Question	Answer	Marks	Guidance
2(a)	Attempt at conservation of momentum $[1.2v = (1.2 + 0.004) \times 40]$	M1	
	$v = \frac{602}{15}$	A1	oe
		2	
2(b)	$0^2 = (40)^2 + 2 \times 0.04 \times a \quad [a = -20000]$ or $0.04 = \frac{0+40}{2}t$ gets $t = 0.002$, so $0 = 40 + 0.002a [a = -20000]$	M1	Use of a 'suvat' method to get an equation in a. Allow sign errors. Allow ± 20000. Do not allow 4 in place of 0.04. Allow use of 40.1 or $\frac{602}{15}$ for velocity in place of 40.
	Attempt to use Newton's Second Law vertically. $[-R + (1.2 + 0.004)g = (1.2 + 0.004) \times a]$ $[-R + 12.04 = 1.204a]$	M1	Must have the correct number of relevant terms. Allow sign errors, but terms including masses must be effectively added. Do not allow any mass other than (1.2 + 0.004).
	$R = 24\,100$ N $[24\,092.04 = \frac{602301}{25}]$	A1	WWW. Note: use of wrong sign for g leads to answers 24 067.96 which gets max M1M1A0. Note: Missing weight term gets 24 080 which gets Max M1M0A0.
		3	

Question	Answer	Marks	Guidance
5(a)	For attempt at integration	M1	The power of t must increase by 1 with a change of coefficient. Do not penalise missing c. Use of $v = at$ scores M0.
	$v = \frac{2}{3}kt^{\frac{3}{2}}[+c]$	A1	Allow unsimplified e.g. $v = \frac{1}{1.5}kt^{\frac{1}{2}+1}[+c]$.
	$1.8 = \frac{2}{3}k \times 9^{\frac{3}{2}} \Rightarrow k = \left[\frac{3}{2} \times 1.8 \div 27 = \right] 0.1$	B1	AG. Must show values substituted OE (e.g. $1.8 = 18k$).
		3	

Question	Answer	Marks	Guidance
5(b)	**Alternative Method for Question 5(b): Special Case for those who use a calculator to integrate. Award max 2/4**		
	Either $\int_0^9 \left(\frac{2}{3}kt^{\frac{3}{2}}\right)dt = 6.48$ or $\frac{162}{25}$ Or $\int_9^{18} \left(0.2(t-9)^2 + 1.8\right)dt = 64.8$ or $\frac{324}{5}$	**SC B1**	
	$6.48 = \frac{1}{10} \times 64.8$ or $64.8 = 10 \times 6.48$ or $\frac{324}{5} = 10 \times \frac{162}{25}$	**SC B1**	OE.
		4	
5(c)	For differentiation Should get $a = 0.4(t-9)$ or $a = 0.4t - 3.6$	**M1**	The power of t or $(t-9)$ must decrease by 1 with a change of coefficient. M0 for $a = \frac{v}{t}$.
	$0.4\,[\text{ms}^{-2}]$ [at $t = 10$]	**A1**	**SC B1** for 0.4 with no differentiation seen.
	0.3 seen (from the first phase) and state that 0.4 is final answer	**B1**	No working needed. If M1A0 or M0A0 scored, then **SC B1** for 0.3 without mention of the maximum acceleration.
		3	

Question	Answer	Marks	Guidance
4(b)	$T_A \times 0.6 - 10g = 0 \Rightarrow T_A = \frac{500}{3}$	B1	From using $T_B = 0$
	$T_A \times 0.8 - F = 0$	M1	
	$F = \frac{400}{3}$	A1	Allow $F = 133$ to 3 s.f.
		3	

Question	Answer	Marks	Guidance
5(a)	$F - 30 = 70 \times 0.3$	M1	Use of Newton's Second law
	$P = 4F$	B1	Using $P = Fv$
	$[= 51 \times 4] = 204$ W	A1	
		3	
5(b)	Change in KE $= \frac{1}{2} \times 70 \times 12^2 - \frac{1}{2} \times 70 \times 6^2$	M1	
	3780 J	A1	
		2	
5(c)	For work energy equation	M1	
	$70g \times d \sin 5 - 30d = 3780$	A1 FT	FT change in kinetic energy from (b)
	$d = 122$	A1	
		3	

