Work, Energy and Power

Questions

Q1.

A car of mass 1200 kg moves up a straight road that is inclined to the horizontal at an angle α, where $\sin \alpha = \frac{1}{15}$

The total resistance to the motion of the car from non-gravitational forces is modelled as a constant force of magnitude R newtons.

At the instant when the engine of the car is working at a rate of 32 kW and the speed of the car is 20 m s^{-1} , the acceleration of the car is 0.5 m s^{-2}

Find the value of R

(Total for question = 5 marks)

Q2.

A small ball of mass 0.3 kg is released from rest from a point 3.6 m above horizontal ground. The ball falls freely under gravity, hits the ground and rebounds vertically upwards.

In the first impact with the ground, the ball receives an impulse of magnitude 4.2 N s. The ball is modelled as a particle.

(a) Find the speed of the ball immediately after it first hits the ground.

(5)

(b) Find the kinetic energy lost by the ball as a result of the impact with the ground.

(3)

(Total for question = 8 marks)

Q3.

A truck of mass 1200 kg is moving along a straight horizontal road.

At the instant when the speed of the truck is v m s^{-1}, the resistance to the motion of the truck is modelled as a force of magnitude $(900 + 9v)$ N.

The engine of the truck is working at a constant rate of 25 kW.

(a) Find the deceleration of the truck at the instant when $v = 25$

(4)

Later on, the truck is moving up a straight road that is inclined at an angle θ to the horizontal, where $\sin\theta = \frac{1}{20}$

At the instant when the speed of the truck is v m s^{-1}, the resistance to the motion of the truck from non-gravitational forces is modelled as a force of magnitude $(900 + 9v)$ N.

When the engine of the truck is working at a constant rate of 25 kW the truck is moving up the road at a constant speed of V m s^{-1}.

(b) Find the value of V.

(5)

(Total for question = 9 marks)

Q4.

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

At the instant when the speed of the van is v m s^{-1}, the resistance to the motion of the van is modelled as a force of magnitude $(500 + 7v)$ N.

When the engine of the van is working at a constant rate of 18 kW, the van is moving along the road at a constant speed V m s^{-1}

(a) Find the value of V.

(5)

Later on, the van is moving up a straight road that is inclined to the horizontal at an angle θ , where $\sin\theta = \frac{1}{21}$

At the instant when the speed of the van is v m s^{-1}, the resistance to the motion of the van from non-gravitational forces is modelled as a force of magnitude $(500 + 7v)$ N.

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

(b) Find the acceleration of the van at the instant when $v = 15$

(4)

(Total for question = 9 marks)

Q5.

Unless otherwise indicated, whenever a numerical value of g is required, take g = 9.8 m s^{-2} and give your answer to either 2 significant figures or 3 significant figures.

[*In this question use g =10 m s^{-2}*]

A jogger of mass 60 kg runs along a straight horizontal road at a constant speed of 4 m s^{-1}. The total resistance to the motion of the jogger is modelled as a constant force of magnitude 30 N.

(a) Find the rate at which the jogger is working.

(3)

The jogger now comes to a hill which is inclined to the horizontal at an angle α, where $\sin\alpha = \frac{1}{15}$. Because of the hill, the jogger reduces her speed to 3 m s^{-1} and maintains this constant speed as she runs up the hill. The total resistance to the motion of the jogger from non-gravitational forces continues to be modelled as a constant force of magnitude 30 N.

(b) Find the rate at which she has to work in order to run up the hill at 3 m s^{-1}.

(5)

(Total for question = 8 marks)

Q6.

Unless otherwise indicated, whenever a numerical value of g is required, take g = 9.8 ms^{-2} and give your answer to either 2 significant figures or 3 significant figures.

A car of mass 600 kg is moving along a straight horizontal road.

At the instant when the speed of the car is v m s^{-1}, the resistance to the motion of the car is modelled as a force of magnitude (200 + 2v)N.

The engine of the car is working at a constant rate of 12 kW.

(a) Find the acceleration of the car at the instant when v = 20

(4)

Later on the car is moving up a straight road inclined at an angle θ to the horizontal, where $\sin\theta = \frac{1}{14}$

At the instant when the speed of the car is v m s^{-1}, the resistance to the motion of the car from non-gravitational forces is modelled as a force of magnitude $(200 + 2v)$N.

The engine is again working at a constant rate of 12 kW.

At the instant when the car has speed w m s^{-1}, the car is decelerating at 0.05 m s^{-2}.

(b) Find the value of w.

(5)

(Total for question = 9 marks)

Q7.

A truck of mass 900 kg is towing a trailer of mass 150 kg up an inclined straight road with constant speed 15 m s^{-1}. The trailer is attached to the truck by a light inextensible towbar which is parallel to the road. The road is inclined at an angle θ to the horizontal, where $\sin\theta = \frac{1}{9}$. The resistance to motion of the truck from non-gravitational forces has constant magnitude 200 N and the resistance to motion of the trailer from non-gravitational forces has constant magnitude 50 N.

(a) Find the rate at which the engine of the truck is working.

(5)

When the truck and trailer are moving up the road at 15 m s^{-1} the towbar breaks, and the trailer is no longer attached to the truck. The rate at which the engine of the truck is working is unchanged. The resistance to motion of the truck from non-gravitational forces and the resistance to motion of the trailer from non-gravitational forces are still forces of constant magnitudes 200 N and 50 N respectively.

(b) Find the acceleration of the truck at the instant after the towbar breaks.

(3)

(c) Use the work-energy principle to find out how much further up the road the trailer travels before coming to instantaneous rest.

(4)

(Total for question = 12 marks)

Q8.

Unless otherwise indicated, whenever a numerical value of g is required, take $g = 9.8 \text{ m s}^{-2}$ and give your answer to either 2 significant figures or 3 significant figures.

A small stone of mass 0.5 kg is thrown vertically upwards from a point A with an initial speed of 25 m s^{-1}. The stone first comes to instantaneous rest at the point B which is 20 m vertically above the point A. As the stone moves it is subject to air resistance. The stone is modelled as a particle.

(a) Find the energy lost due to air resistance by the stone, as it moves from A to B.

(3)

The air resistance is modelled as a constant force of magnitude R newtons.

(b) Find the value of R.

(2)

(c) State how the model for air resistance could be refined to make it more realistic.

(1)

(Total for question = 6 marks)

Q9.

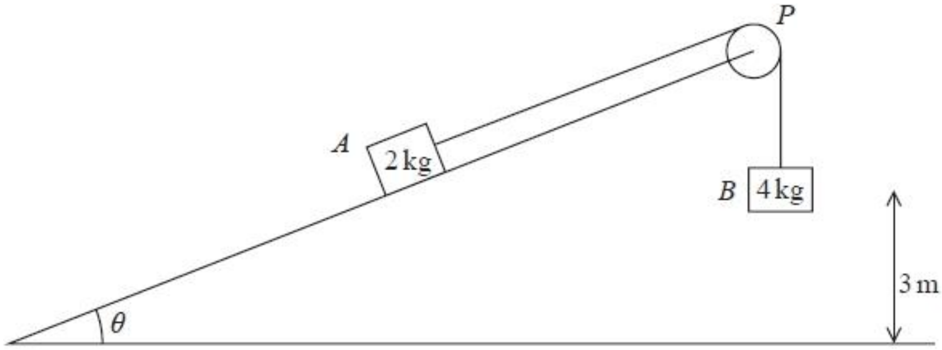


Figure 4

Two blocks, *A* and *B*, of masses 2 kg and 4 kg respectively are attached to the ends of a light inextensible string.

