1		**M1**		Attempt KE gain **or** WD against Res
	KE gain = ½ × 105 × ($10^2 - 5^2$) WD against Resistance = 50 × 40	**A1**		Both correct (unsimplified) KE gain = 3937.5 J WD = 2000 J
	Total WD = 5937.5 J	**B1**	3	WD = KE gain + WD against Res
	Alternative method			
	$10^2 = 5^2 + 2 \times 50 \times a$ [$a = 0.75$] DF – 40 = 105a	**M1**		Using $v^2 = u^2 + 2as$ and applying Newton's 2nd law to the system
	DF = 40 + 105 × 0.75 = 118.75	**A1**		
	Total WD = 118.75 × 50 = 5937.5 J	**B1**	3	WD = DF × 50
2 (i)	DF = 1350	**B1**		
	P = 1350 × 32 = 43.2 kW	**B1**	2	
(ii)	DF – 1350 – 1200g × 0.1 = 0 [DF = 2550]	**M1**		For using Newton's 2nd law applied to the car up the hill (3 terms) Allow use of θ = 5.7°
	DF = 76500/v	**M1**		For using DF = P/v
	$v = 30\ \text{ms}^{-1}$	**A1**	3	
3 (i)		**M1**		For resolving forces horizontally
	$R_x = 40 \times (24/25) - 30 \times (7/25)$ [= 30]	**A1**		Allow $R_x = 40 \cos 16.3 - 30 \sin 16.3$
		M1		For resolving forces vertically
	$R_y = 50 - 40 \times (7/25) - 30 \times (24/25)$ [= 10]	**A1**		Allow $R_y = 50 - 40 \sin 16.3 - 30 \cos 16.3$
	$R = \sqrt{R_x^2 + R_y^2}$ **and** $\theta = \tan^{-1}\left(\frac{R_y}{R_x}\right)$	**M1**		For using Pythagoras to find the resultant force R **and** trigonometry to find the angle θ made by the resultant with the x-axis
	R = 31.6 N **and** θ = 18.4° with the positive x-axis	**A1**	6	

Alternative method for 3(i)				
(i)		**M1**		Resolve forces along 40 N direction
	$R_1 = 40 - 50 \times (7/25)$ [= 26]	**A1**		Allow $R_1 = 40 - 50 \sin 16.3$
		M1		Resolve forces along 30 N direction
	$R_2 = 30 - 50 \times (24/25)$ [= –18]	**A1**		Allow $R_2 = 30 - 50 \cos 16.3$
	$R^2 = R_1^2 + R_2^2$ **and** $\arctan(-R_2/R_1)$	**M1**		Use Pythagoras **and** trigonometry
	$R = 31.6$ N **and** direction is $34.7 - \alpha = 18.4°$ with positive x–axis	**A1**	6	Using $\arctan(18/26) = 34.7°$ is the angle between R and the 40 N force
(ii)	$P = 40$	**B1**	1	
4 (i)	$5\cos\alpha = F$ [$F = 4$]	**M1**		For resolving forces horizontally Allow use of $\alpha = 36.9^\circ$ throughout
	$R + 5\sin\alpha = 8$ [$R = 5$]	**M1**		For resolving forces vertically
	$4 = 5\mu$	**M1**		For using $F = \mu R$
	$\mu = 0.8$	**A1**	4	
(ii)	$R + 10\sin\alpha = 8$ [$R = 2$] **and** $F = 0.8 \times R$ [$F = 1.6$]	**B1**		For resolving forces vertically to find the new value of R **and** using $F = \mu R$
	$10\cos\alpha - F = 0.8a$	**M1**		For resolving horizontally
	$a = 8\text{ ms}^{-2}$	**A1**	3	
5 (i)	[$2500 - 2000g \times 0.1 - 250 = 2000a$]	**M1**		For using Newton's 2nd law for the system or for applying Newton's 2nd law to the car and to the trailer and for solving for a Allow use of $\alpha = 5.7^\circ$ throughout
	$a = 1/8 = 0.125\text{ ms}^{-2}$	**A1**		
	$2500 - T - 100 - 1200g \times 0.1 = 1200 \times 0.125$ or $T - 150 - 800g \times 0.1 = 800 \times 0.125$	**M1**		For applying Newton's 2nd law either to the car or to the trailer to set up an equation for T
	$T = 1050$ N	**A1**	4	

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(ii)	$-2000g \times 0.1 - 250 = 2000a$ $[a = -1.125]$	**M1**		For applying Newton's 2nd law to the system with no driving force to set up an equation for a
	$0 = 30 - 1.125t$	**M1**		For using $v = u + at$
	$t = 26.7$ s	**A1**	3	Allow $t = 80/3$ s
Alternative method for 5(ii)				
(ii)	$[\frac{1}{2}(2000)30^2 = 250s + 2000 \times g \times 0.1s]$ $\rightarrow s = 400$	**M1**		Apply work/energy equation to find s the distance travelled up the plane with no driving force (3 terms) as: KE loss = WD against F + PE gain
	$[400 = \frac{1}{2}(30 + 0)t]$	**M1**		For using $x = \frac{1}{2}(u + v)t$
	$t = 26.7$ s	**A1**	3	Allow $t = 80/3$ s
6 (i)	$[T = 0.8a$ for A $2 - T = 0.2a$ for B $0.2g = (0.2 + 0.8)a$ system$]$	**M1**		For applying Newton's 2nd law either to particle A or to particle B or to the system
		M1		For applying N2 to a second particle (if needed) and solving for a
	$[a = 2]$	**A1**		
	$[2.5 = \frac{1}{2} \times 2 \times t^2]$	**M1**		A complete method for finding t such as using $s = ut + \frac{1}{2}at^2$
	$t = 1.58$ s	**A1**	5	Allow $t = \frac{1}{2}\sqrt{10}$
First Alternative Method for 6(i)				
(i)	$[0.2 \times g \times 2.5$ or $\frac{1}{2}(0.2 + 0.8)v^2]$	**M1**		Finding PE loss or KE gain (system)
	$[0.2 \times g \times 2.5 = \frac{1}{2}(0.2 + 0.8)v^2]$	**M1**		Using PE loss = KE gain and find v
	$[v^2 = 10]$	**A1**		
	$[2.5 = \frac{1}{2}(0 + \sqrt{10})t]$	**M1**		For using $s = \frac{1}{2}(u + v)t$
	$t = 1.58$ s	**A1**	5	Allow $t = \frac{1}{2}\sqrt{10}$

