

Cambridge International AS & A Level

MATHEMATICS**9709/41**

Paper 4 Mechanics

May/June 2024**MARK SCHEME**Maximum Mark: 50

Published

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This document consists of **17** printed pages.

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Marks must be awarded in line with:

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- the specific skills defined in the mark scheme or in the generic level descriptors for the question
- the standard of response required by a candidate as exemplified by the standardisation scripts.

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Marks awarded are always **whole marks** (not half marks, or other fractions).

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- marks are awarded when candidates clearly demonstrate what they know and can do
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Question	Answer	Marks	Guidance
1(a)	Trapezium on the t -axis starting at (0, 0)	B1	
	Fully correct with correct labels	B1	With height 20, intersecting the t -axis at 60, horizontal line segment between 10 and 40. Axis need not be labelled with t and v but if they are they must be correct. If not labelled, then must assume t is on the horizontal axis.
		2	
1(b)	$\text{Area} = \frac{1}{2}(30 + 60) \times 20$ or $\text{Area} = \frac{1}{2} \times 10 \times 20 + 30 \times 20 + \frac{1}{2} \times 20 \times 20$	M1	Must be considering the area of a trapezium. Allow a single slip in one term only. Must be adding all terms together if considering two triangles and a rectangle. Using <i>their</i> 20 from (a) . If no value for the height shown on the graph in (a) , then it must be correct.
	= 900m	A1FT	FT <i>their</i> 20 (= 45 × <i>their</i> 20) but A0 FT if using 2.
		2	

Question	Answer	Marks	Guidance
2(a)	$F = 20 \sin 60$	M1	Attempt to resolve in y -direction; 2 terms; must be $20 \cos 60$ or $20 \sin 60$ and must be linked to F (can be implied by the correct answer seen only).
	= 17.3 N	A1	AWRT 17.3 (17.320508...) or $10\sqrt{3}$.
		2	

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Question	Answer	Marks	Guidance
2(b)	For resolving in any direction	*M1	Correct number of terms; allow sin/cos mix; allow sign errors.
	(Horizontal component = $X = R \cos \theta = \pm(20 \cos 60)$ [± 10] (Vertical component = $Y = R \sin \theta = \pm(20 \sin 60 - 10)$ [$= \pm 7.3205 \dots$])	A1	For both correct.
	Magnitude = $\sqrt{(20 \sin 60 - 10)^2 + (20 \cos 60)^2}$ [$= 12.393136 \dots$]	DM1	OE – correct number of terms.
	Angle = $\tan^{-1} \left(\frac{20 \sin 60 - 10}{20 \cos 60} \right)$ [$= 36.206023 \dots$]	DM1	OE (e.g. reciprocal) - correct number of terms.
	Magnitude = 12.4 N and Direction = 36.2° above (positive) x -axis	A1	OE for direction e.g. 36.2° anticlockwise from (positive) x -direction, 36.2° above the horizontal. Possibly seen on a diagram. (Radians: 0.63191... to 3sf or better)
		5	

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Question	Answer	Marks	Guidance
3	PE gained = $180000g \times 1500 \sin 1.5$ [= 70677760.4...]	B1	$180000g \times 39.2654...$
	$KE_{\text{Initial}} = \frac{1}{2} \times 180000 \times 45^2$ [= 182 250 000] $KE_{\text{Final}} = \frac{1}{2} \times 180000 \times 40^2$ [= 144 000 000]	B1	For initial KE or final KE (for reference: difference in KE is 38 250 000).
	For work energy equation: $WD = 180000g \times 1500 \sin 1.5 + 12000000$ $\quad - \left(\frac{1}{2} \times 180000 \times 45^2 - \frac{1}{2} \times 180000 \times 40^2 \right)$	M1	Correct number of terms; dimensionally correct; allow sign errors and minor slip(s) in values; allow sin/cos mix on PE term. Work done = $(70677760.4... + 12000000 - 38250000)$ $J = (70677.7... + 12000 - 38250) \text{ kJ}$
	= 44400 kJ [44427.7604...]	A1	Must be in kJ.
	Alternative Method for Question 3: Newton's second law and equations of motion		
	$a = -0.142$ [= -0.141666...]	(B1)	Correct acceleration from $40^2 = 45^2 + 2a(1500)$. Allow AWRT -0.14 or exact $-\frac{17}{120}$.
	$1500(D - \frac{12000000}{1500} - 180000g \sin 1.5) = 180000 \times -\frac{17}{120} \times 1500$	(M1)	M1 for applying Newton's second law parallel to the hill. Correct number of terms, allow sin/cos mix on weight component, dimensionally correct and multiplying both sides by 1500. Allow <i>their</i> a or a for acceleration (and minor slip(s) in values).
		(B1)	Correct weight component multiplied by 1500.
	$WD (= 1500D) = 44400 \text{ kJ}$ [44427.7604...]	(A1)	Must be in kJ.
		4	

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Question	Answer	Marks	Guidance
4	Driving force = $\frac{14000}{20}$ [= 700]	B1	OE, e.g. $20 \times DF = 14000$.
	Attempt at Newton's second law on car or trailer or system	*M1	Correct number of relevant terms (e.g. correct masses); allow sign errors.
	$700 - 400 - T = 1700a$ $T - 150 = 300a$ $700 - 400 - 150 = (1700 + 300)a$	A2	A1 for one correct and A2 for any two correct. May have <i>DF</i> (or <i>their DF</i>) for 700 but A0 if using 14000 as <i>DF</i> without first stating <i>DF</i> . Must have same <i>T</i> if using first two equations for A2.
	Solving for <i>a</i> or <i>T</i>	DM1	From equations with the correct number of relevant terms.
	Acceleration = $\frac{3}{40} = 0.075 \text{ ms}^{-2}$		For both correct answers.
	Tension = 172.5 N	A1	Condone 173.
		6	