Initially *A* is held on a fixed rough plane. The plane is inclined to horizontal ground at an angle θ, where $\tan\theta = \frac{3}{4}$

The string passes over a small smooth light pulley *P* that is fixed at the top of the plane. The part of the string from *A* to *P* is parallel to a line of greatest slope of the plane.

Block *A* is held on the plane with the distance *AP* greater than 3 m.
Block *B* hangs freely below *P* at a distance of 3 m above the ground, as shown in Figure 4.

The coefficient of friction between *A* and the plane is μ

Block *A* is released from rest with the string taut.

By modelling the blocks as particles,

(a) find the potential energy lost by the whole system as a result of *B* falling 3 m.

(3)

Given that the speed of *B* at the instant it hits the ground is 4.5 m s^{-1} and ignoring air resistance,

(b) use the work-energy principle to find the value of μ

(6)

After *B* hits the ground, *A* continues to move up the plane but does not reach the pulley in the subsequent motion. Block *A* comes to instantaneous rest after moving a total distance of $(3 + d)$m from its point of release.

Ignoring air resistance,

(c) use the work-energy principle to find the value of *d*

(4)

(Total for question = 13 marks)

Q10.

A car of mass 600 kg pulls a trailer of mass 150 kg along a straight horizontal road. The trailer is connected to the car by a light inextensible towbar, which is parallel to the direction of motion of the car. The resistance to the motion of the trailer is modelled as a constant force of magnitude 200 N. At the instant when the speed of the car is v m s^{-1}, the resistance to the motion of the car is modelled as a force of magnitude $(200 + \lambda v)$ N, where λ is a constant.

When the engine of the car is working at a constant rate of 15 kW, the car is moving at a constant speed of 25 m s^{-1}

(a) Show that $\lambda = 8$

(4)

Later on, the car is pulling the trailer up a straight road inclined at an angle θ to the horizontal, where $\sin\theta = \frac{1}{15}$

The resistance to the motion of the trailer from non-gravitational forces is modelled as a constant force of magnitude 200 N at all times. At the instant when the speed of the car is v m s^{-1}, the resistance to the motion of the car from non-gravitational forces is modelled as a force of magnitude $(200 + 8v)$ N.

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

When $v = 10$, the towbar breaks. The trailer comes to instantaneous rest after moving a distance d metres up the road from the point where the towbar broke.

(b) Find the acceleration of the car immediately after the towbar breaks.

(4)

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

(4)

(Total for question = 12 marks)

Q11.

A van of mass 750 kg is moving along a straight horizontal road. At the instant when the van is moving at v m s^{-1}, the resistance to the motion of the van is modelled as a force of magnitude λvN, where λ is a constant.

The engine of the van is working at a constant rate of 18 kW.
At the instant when $v = 15$, the acceleration of the van is 0.6 m s^{-2}

(a) Show that $\lambda = 50$

(4)

The van now moves up a straight road inclined at an angle to the horizontal, where

$$\sin\alpha = \frac{1}{15}$$

At the instant when the van is moving at v m s^{-1}, the resistance to the motion of the van from non-gravitational forces is modelled as a force of magnitude $50v$ N.
When the engine of the van is working at a constant rate of 12 kW, the van is moving at a constant speed V m s^{-1}

(b) Find the value of V.

(5)

(Total for question = 9 marks)

Q12.

Unless otherwise indicated, whenever a numerical value of g is required, take $g = 9.8$ ms^{-2} and give your answer to either 2 significant figures or 3 significant figures.

A parcel of mass 5 kg is projected with speed 8 m s^{-1} up a line of greatest slope of a fixed rough inclined ramp.

The ramp is inclined at angle α to the horizontal, where $\sin\alpha = \frac{1}{7}$

The parcel is projected from the point A on the ramp and comes to instantaneous rest at the point B on the ramp, where AB = 14m.

The coefficient of friction between the parcel and the ramp is μ.

In a model of the parcel's motion, the parcel is treated as a particle.

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

(5)

(b) Suggest one way in which the model could be refined to make it more realistic.

(1)

(Total for question = 6 marks)

Q13.

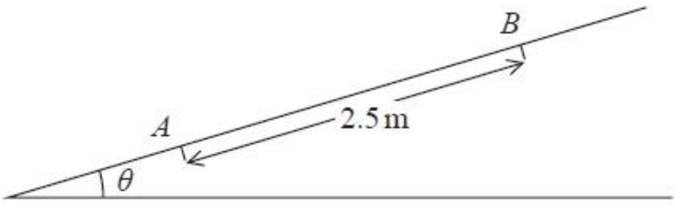


Figure 1

Figure 1 shows a ramp inclined at an angle θ to the horizontal, where $\sin\theta = \frac{2}{7}$

A parcel of mass 4 kg is projected, with speed 5 m s^{-1}, from a point *A* on the ramp.
The parcel moves up a line of greatest slope of the ramp and first comes to instantaneous rest at the point *B*, where *AB* = 2.5 m.
The parcel is modelled as a particle.

The total resistance to the motion of the parcel from non-gravitational forces is modelled as a constant force of magnitude *R* newtons.

(a) Use the work-energy principle to show that *R* = 8.8

(4)

After coming to instantaneous rest at *B*, the parcel slides back down the ramp. The total resistance to the motion of the particle is modelled as a constant force of magnitude 8.8 N.

(b) Find the speed of the parcel at the instant it returns to *A*.

(3)

(c) Suggest two improvements that could be made to the model.

(2)

(Total for question = 9 marks)

Q14.

A lorry of mass 16 000 kg moves along a straight horizontal road.

The lorry moves at a constant speed of 25 m s^{-1}

In an initial model for the motion of the lorry, the resistance to the motion of the lorry is modelled as having constant magnitude 16 000 N.

(a) Show that the engine of the lorry is working at a rate of 400 kW.

(4)

The model for the motion of the lorry along the same road is now refined so that when the speed of the lorry along the same road is V m s^{-1}, the resistance to the motion of the lorry is modelled as having magnitude 640*V* newtons.

Assuming that the engine of the lorry is working at the same rate of 400 kW

(b) use the refined model to find the speed of the lorry when it is accelerating at 2.1 m s^{-2}

(6)

(Total for question = 10 marks)

Q15.

Unless otherwise indicated, whenever a numerical value of g is required, take g = 9.8 ms^{-2} and give your answer to either 2 significant figures or 3 significant figures.

A particle *P* of mass 0.5 kg is moving with velocity (4**i** + **j**) m s^{-1} when it receives an impulse (2**i** – **j**) N s.

Show that the kinetic energy gained by *P* as a result of the impulse is 12 J.

(6)

(Total for question = 6 marks)

Q16.