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Second Alternative Method for 6(i)

(i)	$[T = 0.8a \quad 2 - T = 0.2a \rightarrow T = 1.6\text{ N}]$	**M1**		Apply N2 to A and B and solve for T
	$[T \times 2.5 = ½ (0.8) v^2]$	**M1**		Use WD by T = KE gain by A, find v
	$[v^2 = 10]$	**A1**		
	$[2.5 = ½ (0 + \sqrt{10})t]$	**M1**		Using $s = ½(u + v)t$
	$t = 1.58\text{ s}$	**A1**	5	Allow $t = \frac{1}{2}\sqrt{10}$
(ii)	$N = 8$ and $F = 0.1 \times N = 0.8$	**B1**		
	$T - 0.8 = 0.8a$ and $2 - T = 0.2a$ or $0.2g - 0.8 = (0.2 + 0.8)a$	**M1**		For applying N2 to both particles or to the system and solving for a
	$a = 1.2$	**A1**		
	$v^2 = 0 + 2 \times 1.2 \times 2.5$	**M1**		For using $v^2 = u^2 + 2as$
	$v = \sqrt{6} = 2.45\text{ ms}^{-1}$	**A1**	5	

First Alternative Method for 6(ii)

(ii)	$N = 8$ and $F = 0.1 \times N = 0.8$	**B1**		
	$[0.2 \times g \times 2.5 = ½ (0.8 + 0.2) v^2 + 0.8 \times 2.5]$	**M1**		Apply work/energy to the system as PE loss = KE gain + WD against resistance
		A1		Correct Work/Energy equation
		M1		For solving for v
	$v = \sqrt{6} = 2.45\text{ ms}^{-1}$	**A1**	5	

Second Alternative Method for 6(ii)

(ii)	$N = 8$ and $F = 0.1 \times N = 0.8$	**B1**		
	$T - 0.8 = 0.8a$ and $2 - T = 0.2a$	**M1**		Use N2 for A and B and solve for T
	$T = 1.76\text{ N}$	**A1**		
	$[T \times 2.5 = 0.8 \times 2.5 + ½ (0.8) v^2]$	**M1**		Apply Work/Energy equation to A
	$v = \sqrt{6} = 2.45\text{ ms}^{-1}$	**A1**	5	

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7 (i)	$k = 40$	B1	1	
(ii)	Correct for $0 \leqslant t \leqslant 4$	B1√		Quadratic curve with minimum at $t = 1$ approximately, $v = 0$ at $t = 2$ and $v = k$ at $t = 4$. ft on k
	Correct for $4 \leqslant t \leqslant 14$	B1√		Horizontal line at $v = k$. ft on k
	Correct $14 \leqslant t \leqslant 20$	B1√	3	Line with negative gradient from (14, k) to (20, 28). ft on k
(iii)	For $0 \leqslant t \leqslant 4$ $a = 10t - 10$	M1		Attempting to differentiate to find a
	$1 < t \leqslant 4$	A1	2	
(iv)	$\int(5t^2 - 10t)dt =$ $\frac{5}{3}t^3 - 5t^2$	M1		For attempting to integrate the given quadratic expression and attempting to apply limits over the interval $t = 0$ to $t = 4$
	$A = \left[\frac{5}{3}t^3 - 5t^2\right]_0^2 =$ $\left(\frac{5}{3}2^3 - 5\times2^2\right)$ $-\left(\frac{5}{3}0^3 - 5\times0^2\right)$			Use of limits to obtain A, the integral from $t = 0$ to $t = 2$ and B, the integral from $t = 2$ to $t = 4$ Full evaluation of A not necessary at this stage $\left[A = -\frac{20}{3}\right]$
	$B = \left[\frac{5}{3}t^3 - 5t^2\right]_2^4 =$ $\left(\frac{5}{3}4^3 - 5\times4^2\right)$ $-\left(\frac{5}{3}2^3 - 5\times2^2\right)$	A1		Full evaluation of B not necessary at this stage $\left[B = \frac{100}{3}\right]$
	$C = (40 \times 10) +$ $0.5 \times (40 + 28) \times 6$	B1√		For finding the distance travelled in the interval $t = 4$ to $t = 20$ using area properties or integration. ft on k
	$-A + B + C =$ [20/3 + 100/3 + 400 + 204]	M1		For attempting to evaluate the total distance travelled by P in the interval $t = 0$ to $t = 20$. The distance travelled in the first 4 seconds must have been found using integration methods.
	Total distance travelled = 644 m	A1	5	

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