them to use work-energy. Need all terms, dimensionally correct but condone sign errors
	$\frac{4mg}{35} \times 14a = \frac{1}{2} m \times 10ag - \frac{1}{2} mV^2$	A1ft	unsimplified equation with at most one error, ft on their AB
	or $\frac{4mg}{35} \times 7a = mg \times 7a \times \frac{3}{5} - \frac{1}{2} mV^2$	A1ft	correct unsimplified equation
	or $\frac{4mg}{35} \times d = mg \times d \times \frac{3}{5} - \frac{1}{2} mV^2$		Allow A1A1 if they have substituted for g
	$V = \sqrt{\frac{34ag}{5}}$	A1	accept $2.6\sqrt{ag}$, $\sqrt{6.8ag}$ or better. Accept $\sqrt{\frac{170ag}{25}}$
		(4)	
		(10)	

2a	NB If they use $a = 0$ then max score is 1/7 (3 rd M1 only)		
	Equation of motion for van + trailer:	M1	First equation: Dimensionally correct. Need all terms. In F or P . Condone sign errors.
	$F - (500 + 200) = (900 + 300)a$	A1	Correct unsimplified equation
	Equation of motion for the trailer	M1	Second equation: Dimensionally correct. Need all terms. In F or P . Condone sign errors. Correct mass
	$T - 200 = 300a$	A1	Correct unsimplified equation. Follow their a .
	Equation of motion for van $F - T - 500 = 900a$		There are 3 possible equations. They need 2 of them. M1A1 for each correct unsimplified equation.
	$F = \frac{18000}{12} (= 1500)$	M1	Use of $P = Fv$ Need to have substituted relevant values Condone use of 18 in place of 18000 (or incorrect number of zeros)
	Solve for T	DM1	Dependent on previous 3 M marks
	$T = 400$	A1	Correct only
			NB: Inclusion of g should be marked as an accuracy error
		[7]	
2b	Equation of motion for van + trailer	M1	Dimensionally correct. Need all terms. Condone sign errors. Condone sine / cosine confusion Alt: Obtains separate equations for van and trailer and eliminates T
	$F - (200 + 500) - (300 + 900)g \sin \alpha = 0$ $\left(\frac{18000}{v} = 700 + \frac{1200g}{15} \right)$	A1 A1	Unsimplified equation in F or v with at most one error. Consistent trig confusion is one error. Consistent sign error is one error. Missing g is one error. Correct unsimplified equation in v Allow with trig value not substituted
	$v = 12$ or $v = 12.1$	A1	2 sf or 3 sf
		[4]	
		(11)	

Question	Scheme	Marks	Notes
6a	Equation of motion	M1	Need all terms and dimensionally correct
	$F - 600 = 900 \times 2$	A1	Correct unsimplified equation
	$\frac{24000}{V} - 600 = 1800$	M1	Use of $24000 = FV$ Allow with 24 for 24000 or with a 0 missing
	$V = 10$	A1	Correct only
		(4)	
6b	Equation of motion	M1	Need all terms and dimensionally correct. Mark omission of g as an accuracy error, not a dimension error. Condone sign error(s) and sin/cos confusion If they form separate equations for each vehicle they need both equations and to eliminate T to score the M1
	$F - (700 + 900)g \sin \theta - (550 + 600) = 1600a$	A1	Unsimplified combined equation with at most one error – allow with F
	$\left(\frac{24000}{8} - (1600)g \sin \theta - 1150 = 1600a \right)$	A1	Correct combined unsimplified equation with correct substitution for F
	$a = 0.456 \quad (0.46) \text{ (ms}^{-2}\text{)}$	A1	2 sf or 3 sf not $\frac{73}{160}$
		(4)	
6c	Work-energy equation	M1	Must be work-energy. Must be using the mass of the trailer only and the resistance for the trailer only. Dimensionally correct. All relevant terms, no duplication of terms and no extras. Condone sign error(s) and sin/cos confusion.
	$\frac{1}{2} \times 700 \times 9^2 = 550d + 700gd \sin \theta$	A1 A1	Unsimplified equation with at most one error Correct unsimplified equation
	$d = 27 \quad (27.3)$	A1	2 sf or 3 sf
		(4)	