A particle, P, of mass m kg is projected with speed 5 m s^{-1} down a line of greatest slope of a rough plane. The plane is inclined to the horizontal at an angle α, where sin α = $\frac{3}{5}$

The total resistance to the motion of P is a force of magnitude $\frac{1}{5}mg$

Use the work-energy principle to find the speed of P at the instant when it has moved a distance 8 m down the plane from the point of projection.

(Total for question = 7 marks)

Q17.

A car of mass 1000 kg moves along a straight horizontal road.

In all circumstances, when the speed of the car is v m s^{-1}, the resistance to the motion of the car is modelled as a force of magnitude cv^2 N, where c is a constant.

The maximum power that can be developed by the engine of the car is 50 kW.

At the instant when the speed of the car is 72 km h^{-1} and the engine is working at its maximum power, the acceleration of the car is 2.25 m s^{-2}

(a) Convert 72 km h^{-1} into m s^{-1}

(1)

(b) Find the acceleration of the car at the instant when the speed of the car is 144 km h^{-1} and the engine is working at its maximum power.

(7)

The maximum speed of the car when the engine is working at its maximum power is V km h^{-1}.

(c) Find, to the nearest whole number, the value of V.

(4)

(Total for question = 12 marks)

Q18.

A small ball, of mass *m*, is thrown vertically upwards with speed $\sqrt{8gH}$ from a point *O* on a smooth horizontal floor. The ball moves towards a smooth horizontal ceiling that is a vertical distance *H* above *O*. The coefficient of restitution between the ball and the ceiling is $\frac{1}{2}$

In a model of the motion of the ball, it is assumed that the ball, as it moves up or down, is subject to air resistance of constant magnitude $\frac{1}{2}mg$.

Using this model,

(a) use the work-energy principle to find, in terms of *g* and *H*, the speed of the ball immediately before it strikes the ceiling,

(5)

(b) find, in terms of *g* and *H*, the speed of the ball immediately before it strikes the floor at *O* for the first time.

(5)

In a simplified model of the motion of the ball, it is assumed that the ball, as it moves up or down, is subject to no air resistance.

Using this simplified model,

(c) explain, without any detailed calculation, why the speed of the ball, immediately before it strikes the floor at *O* for the first time, would still be less than $\sqrt{8gH}$

(1)

(Total for question = 11 marks)

Q19.

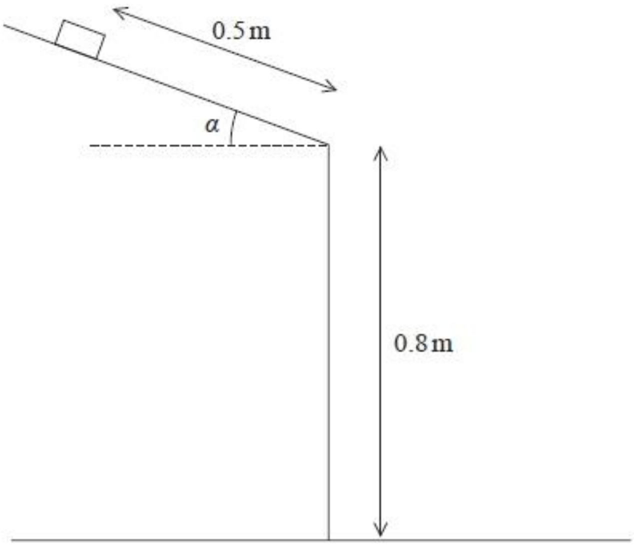


Figure 1

A small book of mass *m* is held on a rough straight desk lid which is inclined at an angle *α* to the horizontal, where $\tan\alpha = \frac{3}{4}$. The book is released from rest at a distance of 0.5 m from the edge of the desk lid, as shown in Figure 1. The book slides down the desk lid and then hits the floor that is 0.8 m below the edge of the desk lid. The coefficient of friction between the book and the desk lid is 0.4

The book is modelled as a particle which, after leaving the desk lid, is assumed to move freely under gravity.

(a) Find, in terms of *m* and *g*, the magnitude of the normal reaction on the book as it slides down the desk lid.

(2)

(b) Use the work-energy principle to find the speed of the book as it hits the floor.

(5)

(Total for question = 7 marks)

Q20.

The total mass of a cyclist and his bicycle is 100 kg.

In all circumstances, the magnitude of the resistance to the motion of the cyclist from non-gravitational forces is modelled as being kv^2 N, where v m s^{-1} is the speed of the cyclist.

The cyclist can freewheel, without pedalling, down a slope that is inclined to the horizontal at an angle α, where $\sin\alpha = \frac{1}{35}$, at a constant speed of V m s^{-1}

When he is pedalling up a slope that is inclined to the horizontal at an angle β, where $\sin\beta = \frac{1}{70}$, and he is moving at the same constant speed V m s^{-1}, he is working at a constant rate of P watts.

(a) Find P in terms of V.

(7)

If he pedals and works at a rate of 35 V watts on a horizontal road, he moves at a constant speed of U m s^{-1}

(b) Find U in terms of V.

(4)

(Total for question = 11 marks)

Q21.

A plane is inclined to the horizontal at an angle α, where $\tan\alpha = \frac{3}{4}$

A particle P is held at rest at a point A on the plane.

The particle P is then projected with speed 25 m s^{-1} from A, up a line of greatest slope of the plane.

In an initial model, the plane is modelled as being smooth and air resistance is modelled as being negligible.

Using this model and the principle of conservation of mechanical energy,

(a) find the speed of P at the instant when it has travelled a distance $\frac{25}{6}$ m up the plane from A.

(4)

In a refined model, the plane is now modelled as being rough, with the coefficient of friction between P and the plane being $\frac{3}{5}$

Air resistance is still modelled as being negligible.

Using this refined model and the work-energy principle,

(b) find the speed of P at the instant when it has travelled a distance $\frac{25}{6}$ m up the plane from A.

(8)

(Total for question = 12 marks)

Q22.

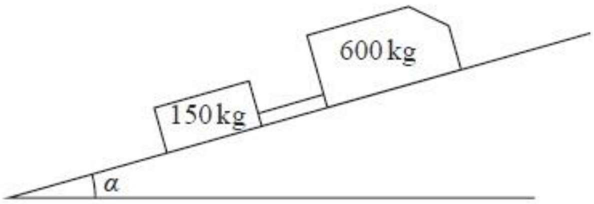


Figure 1

A van of mass 600 kg is moving up a straight road which is inclined at an angle α to the horizontal, where $\sin \alpha = \frac{1}{15}$. The van is towing a trailer of mass 150 kg. The van is attached to the trailer by a towbar which is parallel to the direction of motion of the van and the trailer, as shown in Figure 1.

The resistance to the motion of the van from non-gravitational forces is modelled as a constant force of magnitude 200 N.
The resistance to the motion of the trailer from non-gravitational forces is modelled as a constant force of magnitude 100 N.

The engine of the van is working at a constant rate of 12 kW.

Find the tension in the towbar at the instant when the speed of the van is 9 m s^{-1}

(Total for question = 8 marks)

Mark Scheme – Work, Energy and Power

Q1.