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Question	Answer	Marks	Guidance
5(a)	$a = 2.08$ [2.07911...]	B1	From $mg \sin 12 = ma$. Allow exact (e.g. $a = g \sin 12$).
	$v^2 = 5^2 + 2a \times 60$	M1	For use of $v^2 = u^2 + 2as$ with $u = 5$ and $s = 60$. Allow sign errors but a must be either $g \sin 12$ or $g \cos 12$ only.
	Speed = 16.6 ms^{-1} [16.567861...]	A1	AWRT 16.6
	Alternative Method for Q5(a)		
	For attempt at work energy equation	(M1)	3 terms, dimensionally correct. Allow sign errors; allow sin/cos mix on PE term – condone m missing from all terms. Must be a weight component.
	$\frac{1}{2}mv^2 = \frac{1}{2}m \times 5^2 + mg \times 60 \sin 12$	(A1)	Correct equation. (for reference: $60 \sin 12 = 12.4747...$)
	Speed = 16.6 ms^{-1} [16.567861...]	(A1)	AWRT 16.6
		3	

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Question	Answer	Marks	Guidance
5(b)	$R = mg \cos 12$	B1	Resolving correctly perpendicular to the plane.
	$mg \sin 12 - F = ma$	*M1	Use of Newton's second law, correct number of terms; allow sign errors; allow sin/cos mix (must be a weight component).
	For use of $F = 0.03R$ to get equation in a (and m) only	DM1	Where R is a component of weight only (dimensionally correct but allow sin/cos mix). $[\Rightarrow a = 1.79 [1.78567 \dots]]$
	$60 = 5t + \frac{1}{2}at^2$ and solve for t	DM1	Dependent on previous two M marks. For use of $s = ut + \frac{1}{2}at^2$ with $s = 60$, $u = 5$ and <i>their</i> a or other complete method to find positive value(s) of t .
	Time = 5.86 s [5.86260...]	A1	AWRT 5.86 (from using $a = 1.79$ or better). AWRT 5.85 (from using $a = 1.8$). AWRT 5.87 (from correct working).

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Question	Answer	Marks	Guidance
5(b)	Alternative method for Question 5(b): Using energy		
	$R = mg \cos 12$	(B1)	Resolving correctly perpendicular to the plane.
	$\frac{1}{2}mv^2 - \frac{1}{2}m \times 5^2 = 60 \times mg \sin 12 - 60 \times F$	(*M1)	Use of work-energy principle, correctly number of relevant terms; allow sign errors; allow sin/cos mix on PE term (must be a weight component).
	For use of $F = 0.03R$ to get equation in v (and m) only	(DM1)	Where R is a component of weight only (dimensionally correct but allow sin/cos mix) $\left[\Rightarrow v = 15.5 \text{ [15.46870...]} \right]$.
	$60 = \frac{1}{2}(5 + v)t$ and solve for t	(DM1)	Dependent on previous two M marks. Use of $s = \frac{1}{2}(u + v)t$ with $s = 60$, $u = 5$ and <i>their</i> v or other complete method to find positive value(s) of t .
	Time = 5.86 s [5.86260...]	(A1)	
		5	

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Question	Answer	Marks	Guidance
6(a)	For an attempt at differentiation	*M1	Decrease power by 1 and a change in coefficient in at least one term (which must be the same term). Therefore, must see $\frac{d}{dt}(kt^{\frac{1}{2}}) = ct^{-\frac{1}{2}}$ with $c \neq k$.
	$a = \frac{1}{2}kt^{\frac{1}{2}-1} - 2t^{1-1} + 0 = \frac{1}{2}kt^{-\frac{1}{2}} - 2$	A1	May be unsimplified.
	$a = 0 \Rightarrow \frac{1}{2}kt^{-\frac{1}{2}} - 2 = 0 \left[t = \frac{k^2}{16} \right] \text{ or } k = 4t^{\frac{1}{2}}$	DM1	Equate a to 0 and attempt to solve for t or k . Must be of the correct form, e.g. $t = \lambda k^2$ or $k = \delta t^{\frac{1}{2}}$ (possibly implied by forming a correct equation in k).
	$(v =) k \left(\frac{k^2}{16} \right)^{\frac{1}{2}} - 2 \frac{k^2}{16} - 8 = 4.5$	M1	Or complete method to find k or an equation involving k , e.g. $4t^{\frac{1}{2}} \times t^{\frac{1}{2}} - 2t - 8 = 4.5 \Rightarrow t = 6.25$ therefore $k = 4(6.25)^{\frac{1}{2}}$. Dependent on both previous M marks.
	$\Rightarrow \frac{k^2}{8} = 12.5 \Rightarrow k = 10$	A1	AG - Allow verification. Any errors seen is A0.
	Alternative method for last two marks of Question 6(a): Completing the square method		
	(Let $x = t^{\frac{1}{2}}$) $v = -2 \left(x^2 - \frac{k}{2}x + 4 \right) = -2 \left(x^2 - \frac{k}{2}x + \frac{k^2}{16} \right) + \frac{k^2}{8} - 8$	(M1)	Dependent on both previous M marks.
	so $\frac{k^2}{8} - 8 = 12.5$ so $k = 10$	(A1)	AG
		5	