QUESTION NUMBER	SCHEME	MARKS
4		
4(a)	Equation of motion	M1
	$D - 30 = 70(0.4)$	A1
	Use of $P = D \times 5$	M1
	$P = 290 \text{ (W)}$	A1
		(4)
4(b)	At least one correct KE term	M1
	$\frac{1}{2} \times 70 \times 8^2 \quad \frac{1}{2} \times 70 \times 5^2$	
	Work done against resistance = 250×30	B1
	Work-energy equation	M1
	$70gH = \frac{1}{2} \times 70 \times 8^2 - \frac{1}{2} \times 70 \times 5^2 + 250 \times 30$	A1
	$H = 13 \text{ or } 12.9 \text{ (m)}$	A1
		(5)
4(c)	Total work done	M1
	$70g(200 \sin 5^\circ) + (30 \times 200)$	A1
	18000 (J)	A1
		(3)
		(12)
	Notes for question	
4(a)		
M1	Equation of motion. Dimensionally correct with all required terms and no extras.	
A1	Correct unsimplified equation.	
M1	Use of $P = D \times 5$	
A1	Correct answer, 290 (W)	
4(b)		
M1	At least one KE term correctly formed.	
B1	Expression seen for work done against resistance.	
M1	Work-energy equation. Dimensionally correct with all required terms and no extras or double counting. Mass must be replaced with 70. Condone sign errors.	
A1	Correct unsimplified equation.	
A1	Correct answer, 2/3sf	
4(c)		
M1	Expression for total work done. Dimensionally correct with all required terms and no extras or double counting . Mass must be replaced with 70. (the 200 may be used as 8x25)	
A1	Correct unsimplified expression for total work done.	
A1	Correct answer, 2/3sf	
	N.B. Penalise accuracy only once in entire question. N.B. Answers only in part a) M0A0M0A0, part b) M0B0M0A0 and in part c) M1A1A1	

4(a)	$F = \frac{20000}{V}$	M1
	$F - 750g \sin \alpha - 200 = 0$	M1
	$\frac{20000}{V} - 750g \sin \alpha - 200 = 0$	A1
	Speed = 16 (m s ⁻¹)	A1
		(4)
4(b)	$D - 750g \sin \alpha - 200 = 750a$	M1
	$\frac{20000}{10} - 750g \sin \alpha - 200 = 750a$	A1A1
	$a = 1 \text{ (m s}^{-2}\text{)}$	A1
		(4)
4(c)	$\frac{1}{2} \times 750 \times 10^2 - 750gh = 200d$	M1
	$\frac{1}{2} \times 750 \times 10^2 - 750gd \sin \alpha = 200d$	A1A1
	OR $\frac{1}{2} \times 750 \times 10^2 - 750gh = 200 \times \frac{h}{\sin \alpha}$	
	$d = 30 \text{ (m)}$	A1
		(4)
		(12)
	Notes for question 4	
4(a)	M1 for use of $P = Fv$, condone wrong number of 0's	
	M1 for equation of motion with correct terms, condone sign errors and sin/cos confusion, F does not need to be substituted	
	A1 Correct equation in V and α	
	A1 cao	
	N.B. Allow use of $-F$ and/or $-V$ throughout.	
4(b)	M1 for equation of motion with correct terms, condone sign errors and sin/cos confusion, D does not need to be substituted.	
	A1 correct equation in a only with at most one error	
	A1 correct equation in a	
	A1 cao	
4(c)	M1 for work-energy equation, dimensionally correct, with correct terms, condone sign errors and allow with h and d	
	N.B. Treat use of 16 instead of 10 an A error.	
	N.B. M0 for $\frac{1}{2} \times 750 \times 10^2 - 750gh = 200h$	
	A1 correct equation in d only or h only with at most one error	
	A1 correct equation in d only or h only	
	A1 cao	