Question	Scheme	Marks	AOs
	$F = \dfrac{32000}{20}$	M1	3.3
	Equation of motion	M1	3.1b
	$F - 1200g\sin\alpha - R = 1200 \times 0.5$	A1	1.1b
	Substitute for g, trig and F and solve for R	DM1	1.1b
	$R = 216$ or 220 (N)	A1	1.1b
		(5)	
			(5 marks)

Notes:

M1	Use of $P = Fv$. Allow $\dfrac{32}{20}$. Allow $32000 = 20F$ or $32 = 20F$, followed by an error when dividing M0 for $32000 = 20(F - R)$ or similar	
M1	Correct no. of terms, condone sign errors and sin/cos confusion M0 if they use power in equation of motion	
A1	Correct equation	
DM1	Dependent on second M1 (allow if g missing)	
A1	Cao ($R = 215.2$ if they use $g = 9.81$)	

Q2.

Question	Scheme	Marks	AOs
(a)	Speed just before impact: $v^2 = u^2 + 2as = 2\times 9.8\times 3.6 (= 70.56)$	M1	3.4
	$v = 8.4$ (m s^{-1})	A1	1.1b
	Use of $I = mv - mu$: $4.2 = 0.3(w - (-8.4))$	M1	3.1b
	Follow their 8.4	A1ft	1.1b
	$w = 5.6$ (m s^{-1})	A1	1.1b
		(5)	
(b)	KE lost $= \frac{1}{2}m(v^2 - w^2)$	M1	3.3
	$= \frac{0.3}{2}(8.4^2 - 5.6^2)$ Follow their 8.4 and 5.6	A1ft	1.1b
	$= 5.88$ (J)	A1	1.1b
		(3)	
			(8 marks)

Notes
(a) **M1:** Use the model and *suvat* or energy to find speed before impact **A1:** Correct answer. Accept $\sqrt{70.56}$, $\sqrt{7.2g}$ **M1:** A complete strategy to find w: Use the model and impulse-momentum equation using given impulse and their speed of impact. Must be using a difference in velocities. Be vigilant for sign fudges that make the original equation incorrect. **A1ft:** Correct unsimplified equation using their speed **A1:** Correct positive answer
(b) **M1:** Correct method to find the KE lost in the impact. Need to be using speeds immediately before and immediately after impact. **A1ft:** Correct expression for their speeds. Accept subtraction either way round **A1:** Correct solution only. Accept 5.9

Q3.

Question	Scheme	Marks	AOs
(a)	Equation of motion: $F-(900+9\times 25)=1200a$	M1	3.3
	Use of $25000=F\times 25$	M1	3.4
	$\frac{25000}{25}-(900+225)=1200a$	A1	1.1b
	$a=-\frac{5}{48}$ deceleration $=\frac{5}{48}$ $(=0.10416..)$ (m s^{-2})	A1	1.1b
		(4)	
(b)	Equation of motion:	M1	3.3
	$\frac{25000}{V}-1200g\sin\theta-(900+9V)=0$	A1 A1	1.1b 1.1b
	Form quadratic and solve for V:	M1	1.1b
	$(9V^2+1488V-25000=0)$ $V=15.4(15)$	A1	1.1b
		(5)	
			(9 marks)

Notes:

(a)M1	Dimensionally correct. Condone sign errors
M1	Correct use of $P=Fv$. Allow in (b) if not seen in (a).
A1	Correct unsimplified equation
A1	0.10 or better. Final answer must be positive.
(b)M1	Need all terms. Dimensionally correct. Condone sign errors
A1 A1	Unsimplified equation with at most one error Correct unsimplified equation
M1	Complete method to solve for V
A1	Correct to 2 sf or 3 sf

Q4.

Question	Scheme	Marks	AOs
(a)	Equation of motion: $F = 500 + 7V$	M1	3.3
	Use of $18000 = F \times V$	M1	3.4
	$\Rightarrow \frac{18000}{V} = 500 + 7V$	A1	1.1b
	$\Rightarrow 7V^2 + 500V - 18000 = 0$	M1	1.1b
	$V = 26 \quad (26.309....)$	A1	1.1b
		(5)	
(b)	Equation of motion:	M1	3.3
	$\frac{18000}{15} - (500 + 7 \times 15) - 900g \times \frac{1}{21} = 900a$	A1 A1	1.1b 1.1b
	$a = 0.194\,(0.19)\,(\text{ms}^{-2})$	A1	1.1b
		(4)	
			(9 marks)

Notes:	
(a) M1	Dimensionally correct. Condone sign errors. Must be using $a = 0$
M1	Correct use of $P = Fv$
A1	Correct unsimplified equation. Allow with F. Allow with 18K
M1	Form and solve a 3 term quadratic
A1	26 or better (26.309……)
(b)M1	Dimensionally correct. All terms required. Condone sign errors and sin/cos confusion. Omission of g is an accuracy error
A1 A1	Unsimplified equation with at most one error Correct unsimplified equation. Allow if $\sin\theta$ not substituted. Allow with 18K
A1	2 sf or 3 sf only not $\frac{7}{36}$

Q5.

Question	Scheme	Marks	AOs
(a)	Force = Resistance (since no acceleration) = 30	B1	3.1b
	Power = Force ← Speed = 30 ← 4	M1	1.1b
	= 120 W	A1 ft	1.1b
		(3)	
(b)	Resolving parallel to the slope	M1	3.1b
	$F - 60g\sin\alpha - 30 = 0$	A1	1.1b
	$F = 70$	A1	1.1b
	Power = Force ← Speed = 70 ← 3	M1	1.1b
	= 210 W	A1 ft	1.1b
		(5)	
			(8 marks)

Notes:

(a)

B1: for force = 30 seen

M1: for use of $P = Fv$

A1ft: for 120 (W), follow through on their '30'

(b)

M1: for resolving parallel to the slope with correct no. of terms and $60g$ resolved

A1: for a correct equation

A1: for $F = 70$

M1: for use of $P = Fv$

A1ft: for 210 (W), follow through on their '70'

Q6.

Question	Scheme	Marks	AOs
(a)	Use of $P = Fv$: $F = \dfrac{12000}{20}$	B1	3.3
	Equation of motion: $F - (200 + 2v) = 600a$	M1	3.4
	$600 - 240 = 600a$	A1ft	1.1b
	$360 = 600a$, $a = 0.6$ (m s^{-2})	A1	1.1b
		(4)	
(b)	Equation of motion	M1	3.3
	$\dfrac{12000}{w} - (200 + 2w) - 600g\sin\theta = -600 \times 0.05$	A1 A1	1.1b 1.1b
	3 term quadratic and solve: $2w^2 + 590w - 12000 = 0$	M1	1.1b
	$w = \dfrac{-590 + \sqrt{590^2 + 96000}}{4} = 19.1$ (m s^{-1})	A1	1.1b
		(5)	
			(9 marks)

Notes:

(a)

B1: 600 or equivalent

M1: Use the model to form the equation of motion.
Must include all terms.Condone sign errors.

A1ft: Correct for their F

A1: cao.

(b)

M1: Use the model to form the equation of motion.
All terms needed.
Condone sign errors and sin/cos confusion.

A1: All correct A1A1
One error A1A0

M1: Dependent on the preceding M1. Use the equation of motion to form a 3-term quadratic in w only

A1: Accept 19. Do not accept more than 3 s.f.