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Question	Answer	Marks	Guidance
6(b)(i)	$10 \times 1^{\frac{1}{2}} - 2 \times 1 - 8 = 0$ and $10 \times 16^{\frac{1}{2}} - 2 \times 16 - 8 = 0$ Or equate $v = 0$ and solve for t to get $t = 1$ and $t = 16$.	B1	AG Any errors seen is B0.
		1	
6(b)(ii)	For integration (do not penalise missing c)	*M1	Increase power by 1 and a change in coefficient in at least one term (which must be the same term).
	$(s =) \frac{10}{\frac{3}{2}} t^{\frac{3}{2}} - \frac{2t^2}{2} - 8t [+c] = \frac{20}{3} t^{\frac{3}{2}} - t^2 - 8t [+c]$ or $(s =) \frac{k}{\frac{3}{2}} t^{\frac{3}{2}} - \frac{2t^2}{2} - 8t [+c] = \frac{2k}{3} t^{\frac{3}{2}} - t^2 - 8t [+c]$	A1	Allow unsimplified; allow with k not substituted.
	$\left(\frac{20}{3} 1^{\frac{3}{2}} - 1^2 - 8 \times 1 \right) - 0 \left[= -\frac{7}{3} \right]$ and $\left(\frac{20}{3} 16^{\frac{3}{2}} - 16^2 - 8 \times 16 \right) - \left(\frac{20}{3} 1^{\frac{3}{2}} - 1^2 - 8 \times 1 \right) =$ $\left[\frac{128}{3} - -\frac{7}{3} = 45 \right]$	DM1	Attempt at correct use of limits 0 and 1 or 1 and 16 – allow a single slip.
	For both set of limits applied correctly	DM1	Allow at most one slip in both.
	$\frac{142}{3} \text{ m}$	A1	Allow 47.3 or better (47.3333...) SC if no integration shown: B1 for $\pm \frac{7}{3}$ or 45, B1 for $\frac{142}{3}$ (so 2 marks max).
		5	

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Question	Answer	Marks	Guidance
7(a)	$v^2 = 25^2 - 2g \times 20$	M1	For use of $v^2 = u^2 + 2as$ or equivalent to get an equation in v only with $u = 25$, $s = 20$ and $a = \pm g$.
	$\Rightarrow \text{speed} = 15 \text{ ms}^{-1}$	A1	AG Allow verification – at least one intermediate step from equation of motion to given result. Any errors seen is A0.
	Alternative method for Question 7(a):		
	$0.2g \times 20 = \frac{1}{2} \times 0.2 \times 25^2 - \frac{1}{2} \times 0.2 \times v^2$	(M1)	Attempt at energy with $m = 0.2$, $h = 20$, $u = 25$; correct number of terms, allow sign errors.
	$\Rightarrow \text{speed} = 15 \text{ ms}^{-1}$	(A1)	AG Allow verification - at least one intermediate step from conservation of energy to given result. Any errors seen is A0.
		2	
7(b)	$0.2 \times 15 - 0.1 \times 20 = 0 + 0.1v$ or $0.2 \times 15 - 0.1 \times 20 = 0 - 0.1V$	M1	OE Attempt at conservation of momentum; 3 non-zero terms; allow sign errors – use of 25 is M0.
	$v = 10 \text{ ms}^{-1}$ upwards	A1	Must have direction (possibly seen on diagram). If using mgv for momentum, then M1 A0 max.
		2	

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Question	Answer	Marks	Guidance
7(c)	Speed of P at impact is 20 ms^{-1}	B1	From $v^2 = 0 + 2 \times g \times 20$ (OE) - possibly implied by speed of P after impact being stated at 10.
	Time to when P reaches ground = 2 s	B1	From $20 = 0 + \frac{1}{2} \times g \times t^2$ (OE).
	$s_P = 10t + \frac{1}{2} \times -g \times t^2$	M1	Distance travelled by P after impact with the ground. Must be using <i>their</i> 10 (speed of P after impact with the ground) and $a = \pm g$.
	$s_Q = 10t + \frac{1}{2} \times g \times t^2$	M1	Distance travelled by Q after P 's impact with the ground. Must be using their ± 10 (the speed/vel. of Q after <i>their</i> 2 s (= $ '10' + (-g) \times 2 $ where '10' is the value from (b)) and $a = \pm g$.
	$s_P + s_Q = 20 \Rightarrow t = 1$	A1	Time after P hits the ground to next collision.
	Height = 5 m	A1	CWO

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Question	Answer	Marks	Guidance
7(c)	Alternative Method for last 4 marks:		
	$s_Q = 10t + \frac{1}{2} \times -g \times t^2$	(M1)	Expression for the displacement of Q after first impact of P and Q . Must be using <i>their</i> 10 (from (b)) and $a = \pm g$.
	$s_P = 10 \times (t - 2) + \frac{1}{2} \times -g \times (t - 2)^2$	(M1)	Expression for the displacement of P (for values of $t \geq 2$) measured from point of first collision between P and Q . Must be using <i>their</i> 2 (time for P to reach ground), <i>their</i> 10 (speed of P after impact with the ground), $a = \pm g$.
	$s_Q + 20 = s_P \Rightarrow t = 3$	(A1)	Correct time between collisions of P and Q .
	Height = 5 m	(A1)	CWO
		6	