Question	Scheme	Mark	Notes
5a	Use of $P = Fv$ $\left(F = \frac{500}{6}\right)$	M1	
	Equation of motion	M1	Dimensionally correct. Required terms and no extras
	$F - 60 = 80a$	A1	Correct unsimplified equation in F
	$a = \frac{7}{24}(\text{ms}^{-2})$	A1	0.29 or better (0.291666666..)
		[4]	
5b	Gain in KE = $\frac{1}{2} \times 80 \times 8^2 (\text{J}) (= 2560(\text{J}))$ Gain in GPE = $80 \times 9.8 \times 300 (\text{J}) (= 235200(\text{J}))$ Work done against resistance = 20000×60	B1 B1	Any one correct (seen or implied) A second term correct (seen or implied) (KE gain + GPE gain = 237760 J)
	Use of <i>suvat</i> and $F = ma$ is M0A0A0		
	expression for combined work and energy	M1	All terms required and no double counting. Mass replaced with 80. Condone sign errors. Dimensionally correct. Condone error in zeros in 20000
	Total work done = $40 \times 64 + 80 \times 9.8 \times 300 + 20000 \times 60$	A1	Correct unsimplified expression for the work done
	$1440(\text{kJ})$ or $1400(\text{kJ})$	A1	Accept answers in joules. 3 sf or 2 sf (1437760)
		[5]	
5c	Equation of motion	M1	Dimensionally correct. Required terms and no extras
	$F - 60 - 80g \times \sin \alpha = 0$ $\frac{P}{7} - 60 - 80g \times \frac{1}{20} = 0$	A1 A1	Unsimplified equation in P or F with at most one error Correct unsimplified equation in P
	$P = 694$ or $P = 690$	A1	3sf or 2 sf only
		[4]	
		(13)	

	$\theta^\circ = \tan^{-1} 2 - \tan^{-1} \left(\frac{29}{59} \right)$	M1	Use their v to find the required angle ($63.43^\circ - 26.175^\circ$)
	$\theta = 37.3$	A1	37 or better
		[7]	
		(12)	
8a	Normal reaction between P and the ramp $= 3g \cos \alpha \quad \left(= \frac{18g}{\sqrt{37}} = 29.0 \right)$	B1	cao ISW
	Use of $F = \frac{3}{4} R$	M1	$\frac{3}{4} \times$ their R (Must have an R)
	Work done $= 4F$	M1	Their F (Must have an F)
	$= 87.0 (87) (J)$	A1	3 sf or 2 sf only (follows 9.8) do not allow $\frac{54}{\sqrt{37}} g$ (this is an acceleration)
		[4]	
8b	Work-energy equation	M1	M0 if not using work-energy. All terms required. Condone sign errors Condone sin/cos confusion
	$\frac{1}{2} \times 3U^2 - \text{their}(a) - 3g \times 4 \sin \alpha = \frac{1}{2} \times 3 \times 25$	A1ft A1ft	Unsimplified equation with at most one error. Follow their (a) Correct unsimplified equation Follow their (a)
	$U = 9.79$ or $U = 9.8$	A1	3 sf or 2 sf only (follows 9.8)
		[4]	
8c	Time taken:	M1	Complete method using <i>suvat</i> and $u = 5$ to form an equation in t only
	$-4 \sin \alpha = (5 \sin \alpha) t - \frac{1}{2} g t^2$ $(4.9\sqrt{37} t^2 - 5t - 4 = 0)$	A1	Correct unsimplified equation for t .
	$t = 0.45969 \dots$	A1	Seen or implied
	Horizontal distance	M1	Complete method using <i>suvat</i> and $u = 5$
	$= (5 \cos \alpha) t \quad \left(= \frac{30}{\sqrt{37}} t \right)$	A1ft	Follow their t
	$= 2.27$ or $2.3 (m)$	A1	3 sf or 2 sf only
		[6]	
	Alternative: First M1A1 as above Second M1A1 as above Second A1 correct quadratic in horizontal distance e.g. $\frac{37 \times 4.9}{35 \times 25} d^2 - \frac{1}{6} d - \frac{4}{\sqrt{37}} = 0$ Final A1 as above		
		(14)	

5. For misreading which does not alter the character of a question or materially simplify it, deduct two from any A or B marks gained, in that part of the question affected.
6. If a candidate makes more than one attempt at any question:
 - If all but one attempt is crossed out, mark the attempt which is NOT crossed out.
 - If either all attempts are crossed out or none are crossed out, mark all the attempts and score the highest single attempt.
7. Ignore wrong working or incorrect statements following a correct answer.