Q7.

Q.	Scheme	Marks	Notes
a	Constant speed $\Rightarrow$ no acceleration. Driving force $= 200 + 50 + 900g\sin\theta + 150g\sin\theta$	M1	Equation of motion of the truck. All terms required & dimensionally correct. Condone sin/cos confusion and sign error(s)
	Or $D - T - 200 - 900g\sin\theta = 0$ **and** $T - 50 - 150g\sin\theta = 0$		
		A1	At most one error. Allow for 2 separate equations including T
		A1	Correct unsimplified expression for the driving force (no T)
	$= 250 + 1050g \times \frac{1}{9} (= 1393.3333...)$		$\left(\frac{4180}{3}\right)$
	$P = \left(250 + 1050g \times \frac{1}{9}\right) \times 15$	M1	Use of $P = Fv$ with their F. Independent M1. Could appear in first equation as $F = \frac{P}{v}$.
	$= 20900\text{ W} (20.9\text{ kW})$	A1	Accept 21000 W, 21kW. Maximum 3 s.f.
		(5)	
b	$\left(their 1393\frac{1}{3}\right) - 200 - 900g \times \frac{1}{9} = 900a$	M1	Equation of motion for the truck at instant after the towbar breaks. All terms required & dimensionally correct. Allow for an equation to find acceleration down the slope
		A1ft	Correct for their driving force $\left(1393\frac{1}{3}\right)$.
	$a = 0.237\text{ m s}^{-2}$	A1	Accept 0.24, not $\frac{32}{135}$ must be +ve
		(3)	
c	$\frac{1}{2} \times 150 \times 15^2 = 50d + 150g\sin\theta d$	M1	**Must be using work-energy (for trailer only)** All terms required & dimensionally correct. Condone sin/cos confusion and sign error(s)
		A1	Unsimplified equation with at most one error
	$\left(16875 = 50d + \frac{150}{9}gd\right)$	A1	Correct unsimplified equation for d
	$d = 79\text{ m}$ (79.1)	A1	Maximum 3 s.f.
		(4)	
		[12]	

Q8.

Question	Scheme	Marks	AOs
(a)	Energy Loss = KE Loss – PE Gain	M1	3.3
	$= \frac{1}{2} \times 0.5 \times 25^2 - 0.5\,g \times 20$	A1	1.1b
	$= 58.25 = 58$ (J) or 58.3 (J)	A1	1.1b
		(3)	
(b)	Using work-energy principle, $20\,R = 58.25$	M1	3.3
	$R = 2.9125 = 2.9$ or 2.91	A1 ft	1.1b
		(2)	
(c)	Make resistance variable (dependent on speed)	B1	3.5c
		(1)	
			(6 marks)

Notes:

(a)
M1: for a difference in KE and PE
A1: for a correct expression
A1: for either 58 (2SF) or 58.3(3SF)

(b)
M1: for use of work-energy principle
A1ft: for either 2.9 (2SF) or 2.91 (3SF) follow through on their answer to (a)

(c)
B1: for variable resistance oe

Q9.

Question	Scheme	Marks	AOs
(a)	GPE lost by B – GPE gained by A	M1	3.4
	$= 4 \times g \times 3 - 2 \times g \sin\theta \times 3$	A1	1.1b
	$= 82\,(82.3)\,(\text{J})$	A1	1.1b
		(3)	
(b)	Total KE gained $= \frac{1}{2} \times 6 \times 4.5^2\ (= 60.75)\,(\text{J})$	B1	3.1b
	Max friction $\mu 2g\cos\theta\ (= \mu \times 2 \times 9.8 \times \cos\theta = 15.68\mu)$	B1	3.1b
	Work done against friction $= 3 \times F_{\max}\ (= 47.04\mu)$	B1ft	3.4
	Work-energy equation: their GPE lost = their KE gained + their WD against friction	M1	3.4
	$82.32 = 60.75 + 47.04\mu$	A1	1.1b
	$\mu = 0.459\,(0.46)$	A1	1.1b
		(6)	
(c)	Work-energy equation for A:	M1	3.4
	$\frac{1}{2} \times 2 \times 4.5^2 = 2g\sin\theta \times d + 2g\cos\theta \times \mu d$ $\left(= 19.6 \times \frac{3}{5} \times d + 19.6 \times \frac{4}{5} \times \mu d\right)$	A1ft A1ft	1.1b 1.1b
	$d = 1.07\,(1.1)$	A1	1.1b
		(4)	
		(Total 13 marks)	

Notes	
(a)M1	Expression for change in GPE. Must be dimensionally correct and resolved terms where necessary. Allow subtraction either way round
A1	Correct unsimplified expression for the change in PE (before substitution for $\sin\theta$) Allow subtraction either way round
A1	2 sf or 3 sf. Accept 8.4g or $\frac{42g}{5}$ ISW Must be positive but condone a sign change at the end without explanation
(b) B1	Gain in KE for the system (not just for one block)

B1	Correct unsimplified expression for F_{max} seen or implied
B1ft	Correct expression for work done: follow their F_{max} This is dependent on them having found an expression for F_{max}
M1	Complete method using work-energy to form an equation in μ. Require all terms (needs to consider the KE and GPE of both blocks). Dimensionally correct. Condone sign errors.
A1	Correct unsimplified equation in μ
A1	3 sf or 2 sf only
	NB: It is possible to find the value of μ by finding the tension in the string and forming a work-energy equation for particle *B*, but in this case the first B1 is for KE of *B* and correct tension (25.7(N)) B1 for F_{max} B1ft is for work done by the tension in the string and against friction M1 for $3 \times 25.7 = 20.25 + 35.28 + 3 \times 15.68\mu$ O.E.
(c)M1	All terms required. Dimensionally correct. Condone sign errors and sin / cos confusion. If the equation uses $d+3$ in place of *d* in the PE term it is correct if it also includes a term for the initial PE. If the equation uses $d+3$ in place of *d* in the term for work done then it scores M0.
A1 A1	Unsimplified equation in *d* and μ with at most one error Correct unsimplified equation in *d* and μ The ft is on their μ if they have substituted a value.
A1	3 sf or 2 sf only

Q10.

Question	Scheme	Marks	AOs	Notes
(a)	Use of $P = Fv$: $F = \frac{15000}{25} (= 600)$	B1	3.3	600 or equivalent
	Equation of motion:	M1	3.4	Use the model to form the equation of motion If they start with two separate equations each one must be correct.
	$F - (200 + 200 + 25\lambda) = 0$	A1	1.1b	Correct unsimplified equation
	$\lambda = 8$ *	A1*	2.2a	Deduce **given answer** from correct working.
		(4)		
(b)	Equation of motion:	M1	3.4	Use the model to form the equation of motion for the car (with $v = 10$ used). All terms required. Dimensionally correct. Condone sign error and sin/cos confusion
	$\frac{15000}{10} - 280 - 600g\sin\theta = 600a$	A1 A1	1.1b 1.1b	Unsimplified equation with at most one error. Correct unsimplified equation
	$a = 1.38$ m s^{-2} (1.4)	A1	1.1b	2 or 3 sf only – follows use of 9.8
		(4)		
(c)	Work energy equation	M1	3.1b	Complete strategy to form the work-energy equation. Condone sin/cos confusion and sign errors
	$\frac{1}{2} \times 150 \times 100 = 200d + 150gd\sin\theta$	A1 A1	1.1b 1.1b	Unsimplified equation with at most one error Correct unsimplified equation for d
	$d = 25.2$ (m) (25)	A1	1.1b	Max 3 sf – follows use of 9.8
		(4)		
		(Total 12 marks)		

Q11.