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1	Initial KE = $\frac{1}{2} \times 72 \times 8^2 [= 2304]$ OR Final KE = $\frac{1}{2} \times 72 \times 16^2 [= 9216]$ OR Work done against resistance = $28 \times 100 [= 2800]$	B1	Correct expression for either KE or correct expression for work done against resistance. For reference, $\frac{1}{2} \times 72 \times (16^2 - 8^2) = 6912$.
	Attempt at work-energy equation $\left[\frac{1}{2} \times 72 \times 8^2 + \text{WD} = \frac{1}{2} \times 72 \times 16^2 + 28 \times 100 \right]$	M1	4 terms; allow sign errors; dimensionally correct.
	WD = 9712 J	A1	OE. Condone 9710 J. Do not ISW.
	Alternative method for Question 1:		
	$\left[16^2 = 8^2 + 2 \times 100 \times a \Rightarrow \right] a = \frac{16^2 - 8^2}{2 \times 100} = 0.96$	(B1)	OE, e.g. $a = \frac{192}{200}$. Use of suvat in a complete method to find an expression for a . Must be of the form ' $a = \dots$ '.
	Attempt at Newton's second law $[\text{DF} - 28 = 72 \times (\text{their } 0.96)]$	(M1)	Three terms; dimensionally correct; allow sign errors; must be using <i>their</i> value of a .
	WD [= 97.12 × 100] = 9712 J	(A1)	OE. Condone 9710 J. Do not ISW.
		3	

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Question	Answer	Marks	Guidance
2(a)	Attempt to differentiate given v	M1	Decrease power by 1 and a change in coefficient in at least one term (which must be the same term); allow unsimplified. Use of $a = \frac{v}{t}$ scores M0.
	$[44 - 12t > 0 \Rightarrow] t < \frac{11}{3}$	A1	OE, e.g. $\frac{44}{12}$, $3\frac{2}{3}$, 3.67 or better. Do not allow $t \leq \frac{11}{3}$. May solve $44 - 12t = 0$, but final answer must be $t < \frac{11}{3}$. If a lower limit included it must be 0. Allow $t > 0$ or $t \geq 0$. Allow $\left[0, \frac{11}{3}\right)$ or $\left(0, \frac{11}{3}\right)$.
	Alternative Method for Question 2(a):		
	Use completing the square to get $-6\left[\left(t - \frac{11}{3}\right)^2 + \dots\right] + \dots$	(M1)	OE
	$t < \frac{11}{3}$	(A1)	CWO If a lower limit included it must be 0. Allow $t > 0$ or $t \geq 0$. Allow $\left[0, \frac{11}{3}\right)$ or $\left(0, \frac{11}{3}\right)$.

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Question	Answer	Marks	Guidance
2(a)	Alternative Method 2 for Question 2(a):		
	Solving $44t - 6t^2 - 36 = 0$ and find $\frac{t_1 + t_2}{2}$, or equivalent.	(M1)	Complete method for finding the value of t at maximum, or use $-\frac{b}{2a}$ with correct a and b . For reference, $t = \frac{11 \pm \sqrt{67}}{3}$.
	$t < \frac{11}{3}$	(A1)	If a lower limit included it must be 0. Allow $t > 0$ or $t \geq 0$. Allow $\left[0, \frac{11}{3}\right)$ or $\left(0, \frac{11}{3}\right)$.
		2	
2(b)	Attempt to integrate given v	M1	Increase power by 1 and a change in coefficient in at least one term (which must be the same term). Use of $s = vt$ is M0.
	$(s =) \frac{44}{1+1}t^{1+1} - \frac{6}{2+1}t^{2+1} - 36t(+c) = 22t^2 - 2t^3 - 36t(+c)$	A1	Allow unsimplified.
	$\left[22t^2 - 2t^3 - 36t = 0 \Rightarrow\right] t = 2, 9(\text{and } 0) \text{ ONLY}$	A1	CWO Ignore $t = 0$ if not rejected.
		3	

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Question	Answer	Marks	Guidance
3	Resolving either direction to get an equation	*M1	Correct number of relevant terms; allow sign errors; allow sin/cos mix.
	$10 \cos 25 = 2 \cos 40 + 16 \sin \theta$ $\left[\begin{array}{l} 9.06307787 = 1.532088886 + 16 \sin \theta \\ 7.530988984 = 16 \sin \theta \\ \sin \theta = 0.4706868115 \end{array} \right]$	A1	
	$P = 10 \sin 25 + 16 \cos \theta + 2 \sin 40$ $\left[\begin{array}{l} P = 4.226182617 + 16 \cos \theta + 1.285575219 \\ P = 5.511757837 + 16 \cos \theta \end{array} \right]$	A1	This may be with <i>their</i> θ .
	Attempt to solve for $\theta = \sin^{-1} \left(\frac{10 \cos 25 - 2 \cos 40}{16} \right)$	DM1	From equation(s) with correct number of relevant terms. Must be a numerical expression for θ .
	Attempt to solve for $P = 10 \sin 25 + 16 \cos(\text{their } \theta) + 2 \sin 40$	DM1	From equation(s) with correct number of relevant terms. Using <i>their</i> θ . Must be a numerical expression for P .
	$\theta = 28.1$ AND $P = 19.6$	A1	28.07888819 and 19.6285636. AWRT 28.1 and AWRT 19.6 from correct work.
		6	