Question	Answer	Marks
1	Use of conservation of momentum	M1
	$m \times 2 + 0 = m \times (-0.5) + 0.2 \times 1$	A1
	$m = 0.08$	A1
		3

Question	Answer	Marks
2(a)	$F - 900 = 4000 \times 0.5$ (M1 for use of Newton's second law, 3 terms)	M1
	$F = 2900$ N	A1
2(b)	900×25 (M1 for use of $P = Fv$ with F = resistance only)	M1
	22 500 W or 22.5 kW	A1

Question	Answer	Marks	Guidance
5(a)	$a = 16k - kt^2$, $v = 16kt - \frac{1}{3}kt^3$	M1	Uses $v = \int a\,dt$.
	$8 = 16k \times 4 - \frac{1}{3} k \times 4^3$ leading to $k = \ldots$	M1	Substitutes $t = 4$, $v = 8$.
	$v = 16kt - \frac{kt^3}{3}$ and $k = \frac{3}{16}$	A1	OE
	$s = 8kt^2 - \frac{1}{12}kt^4$ leading to $s = \frac{24}{16}t^2 - \frac{3}{192}t^4$	M1	Uses $s = \int v dt$ and attempts to find s in terms of t only. May be using $v = 3t - \frac{1}{16}t^3$.
	$s = \frac{1}{64}t^2(96 - t^2)$	A1	AG, no errors seen.
		5	
5(b)	$s = 0$, $t^2 = 96$, $t = 4\sqrt{6}$	M1	Attempt to find t when $s = 0$.
	$v = 16 \times \frac{3}{16} \times \sqrt{96} - \frac{3}{16} \times \frac{1}{3} \times \sqrt{96^3}$	M1	Attempt to find v at this t value
	Speed is 29.4 ms^{-1}	A1	Do not condone $v = -29.4$.
		3	
5(c)	$v = 0$, $t^2 = 48$, $t = 4\sqrt{3}$	M1	Determine the time, t (or t^2) at which $v = 0$
	$s = \frac{1}{64} \times 48 \times (96 - 48)$	M1	Use substitution of the t or t^2 value to find s.
	$s = 36$ m	A1	
		3	

Question	Answer	Marks	Guidance
5(a)	Attempt to resolve in one direction and form equation.	M1	Must have correct number of relevant terms (forces must have components as required). Allow sin/cos mix. Allow sign errors. If only one equation shown and it involves 32, it must be 32, not P.
	$T\sin\theta = 32$ and $T\cos\theta = 80$ or $0 = 80\sin\theta - 32\cos\theta$ and $T = 80\cos\theta + 32\sin\theta$	A1	For both horizontal and vertical, or both parallel and perpendicular.
	Attempt to solve for T or θ	M1	Must get to T or θ; e.g. $T = \sqrt{32^2 + 80^2}$ or $\theta = \tan^{-1}\left(\frac{32}{80}\right)$. Condone, e.g. $\theta = \tan^{-1}\left(\frac{80}{32}\right)$. Must come from equations with correct number of relevant terms.
	$T = 86.2$ [N 86.1626….] or $16\sqrt{29}$ or $\sqrt{7424}$ and $\theta = 21.8$ [21.801…]	A1	For both.
		4	