Question	Scheme	Marks	AOs
(a)	Use of $P = Fv$	B1	1.1a
	Equation of motion: $F - \lambda v = 750 \times 0.6$	M1	2.1
	$\frac{18000}{15} - \lambda \times 15 = 750 \times 0.6$	A1	1.1b
	$1200 - 15\lambda = 450 \Rightarrow \lambda = 50$ *	A1*	1.1b
		(4)	
(b)	Overall strategy	M1	3.1b
	Equation of motion	M1	3.4
	$\frac{12000}{V} - 50V - 750g\sin\alpha = 0$	A1	1.1b
	$\frac{12000}{V} - 50V - 490 = 0 \Rightarrow 5V^2 + 49V - 1200 = 0$	A1	1.1b
	$\Rightarrow V \left(= \frac{-49 + \sqrt{49^2 + 20 \times 1200}}{10} \right) = 11.3$ only	A1	1.1b
		(5)	
			(9 marks)

Notes
(a) **B1**: Use of $P = Fv$ seen or implied. Allow in (b) if not seen in (a) **M1**: Requires all three terms. Must be dimensionally correct. Need not have substituted for F. Condone sign errors. Allow if equation not seen but all steps in working correct. The method needs to show that $\lambda = 50$ is the only solution. **A1**: Correct unsimplified equation **A1**: Obtain given answer correctly
(b) **M1**: Complete strategy e.g. use the model to form quadratic in V and solve for V **M1**: Use the model to form equation of motion. All terms required. Condone sign errors and sin/cos confusion. Need not have substituted for F. **A1**: Substituted equation with at most one error (unsimplified). Allow in F or V. **A1**: Correct quadratic equation. e.g. $5V^2 + 49V - 1200 = 0$ or equivalent Allow in F or V. **A1**: Accept 11 or 11.3 (follows use of 9.8) Negative root should be rejected if seen

Q12.

Question	Scheme	Marks	AOs
(a)	$R = 5g\cos\alpha \left(= 5g \times \frac{4\sqrt{3}}{7} = 48.497... \right)$	M1	3.4
	Force due to friction = $\mu \times 5g\cos\alpha$	M1	3.4
	Work-Energy equation	M1	3.4
	$\frac{1}{2} \times 5 \times 64 = 5 \times 9.8 \times 14\sin\alpha + 14\mu R$	A1	1.1b
	$\mu = 0.0913$ or 0.091	A1	1.1b
		(5)	
(b)	Appropriate refinement	B1	3.5c
		(1)	
			(6 marks)

Notes:

(a)

M1: Condone sin/cos confusion

M1: Use of $\mu \times$ their R

M1: Must be using work-energy. Requires all terms.
Condone sin/cos confusion, sign errors and their R

A1: Correct in θ and μR.

A1: Accept 0.0913 or 0.091

(b)

B1: e.g.
- Do not model the parcel as a particle and therefore take air resistance into account.
- Take into account the dimensions/uniformity of the parcel.

Q13.

Question	Scheme	Marks	AOs
(a)	Work-energy equation: KE lost = PE gained + Work Done	M1	2.1
	$\frac{1}{2}\times 4\times 5^2 - 4\times g\times 2.5\times \sin\theta = 2.5R$	A1	1.1b
	$\frac{1}{2}\times 4\times 5^2 - 4\times g\times 2.5\times \frac{2}{7} = 2.5R$	A1	1.1b
	$2.5R = 22 \Rightarrow R = 8.8$ *	A1*	1.1b
		(4)	
(b)	Work-energy equation: KE after =initial KE – 2 (Work Done)	M1	3.3
	$\frac{1}{2}\times 4\times v^2 = \frac{1}{2}\times 4\times 25 - 2\times 8.8\times 2.5$	A1	1.1b
	$\Rightarrow 2v^2 = 6,\ \ v = 1.7\,(\text{m s}^{-1})$	A1	1.1b
		(3)	
(b) alt	Work-energy equation: KE at B = PE lost – Work Done	M1	
	$\frac{1}{2}\times 4\times v^2 = 4\times 9.8\times \frac{2}{7}\times 2.5 - 8.8\times 2.5$	A1	
	$\Rightarrow 2v^2 = 6,\ \ v = 1.7\,(\text{m s}^{-1})$	A1	
		(3)	
(b) alt	Equation of motion and *suvat*: $4g\sin\theta - 8.8 = 4a \quad (a = 0.6)$	M1	
	$v^2 = 2\times a\times 2.5$	A1	
	$v = 1.7\ (\text{m s}^{-1})$	A1	
		(3)	
(c)	A valid improvement	B1	3.5c
	A second valid, distinct, improvement	B1	3.5c
		(2)	
			(9 marks)

Notes
(a) **M1:** A complete method to obtain R. The question requires the use of work-energy. Need to consider all three terms with no duplication. Condone sign error and sin/cos confusion. **A1:** Unsimplified equation with at most one error **A1:** Correct unsimplified **A1*:** Correct answer with sufficient working shown to justify **given answer**
(b) **M1:** Work-energy equation considering $A \to A$ or $B \to A$. Requires all relevant terms with no duplication. Condone sign errors and sin/cos confusion **A1:** Correct unsimplified equation **A1:** Accept 1.7 or 1.73 (answer depends on use of g). Not $\sqrt{3}$
(b) alt **M1:** Complete method to find v or v^2. **A1:** Correct unsimplified expression for v or v^2. **A1:** Accept 1.7 or 1.73 (answer depends on use of g)
(c) **B1:** it has assumed a constant resistance - have variable resistance – have air resistance proportional to speed ……

Q14.

Question	Scheme	Marks	AOs
(a)	Equation of motion parallel to the road with $a = 0$ and using the model	M1	3.3
	$F - 16000 = 0$	A1	1.1b
	$P = 16\ 000 \times 25$	M1	3.4
	$= 400\ 000 = 400$ kW *	A1*	1.1b
		(4)	
(b)	Use of $\dfrac{400\ 000}{V}$	M1	3.3
	Equation of motion parallel to the road and using the refined model	M1	3.4
	$\dfrac{400\ 000}{V} - 640V = 16000 \times 2.1$	A1	1.1b
	$2V^2 + 105V - 1250 = 0 \quad \left(640V^2 + 33600V - 400000 = 0\right)$	A1	1.1b
	Solve for V	M1	1.1b
	$V = 10$ (i.e. speed is 10 m s^{-1})	A1	1.1b
		(6)	
			(10 marks)

Notes		
(a)	M1	Correct no. of terms with $a = 0$, condone sign errors Given answer, so step must be seen, but allow if in verbal form or on a diagram.
	A1	Correct equation
	M1	Use of $P = Fv$ Independent mark - could be the first mark seen
	A1*	Obtain **given answer** from correct working
(b)	M1	Use of $P = Fv$
	M1	Correct no. of terms, condone sign errors. Dimensionally correct
	A1	Correct unsimplified equation
	A1	Correct 3 term quadratic
	M1	For solving a 3 term quadratic – this mark can be implied by a correct value of V but otherwise can only be earned for evidence of an explicit method being used.
	A1	$V = 10$ only

Q15.