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Question	Answer	Marks	Guidance
4(a)(i)	$\left[k \times 24^2 = 480 \Rightarrow \right] k = \frac{5}{6}$	B1	OE, e.g. $\frac{480}{576}$, 0.833 or better.
		1	
4(a)(ii)	Attempt at Newton's second law $[DF = 480 + 1400g \times 0.12 \Rightarrow DF = 2160]$	*M1	3 terms; allow sign errors; allow sin/cos mix. Allow $DF = 480 + 1400g \times \sin 6.9$ or better. May see $DF = \left(\text{their } \frac{5}{6} \right) 24^2 + 1400g \times 0.12$.
	Power = $(\text{their } 2160) \times 24$	DB1	For using $P = DF \times v$, where DF is numerical.
	51840 W	A1	Allow W missing, but if given in kW units must be present. Allow 51.84 kW. Allow 51800, 51.8 kW.
		3	
4(b)	$DF = \frac{54000}{v}$ and $DF = \left(\text{their } \frac{5}{6} \right) v^2$	*B1FT	FT $\text{their } \frac{5}{6} > 0$.
	Get an equation of the form $av^3 = b$ and attempt to solve for v to get a positive value	DM1	a and b must both be positive or both negative. Must get to a value for v ; if cubic not seen, the cubic may be implied by the correct answer for their equation.
	Speed = 40.2 m s^{-1}	A1	40.165977. AWRT 40.2 from correct work.
		3	

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Question	Answer	Marks	Guidance
5	Attempt at resolving perpendicular to plane to get an equation	*M1	3 relevant terms; allow sign errors; allow sin/cos mix; allow g missing; $m = 0.8$ must be used; correct angles must be used.
	$R + T \sin 35 = 0.8g \cos 28$ $[R + (0.57357...) T = 7.06358]$	A1	
	Attempt to resolve parallel to plane for one of the possible cases to get an equation	*M1	3 relevant terms; allow sign errors; allow sin/cos mix; allow g missing; $m = 0.8$ must be used; correct angles must be used.
	$T \cos 35 = 0.8g \sin 28 + F$ $[(0.81915...)T = 3.75577... + F]$	A1	May use <i>their</i> F .
	$T \cos 35 = 0.8g \sin 28 - F$ $[(0.81915...)T = 3.75577... - F]$	A1	May use <i>their</i> F .
	Use of $F = 0.2R$ to get an equation in T only	DM1	Dependent on previous 2 M marks. May be implied by correct T value. Allow g missing. If resolved equations incorrect and no working seen, then this mark is implied by the correct T value for their equations.
	Solve to get $T = 5.53$	A1	5.534499898 AWRT 5.53 from correct work. Allow 5.54 from correct work.
	Solve to get $T = 3.33$	A1	3.326141531 AWRT 3.33 from correct work. Allow 3.32 from correct work.
		8	

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Question	Answer	Marks	Guidance
6(a)	Attempt at conservation of momentum for the 1st collision $[5 \times 6 = (5 + 1)v_D]$	*M1	3 non-zero terms; allow sign errors; using correct masses. For reference $v_D = 5$. If mgv used, allow M1 M1 A0 max.
	Attempt at conservation of momentum for the 2nd collision $[(5 + 1)(\text{their } v_D) - 2v = (5 + 1 + 2)v_E]$	DM1	6 non-zero terms; allow sign errors; using correct masses; allow their numerical v_D . Allow $v = v_E$ for this mark. Note: $5 \times 6 - 2v = (5 + 1 + 2)v_E$ is M2. If mgv used, allow M1 M1 A0 max.
	$(v_E =) \frac{15 - v}{4}$	A1	AG Must in terms of v , as v is given in the question or explicitly defined their letter used as v . Do not allow $v = v_E$ for this mark. Any error seen is A0 but condone saying ‘divide by 2’ or equivalent. If mgv used, allow M1 M1 A0 max.
		3	

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Question	Answer	Marks	Guidance
6(b)	$\text{KE}_{\text{initial}} = \frac{1}{2} \times 5 \times 6^2 + \frac{1}{2} \times 2 \times v^2 [= 90 + v^2]$ $\text{KE}_{\text{final}} = \frac{1}{2} (5 + 1 + 2) \left(\frac{15 - v}{4} \right)^2$	B1	For either $\text{KE}_{\text{initial}}$ or KE_{final} correct.
	Attempt difference in KE is 63 to get an equation $\left[\frac{1}{2} \times 5 \times 6^2 + \frac{1}{2} \times 2 \times v^2 - \frac{1}{2} (5 + 1 + 2) \left(\frac{15 - v}{4} \right)^2 = 63 \right]$	M1	Using (sum of two initial KEs) – $\text{KE}_{\text{final}} = \pm 63$. Correct number of relevant terms – correct masses, must be adding 2 KE terms for $\text{KE}_{\text{initial}}$. (sum of two initial KEs) and KE_{final} coming from use of correct formula and of the correct form.
	Solve algebraically $3v^2 + 30v - 117 = 0$ OE to get $v = 3$ ONLY	A1	AG Any error seen is A0. Allow solving correct quadratic expression, rather than correct quadratic equation, for full marks. If $v = -13$ seen it must be discarded. Must see solving for this mark. A quadratic equation followed by the answer is insufficient.