Question	Answer	Marks	Guidance
5(b)	Attempt to resolve in one direction and form equation	M1	Must have correct number of relevant terms (forces must have components as required). Allow sin/cos mix. Allow sign errors. Must use 120, not T.
	$120\sin\theta = P$ and $120\cos\theta = 80$ or $0 = 80\sin\theta - P\cos\theta$ and $120 = 80\cos\theta + P\sin\theta$	A1	For both horizontal and vertical, or both parallel and perpendicular.
	Attempt to solve for P or θ	M1	Must get to P or θ; e.g. $P = \sqrt{120^2 - 80^2}$ or $\theta = \cos^{-1}\left(\frac{80}{120}\right)$. Must come from equations with correct number of relevant terms.
	$P = 89.4\ [89.4427]$ or $40\sqrt{5}$ or $\sqrt{8000}$ $\theta = 48.2\ [48.1896\ldots]$	A1	For both; allow $P = 89.5$ (from $120\sin 48.2$).
		4	
	Alternative method using triangle of forces		
	$120^2 = P^2 + 80^2[-2\times 80\times P\cos 90]$ or $120\sin\theta = P$ or $120\cos\theta = 80$	M1	For any of the five; allow sign errors.
	or $80\tan\theta = P$ or $120 = 80\cos\theta + P\sin\theta$ oe	A1	For any two equations.
	Attempt to solve for P or θ	M1	Must get to P or θ; e.g. $P = \sqrt{120^2 - 80^2}$ or $\theta = \cos^{-1}\left(\frac{80}{120}\right)$, oe.
	$P = 89.4\ [89.4427]$ or $40\sqrt{5}$ or $\sqrt{8000}$ $\theta = 48.2\ [48.1896\ldots]$	A1	For both; allow $P = 89.5$ (from $120\sin 48.2$).

Question	Answer	Marks	Guidance
3(a)	Speed = 20 ms^{-1}	B1	
		1	
3(b)	$20 = 0 + a \times 5$	M1	Use of $v = u + at$ OE
	$a = 4\ ms^{-2}$	A1	
		2	
3(c)	$\frac{50+100+50+200}{20}$	M1	Use of $\frac{\text{total distance}}{\text{total time}}$ OE
	Average speed = 20 ms^{-1}	A1	
		2	

Question	Answer	Marks	Guidance
4(a)	$T_A \times 0.8 - T_B \times 0.6 - 20 = 0$ or $T_A \times 0.6 + T_B \times 0.8 - 10g = 0$	M1	Resolving horizontally or vertically
	$T_A \times 0.8 - T_B \times 0.6 - 20 = 0$	A1	
	$T_A \times 0.6 + T_B \times 0.8 - 10g = 0$	A1	
	$0.8T_A - \frac{0.6(10g - 0.6T_A)}{0.8} = 20 \rightarrow T_A = \ldots$	M1	Attempt to solve simultaneously
	$T_A = 76$ N, $T_B = 68$ N	A1	
		5	

Question	Answer	Marks	Guidance
6(a)	$R = 5g$, $F = 6g - 4g$	M1	For resolving forces to find F and R.
	$\mu = \frac{2g}{5g} = 0.4$	A1	AG
		2	
6(b)	$T_1 - 4g = 4a$ or $8g - T_2 = 8a$	M1	For applying Newton's 2nd law to the 4 kg particle or the 8 kg particle.
	$T_1 - 4g = 4a$ and $8g - T_2 = 8a$	A1	Both equations correct.
	$T_2 - T_1 - F = 5a$ and $F = 0.4 \times 5g$	B1	
	Adding gives $8g - 4g - 2g = 17a$ leading to $a = \ldots$.	M1	Attempt to solve for a, T_1 or T_2.
	$a = 1.18\,\text{ms}^{-2}$, $T_1 = 44.7$ N, $T_2 = 70.6$ N	A1	
		5	
6(c)	$T - 4g = 4a$, $-T - F = 5a$, $F = 2g$ or $-4g - 2g = 9a$	M1	Applying Newton's 2nd law to both active particles.
	$a = -\frac{60}{9}$	A1	
	$v^2 = 2 \times \frac{20}{17} \times 0.5 = \frac{20}{17}$ leading to $v = \ldots$ [$v = 1.0846\ldots$]	M1	Use of $v^2 = u^2 + 2as$ or equivalent to find v or v^2 when the 8 kg particle reaches the ground.
	$0 = \sqrt{\frac{20}{17}} - \frac{60}{9}t$	M1	Use of $v = u + at$ or equivalent to find t.
	$t = 0.163$ s	A1	From $t = 0.1626978\ldots$
		5	