Question	Scheme	Marks	AOs
	Use Impulse-momentum principle	M1	2.1
	$2\mathbf{i}-\mathbf{j} = 0.5\mathbf{v} - 0.5(4\mathbf{i}+\mathbf{j})$	A1	1.1b
	$\frac{1}{2}\mathbf{v} = 4\mathbf{i} - \frac{1}{2}\mathbf{j}, \quad \mathbf{v} = 8\mathbf{i} - \mathbf{j}$ (m s^{-1})	A1	1.1b
	Use of $\text{KE} = \frac{1}{2}m\lvert\mathbf{v}\rvert^2 - \frac{1}{2}m\lvert\mathbf{u}\rvert^2$	M1	2.1
	$= \frac{1}{2} \times 0.5 \times \{(64+1)-(16+1)\}$	A1	1.1b
	$= \frac{1}{4} \times 48 = 12$ (J) *	A1*	1.1b
		(6)	
			(6 marks)

Notes:

M1: Difference of terms & dimensionally correct
A1: Correct unsimplified equation
A1: C.A.O.
M1: Must be a difference of two terms.
Must be dimensionally correct.
A1: Correct unsimplified equation
A1*: Complete justification of **given answer**

Q16.

Question	Scheme	Marks	AOs
	Work done $= \frac{1}{5}mg \times 8 \quad (15.68m)$	B1	3.4
	PE Loss $= \ 8mg\sin\alpha \quad (47.04m)$	B1	1.1b
	KE Gain = Difference of two KE terms	M1	3.4
	$= \frac{1}{2}mv^2 - \frac{1}{2}m5^2$	A1	1.1b
	Work done against friction = PE Loss – KE Gain	M1	2.1
	$\frac{1}{5}mg \times 8 = 8mg\sin\alpha - \left(\frac{1}{2}mv^2 - \frac{1}{2}m5^2\right)$	A1	1.1b
	$v = 9.4$ or 9.37 (m s^{-1})	A1	1.1b
		(7)	
			(7 marks)

Notes

The question instructs candidates to use the work-energy principle, so *suvat* methods will not score the second M1.

B1	Work done against friction seen or implied
B1	PE loss seen or implied
	NB: B1B1 for $\left(\frac{3}{5}mg - \frac{1}{5}mg\right) \times 8 \quad \left(= \frac{16}{5}mg\right)$
M1	Difference in two KE terms seen or implied (allow KE loss)
A1	Correct unsimplified expression. Allow $\pm$
M1	Work-energy equation with all terms. Must be dimensionally correct but condone sign errors
A1	Correct unsimplified equation
A1	2 sf or 3 sf (after use of $g = 9.8$)

Q17.

Question	Scheme	Marks	AOs
a	$72 \text{ km h}^{-1} = 20 \text{ m s}^{-1}$	B1	1.1b
		(1)	
b	Use of $F = \frac{P}{v}$ and using the model	M1	3.4
	Equation of motion and using the model to form equation in c	M1	3.1b
	$\frac{50000}{20} - c \times 20^2 = 1000 \times 2.25 \quad \left(c = \frac{5}{8}\right)$	A1ft	1.1b
	Equation of motion and using the model	M1	3.1b
	$\frac{50000}{40} - c \times 40^2 = 1000a$	A1ft	1.1b
	Solve for a	M1	1.1b
	$0.25 \ (\text{m s}^{-2})$	A1	1.1b
		(7)	
c	Equation of motion horizontally and using the model	M1	3.1b
	$\frac{50000}{W} - \frac{5}{8}W^2 = 0$ (max speed is W m s^{-1})	A1ft	1.1b
	Solve for W and convert to km h^{-1} $(W = 43.088...)$	M1	1.1b
	$V = 155$ (nearest whole number)	A1	1.1b
		(4)	
			(12 marks)

Notes		
a	B1	20 m s^{-1} seen
b	M1	Follow through the 72 or their v. Allow for 144 or their 144
	M1	Correct no. of terms required
	A1ft	Correct unsimplified equation ft on their 20
	M1	Correct no. of terms required
		Allow the second and third M marks if they have an equation in F rather than P.
	A1ft	Correct equation ft on their 40 and their c
	M1	Complete method to solve for a
	A1	Cao $\left(\text{Accept } \frac{1}{4}\right)$
c	M1	Equation with correct no. of terms, correct structure and in terms of W only.
	A1ft	Correct equation, ft on their c from part (b).
	M1	Complete method to solve for V (including clear attempt to convert units)
	A1	Cao (The Q asks for a whole number)

Q18.

Question	Scheme	Marks	AOs
a	$\frac{1}{2}mgH$	B1	1.1b
	$\frac{1}{2}m(8gH - v^2)$	B1	1.1b
	Apply the work-energy principle	M1	3.3
	$\frac{1}{2}mgH = \frac{1}{2}m(8gH - v^2) - mgH$	A1	1.1b
	$v = \sqrt{5gH}$	A1	1.1b
		(5)	
b	Use NLR to find rebound speed: $\frac{1}{2}\sqrt{5gH}$	M1	3.4
	Apply the work-energy principle or *suvat* with $a = \frac{1}{2}g$	M1	3.3
	$\frac{1}{2}mgH = mgH - \frac{1}{2}m(v_1^2 - \frac{1}{4}\times 5gH)$ or $(v_1)^2 = \frac{5gH}{4} + 2\times\frac{g}{2}\times H$	A1ft A1	1.1b 1.1b
	$v_1 = \frac{3}{2}\sqrt{gH}$	A1	2.2a
		(5)	
c	Since $e < 1$, ball loses energy in its collision with the ceiling.	B1	2.4
		(1)	
			(11 marks)

Notes		
a	B1	Work done against resistance (allow -ve) Can be implied by use of $\frac{3}{2}mgH$ (work done against resistance + work done against weight)
	B1	KE loss (allow -ve)
	M1	Correct no. of terms, dimensionally correct. Condone sign errors.
	A1	Correct unsimplified equation
	A1	Correct answer (any equivalent but must be in terms of g and H) Accept $2.2\sqrt{gH}$ or better
b	M1	Use of NLR
	M1	Correct no. of terms, dimensionally correct
	A1ft	Correct equation with at most one error ft on their answer to (a)
		M1A1ft is available to a candidate who has not scored the first M1
	A1	Correct equation (no ft)
	A1	Correct answer (any equivalent but must be in terms of g and H)
c	B1	Clear explanation
		Need to identify that the loss of KE occurs in the impact with the ceiling. Do not insist on seeing $e < 1$ or equivalent. If they include incorrect additional statements then B0

Q19.