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Question	Answer	Marks	Guidance
6(b)	Alternative Method for Question 6(b): Using loss of KE in second collision		
	$\text{KE}_{\text{after 1st collision}} = \frac{1}{2} \times 6 \times 5^2 + \frac{1}{2} \times 2 \times v^2 [= 75 + v^2]$ $\text{KE}_{\text{final}} = \frac{1}{2} (5 + 1 + 2) \left(\frac{15 - v}{4} \right)^2$	(B1)	For either $\text{KE}_{\text{after 1st collision}}$ or KE_{final} correct.
	Attempt difference in KE is $63 - \left(\frac{1}{2} \times 5 \times 6^2 - \frac{1}{2} \times 6 \times 5^2 \right) [= 63 - 15 = 48]$ to get an equation $\left[\frac{1}{2} \times 6 \times 5^2 + \frac{1}{2} \times 2 \times v^2 - \frac{1}{2} (5 + 1 + 2) \left(\frac{15 - v}{4} \right)^2 = 63 - 15 \right]$	(M1)	Using $\text{KE}_{\text{after 1st collision}} - \text{KE}_{\text{final}} = \pm (63 - \text{their } 15)$. Correct number of relevant terms. $\text{KE}_{\text{after 1st collision}}$, KE_{final} and <i>their</i> 15 coming from use of correct formula and of the correct form.
	Solve algebraically $3v^2 + 30v - 117 = 0$ OE to get $v = 3$ ONLY	(A1)	AG Any error seen is A0. If $v = -13$ seen it must be discarded. Must see solving for this mark. A quadratic equation followed by the answer is insufficient.
	Alternative Method 2 for Question 6(b): Verifying that $v = 3$		
	$\text{KE}_{\text{initial}} = \frac{1}{2} \times 5 \times 6^2 + \frac{1}{2} \times 2 \times 3^2 = 99$	(B1)	
	$\text{KE}_{\text{final}} = \frac{1}{2} (5 + 1 + 2) \left(\frac{15 - 3}{4} \right)^2 = 36$	(B1)	
	$\text{KE}_{\text{initial}} - \text{KE}_{\text{final}} = 63$, hence loss in KE is 63 J	(B1)	Must have a conclusion for this mark.
		3	

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Question	Answer	Marks	Guidance
6(c)(i)	Time A to $B = 6$ s	B1	
	Distance $BC = 98 - 3 \times (\text{their } 6) [= 80]$	*B1FT	FT <i>their</i> 6 which MUST come from $6t = 36$.
	Use sum of distance moved by D and distance moved by C is 80 m $[(\text{their } 5)t + 3t = \text{their } 80]$ OR use distance moved by C divided by relative velocity $\left[\frac{80}{(\text{their } 5) + 3} \right]$	DM1	Using <i>their</i> v_D from part (a). $v_D \neq 6$ or 3 and <i>their</i> 80 $\neq 98$.
	Time = 10 s	A1	Do not ISW.
		4	
6(c)(ii)	$\left[6 + 10 + \frac{3 \times 10 + 3 \times 6}{3} = \right] 32$ s	B1	
		1	

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Question	Answer	Marks	Guidance
7(a)	$R = 2.5g \cos 30 \left[= \frac{25\sqrt{3}}{2} = 21.65063509 \right]$	B1	Note: $F = 0.5g \cos 30 = \frac{5\sqrt{3}}{2} = 4.330127019$.
	Attempt at Newton's second law	*M1	Correct number of dimensionally correct/relevant terms; allow sign errors; allow sin/cos mix. Using this twice to get equations for P and Q ; allow different T 's (equations with 0.5 and 2.5). Using once to get a system equation (equation with 0.5 + 2.5).
	EITHER: $T - 0.5g = 0.5a$ AND $2.5g \sin 30 - F - T = 2.5a$ OR: $2.5g \sin 30 - F - 0.5g = (2.5 + 0.5)a$	A1	EITHER: Both correct; allow their F ; must be the same T . OR: correct system equation; allow their F .
	Use $F = 0.2R$ to get an equation in a only $[2.5g \sin 30 - 0.2 \times 2.5g \cos 30 - 0.5g = (2.5 + 0.5)a]$	DM1	Where R is a component of weight of P only; from equation(s) with the correct number of dimensionally correct/relevant terms.
	$a = 1.06 \text{ ms}^{-2}$	A1	Allow $\frac{15 - 5\sqrt{3}}{6}$. 1.05662433. AWRT 1.06 from correct work.
		5	

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Question	Answer	Marks	Guidance
7(b)	$[x \sin 30 = 2 - x \Rightarrow] x = \frac{4}{3}$ OR $[(2 - y) \sin 30 = y \Rightarrow] y = \frac{2}{3}$ OR $\left[\frac{1}{2} \times 1.056... \times t^2 + \frac{1}{2} \times 1.056... \times t^2 \times \sin 30 = 2 \Rightarrow t = 1.5886... \right]$ $\Rightarrow x = \left[\frac{1}{2} \times 1.056... \times (1.5886...) \sin 30 \right] = \frac{2}{3}$ OR $\Rightarrow y = \left[\frac{1}{2} \times 1.056... \times (1.5886...) \right] = \frac{4}{3}$	*B1	Where x is the distance P moves down the plane or Q moves vertically upwards, or where y is the vertical distance of Q below P 's starting point. Allow $x = 1.3$ or better; allow $y = 0.67$ or better.
	Change in PE $= \pm(2.5g(\text{their } x) \sin 30 - 0.5g(\text{their } x)) \left[= \pm \frac{3}{4}g(\text{their } x) \right]$ OR $= \pm(2.5g(2 - \text{their } y) \sin 30 - 0.5g(2 - \text{their } y))$ $[= \pm(3(\text{their } y) - 1)g]$	B1	Using <i>their</i> $x (\neq 2 \text{ or } 1 \text{ or } 0)$, $0 < x < 2$; or <i>their</i> $y (\neq 2 \text{ or } 1 \text{ or } 0)$, $0 < y < 2$.
	WD against friction $= 0.2 \times 2.5g \cos 30 \times (\text{their } x) [= 4.33(\text{their } x)]$ OR WD against friction $= 0.2 \times 2.5g \cos 30 \times (2 - (\text{their } y))$	B1	Using <i>their</i> $x (\neq 2 \text{ or } 1 \text{ or } 0)$, $0 < x < 2$; or <i>their</i> $y (\neq 2 \text{ or } 1 \text{ or } 0)$, $0 < y < 2$.
	$\frac{1}{2} \times 2.5 \times v^2 + \frac{1}{2} \times 0.5 \times v^2 =$ $2.5g \left(\frac{4}{3} \right) \sin 30 - 0.5g \left(\frac{4}{3} \right) - 0.2 \times 2.5g \cos 30 \times \left(\frac{4}{3} \right)$ OR $\frac{1}{2} \times 2.5 \times v^2 + \frac{1}{2} \times 0.5 \times v^2 =$ $2.5g \left(2 - \frac{2}{3} \right) \sin 30 - 0.5g \left(2 - \frac{2}{3} \right) - 0.2 \times 2.5g \cos 30 \times \left(2 - \frac{2}{3} \right)$	DM1	Attempt at work energy equation; dimensionally correct; 5 relevant terms; allow sign errors; allow sin/cos mix. Must be using correct values of x or y .