Question	Scheme		Marks	AOs
(a)	Resolve perpendicular to the plane		M1	3.4
	$R = \frac{4}{5}mg$		A1	1.1b
			(2)	
(b)	Work done against friction = $0.4R \times 0.5$	$(= 0.16mg)$	M1	3.4
	PE Loss = $mg \times 0.5\sin\alpha + 0.8mg$	$(= 1.1mg)$	M1	1.1b
	Using work-energy principle		M1	3.4
	$1.1mg = 0.16mg + \frac{1}{2}mv^2$		A1	1.1b
	$v = 4.3$ or 4.29 (m s^{-1})		A1	1.1b
			(5)	
				(7 marks)

Notes:

a	M1	Allow sin/cos confusion
	A1	cao
b	M1	Correct form for work done against friction. $(1.568m)$
	M1	Correct no. of terms, dimensionally correct, condone sin/cos confusion $(10.78m)$
	M1	Correct number of terms (using their WD and PE for the **whole journey** to the floor)
	A1	Correct unsimplified equation
	A1	Either of the two possible answers (as $g = 9.8$ has been used)

Q20.

Question	Scheme	Marks	AOs
(a)	Freewheeling down: Equation of motion down the plane and using the model	M1	3.1b
	$100g\sin\alpha - kV^2 = 0$ $\qquad \left(kV^2 = \dfrac{100g}{35}\right)$	A1	1.1b
	Cycling up: Equation of motion up the plane and using the model	M1	3.1b
	$F - 100g\sin\beta - kV^2 = 0$	A1	1.1b
	Use of $F = \dfrac{P}{V}$ $\qquad \left(\dfrac{P}{V} = \dfrac{100g}{70} + \dfrac{100g}{35}\right)$	M1	3.3
	Solve the problem by solving for P in terms of V and substituting for $\sin\alpha$ and $\sin\beta$	M1	1.1b
	$\left(P = \dfrac{300gV}{70}\right)$ $\qquad P = 42V$	A1	1.1b
		(7)	
(b)	Equation of motion horizontally and using the model	M1	3.4
	$\dfrac{35V}{U} - kU^2 = 0$	A1	1.1b
	Solve for U in terms of V $\qquad \left(\dfrac{35V}{U} - \dfrac{100g}{35V^2}U^2 = 0\right)$	M1	3.1b
	$U = 1.1V$ or $U = 1.08V$	A1	1.1b
		(4)	
		(11 marks)	

Notes:		
a	M1	Dimensionally correct. Correct no. of terms, condone sin/cos confusion
	A1	Correct equation
	M1	Dimensionally correct. Correct no. of terms, condone sin/cos confusion
	A1	Correct equation
	B1	Any equivalent form
	M1	Use correct strategy to set up and solve the equations to solve the problem
	A1	cao
b	M1	Correct no. of terms. Allow $F - kU^2 = 0$ but not $F - kV^2 = 0$
	A1	Correct equation
	M1	Use correct strategy to set up and solve the equations to solve the problem
	A1	Accept 2 sf or 3 sf. $U = \sqrt[3]{\dfrac{5}{4}}V$ scores 3/4 (depends on the use of g)

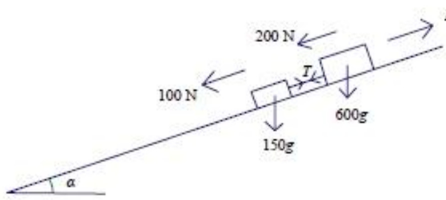
Q21.

Question	Scheme	Marks	AOs
(a)	$mg \times \frac{25}{6}\sin\alpha$	B1	1.1b
	Use of the principle of conservation of mechanical energy	M1	3.4
	$\frac{1}{2}m \times 25^2 - \frac{1}{2}mv^2 = mg \times \frac{25}{6}\sin\alpha$	A1	1.1b
	$v = 24\ (\text{m s}^{-1})$ (23.99895831… = 24 to 2SF if $g = 9.81$)	A1	1.1b
		(4)	
(b)	Resolve perpendicular to the plane	M1	3.1a
	$R = mg\cos\alpha$	A1	1.1b
	$F = \frac{3}{5}R$	B1	3.4
	WD against friction = $F \times \frac{25}{6}$	B1	3.4
	Use of work-energy principle	M1	3.1a
	$\frac{1}{2}m \times 25^2 - \frac{1}{2}mv^2 = mg \times \frac{25}{6}\sin\alpha + \frac{3}{5} \times mg\cos\alpha \times \frac{25}{6}$	A1 A1	1.1b 1.1b
	$v = 23.2$ or $23\ (\text{m s}^{-1})$ (23.16700… = 23.2 or 23 to 3SF or 2SF if $g = 9.81$)	A1	1.1b
		(8)	
		(12 marks)	

Notes:		
		N.B. If consistent use of a specific value of m, allow all the marks but deduct the final A mark in each part but allow full marks if m's have been cancelled or don't appear.
a	B1	Seen anywhere
	M1	Correct no. of terms, dimensionally correct, condone sign errors and sin/cos confusion M0 for non-energy methods. Allow max M1A0A0 if 25/6 not resolved or not resolved correctly in PE term
	A1	Correct equation in m, g, v and α
	A1	cao
b	M1	Correct no. of terms, dimensionally correct, condone sign errors and sin/cos confusion
	A1	Correct equation
	B1	Seen anywhere
	B1	Seen anywhere
	M1	Correct no. of terms, dimensionally correct, condone sign errors and sin/cos confusion M0 for non work-energy methods Allow max M1A1A0A0 if 25/6 not resolved or not resolved correctly in PE term

	A1	Equation in m, g, v and α with at most one error N.B. If KE terms reversed, only penalise ONCE.
	A1	Correct equation in m, g, v and α
	A1	cao

Q22.

Question	Scheme	Marks	AOs
			
	Equation of motion for the system or for the van	M1	3.3
	$F-(100+200)-(150+600)g\sin\alpha=(150+600)a$ or $F-200-T-600g\sin\alpha=600a$	A1 A1	1.1b 1.1b
	Equation of motion for the trailer	M1	3.1b
	$T-100-150g\sin\alpha=150a$	A1	1.1b
	Use of $F=\dfrac{12000}{9}$	M1	3.4
	Solve for T	M1	1.1b
	$T=307\,(310)\,(\text{N})$	A1	2.2a
		(Total 8 Marks)	

Notes	
M1	Need all terms and no extras (the inclusion of $+T$ $-T$ is not an error). Dimensionally correct. Condone sign errors and sin/cos confusion Must have non-zero acceleration and include the driving force
A1 A1	Unsimplified equation in F or their F (and T if relevant) with at most one error Correct unsimplified equation in F or their F (and T if relevant)
M1	Need all terms. Dimensionally correct. Condone sign errors and sin/cos confusion Or a second equation of motion involving the driving force.
A1	Correct unsimplified equation (in T and / or F or their F if relevant)
M1	Use of $P=Fv$ seen or implied.
M1	**Complete** method to find T $(\text{FYI}: a=0.72(4))$
A1	Tension correct to 3 sf or 2 sf A fractional answer $\left(\dfrac{920}{3}\right)$ is not acceptable because this result follows the use of $g=9.8$