Question	Answer	Marks	Guidance
	$v = 1.68$	A1	1.67859014 AWRT 1.68 from correct work.

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Question	Answer	Marks	Guidance
7(b)	Alternative Method for Question 7(b): Considering energy on Q only Must be using tension and mass 0.5 kg only to be awarded the last 4 marks		
	$[x \sin 30 = 2 - x \Rightarrow] x = \frac{4}{3}$ OR $[(2 - y) \sin 30 = y \Rightarrow] y = \frac{2}{3}$ OR $\left[\frac{1}{2} \times 1.056 \dots \times t^2 + \frac{1}{2} \times 1.056 \dots \times t^2 \times \sin 30 = 2 \Rightarrow t = 1.5886 \dots \right]$ $\Rightarrow x = \left[\frac{1}{2} \times 1.056 \dots \times (1.5886 \dots)^2 \sin 30 \right] = \frac{2}{3}$ OR $\Rightarrow y = \left[\frac{1}{2} \times 1.056 \dots \times (1.5886 \dots)^2 \right] = \frac{4}{3}$	(*B1)	Where x is the distance P moves down the plane or Q moves vertically upwards, or where y is the vertical distance of Q below P 's starting point. Allow $x = 1.3$ or better; allow $y = 0.67$ or better.
	Change in PE = $\pm 0.5g \times (\text{their } x)$ OR Change in PE = $\pm 0.5g \times (2 - (\text{their } y))$	(B1)	Using $\text{their } x (\neq 2 \text{ or } 1 \text{ or } 0)$, $0 < x < 2$; or $\text{their } y (\neq 2 \text{ or } 1 \text{ or } 0)$, $0 < y < 2$.
	WD by tension = $(\text{their } 5.528312164) \times (\text{their } x)$ OR WD by tension = $(\text{their } 5.528312164) \times (2 - (\text{their } y))$	(B1)	Using their tension from 7(a) from equation(s) with the correct number of dimensionally correct/relevant terms. Using $\text{their } x (\neq 2 \text{ or } 1 \text{ or } 0)$, $0 < x < 2$; or $\text{their } y (\neq 2 \text{ or } 1 \text{ or } 0)$, $0 < y < 2$.
	$0.5g \left(\frac{4}{3} \right) + \frac{1}{2} \times 0.5 \times v^2 = (\text{their } 5.528312164) \times \left(\frac{4}{3} \right)$ OR $0.5g \left(2 - \frac{2}{3} \right) + \frac{1}{2} \times 0.5 \times v^2 = (\text{their } 5.528312164) \times \left(2 - \frac{2}{3} \right)$	(DM1)	Using their tension from 7(a) from equation(s) with the correct number of dimensionally correct/relevant terms. Attempt at work energy equation; dimensionally correct; 3 relevant terms; allow sign errors. Must be using correct values of x or y .
	$v = 1.68$	(A1)	1.67859014 AWRT 1.68 from correct work.

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Question	Answer	Marks	Guidance
7(b)	Alternative Method 2 for Question 7(b): Considering energy on P only Note: must be using tension and mass 2.5 kg only to be awarded the last 4 marks		
	$[x \sin 30 = 2 - x \Rightarrow] x = \frac{4}{3}$ OR $[(2 - y) \sin 30 = y \Rightarrow] y = \frac{2}{3}$ OR $\left[\frac{1}{2} \times 1.056... \times t^2 + \frac{1}{2} \times 1.056... \times t^2 \times \sin 30 = 2 \Rightarrow t = 1.5886... \right]$ $\Rightarrow x = \left[\frac{1}{2} \times 1.056... \times (1.5886...)^2 \sin 30 \right] = \frac{2}{3}$ OR $\Rightarrow y = \left[\frac{1}{2} \times 1.056... \times (1.5886...)^2 \right] = \frac{4}{3}$	(*B1)	Where x is the distance P moves down the plane or Q moves vertically upwards, or where y is the vertical distance of Q below P 's starting point. Allow $x = 1.3$ or better; allow $y = 0.67$ or better.
	Change in PE = $\pm 2.5g(\text{their } x) \sin 30$ OR = $\pm 2.5g(\text{their } y)$	(B1)	Using <i>their</i> $x (\neq 2 \text{ or } 1 \text{ or } 0)$, $0 < x < 2$; or <i>their</i> $y (\neq 2 \text{ or } 1 \text{ or } 0)$, $0 < y < 2$.
	WD by tension = $(\text{their } 5.528312164) \times (\text{their } x)$ OR WD against friction = $0.2 \times 2.5g \cos 30 \times (\text{their } x)$	(B1)	Using <i>their</i> tension from 7(a) from equation(s) with the correct number of dimensionally correct/relevant terms. Using <i>their</i> $x (\neq 2 \text{ or } 1 \text{ or } 0)$, $0 < x < 2$; or <i>their</i> $y (\neq 2 \text{ or } 1 \text{ or } 0)$, $0 < y < 2$.
	$2.5g \left(\frac{4}{3} \right) \sin 30 = \frac{1}{2} \times 2.5 \times v^2 +$ $0.2 \times 2.5g \cos 30 \times \left(\frac{4}{3} \right) + (\text{their } 5.528312164) \times \left(\frac{4}{3} \right)$	(DM1)	Using <i>their</i> tension from 7(a) from equation(s) with the correct number of dimensionally correct/relevant terms. Attempt at work energy equation; dimensionally correct; 4 relevant terms; allow sign errors; allow sin/cos mix. Must be using correct values of x or y .
	$v = 1.68$	(A1)	1.67859014 AWRT 1.68 from correct work.

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Question	Answer	Marks	Guidance
7(b)	Special Case for using constant acceleration: Maximum 2 marks		
	$[x \sin 30 = 2 - x \Rightarrow] x = \frac{4}{3}$ OR $[(2 - y) \sin 30 = y \Rightarrow] y = \frac{2}{3}$ OR $\left[\frac{1}{2} \times 1.056 \dots \times t^2 + \frac{1}{2} \times 1.056 \dots \times t^2 \times \sin 30 = 2 \Rightarrow t = 1.5886 \dots \right]$ $\Rightarrow x = \left[\frac{1}{2} \times 1.056 \dots \times (1.5886 \dots)^2 \sin 30 \right] = \frac{2}{3}$ OR $\Rightarrow y = \left[\frac{1}{2} \times 1.056 \dots \times (1.5886 \dots)^2 \right] = \frac{4}{3}$	(B1)	Where x is the distance P moves down the plane or Q moves vertically upwards, or where y is the vertical distance of Q below P 's starting point. Allow $x = 1.3$ or better; allow $y = 0.67$ or better.
	$\left[v^2 = 2 \times 1.06 \times \frac{4}{3} \Rightarrow \right] v = 1.68$	(B1)	1.67859014 AWRT 1.68 from correct work.
		5	

Cambridge International AS & A Level

MATHEMATICS**9709/43**

Paper 4 Mechanics

May/June 2024**MARK SCHEME**Maximum Mark: 50

Published

This mark scheme is published as an aid to teachers and candidates, to indicate the requirements of the examination. It shows the basis on which Examiners were instructed to award marks. It does not indicate the details of the discussions that took place at an Examiners' meeting before marking began, which would have considered the acceptability of alternative answers.

Mark schemes should be read in conjunction with the question paper and the Principal Examiner Report for Teachers.

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This document consists of **22** printed pages.

PUBLISHED**Generic Marking Principles**

These general marking principles must be applied by all examiners when marking candidate answers. They should be applied alongside the specific content of the mark scheme or generic level descriptions for a question. Each question paper and mark scheme will also comply with these marking principles.

GENERIC MARKING PRINCIPLE 1:

Marks must be awarded in line with:

- the specific content of the mark scheme or the generic level descriptors for the question
- the specific skills defined in the mark scheme or in the generic level descriptors for the question
- the standard of response required by a candidate as exemplified by the standardisation scripts.

GENERIC MARKING PRINCIPLE 2:

Marks awarded are always **whole marks** (not half marks, or other fractions).

GENERIC MARKING PRINCIPLE 3:

Marks must be awarded **positively**:

- marks are awarded for correct/valid answers, as defined in the mark scheme. However, credit is given for valid answers which go beyond the scope of the syllabus and mark scheme, referring to your Team Leader as appropriate
- marks are awarded when candidates clearly demonstrate what they know and can do
- marks are not deducted for errors
- marks are not deducted for omissions
- answers should only be judged on the quality of spelling, punctuation and grammar when these features are specifically assessed by the question as indicated by the mark scheme. The meaning, however, should be unambiguous.

GENERIC MARKING PRINCIPLE 4:

Rules must be applied consistently, e.g. in situations where candidates have not followed instructions or in the application of generic level descriptors.

GENERIC MARKING PRINCIPLE 5:

Marks should be awarded using the full range of marks defined in the mark scheme for the question (however; the use of the full mark range may be limited according to the quality of the candidate responses seen).

GENERIC MARKING PRINCIPLE 6:

Marks awarded are based solely on the requirements as defined in the mark scheme. Marks should not be awarded with grade thresholds or grade descriptors in mind.

PUBLISHED**Mathematics-Specific Marking Principles**

- 1 Unless a particular method has been specified in the question, full marks may be awarded for any correct method. However, if a calculation is required then no marks will be awarded for a scale drawing.
- 2 Unless specified in the question, non-integer answers may be given as fractions, decimals or in standard form. Ignore superfluous zeros, provided that the degree of accuracy is not affected.
- 3 Allow alternative conventions for notation if used consistently throughout the paper, e.g. commas being used as decimal points.
- 4 Unless otherwise indicated, marks once gained cannot subsequently be lost, e.g. wrong working following a correct form of answer is ignored (isw).
- 5 Where a candidate has misread a number or sign in the question and used that value consistently throughout, provided that number does not alter the difficulty or the method required, award all marks earned and deduct just 1 A or B mark for the misread.
- 6 Recovery within working is allowed, e.g. a notation error in the working where the following line of working makes the candidate's intent clear.

PUBLISHED**Mark Scheme Notes**

The following notes are intended to aid interpretation of mark schemes in general, but individual mark schemes may include marks awarded for specific reasons outside the scope of these notes.

Types of mark

- M** Method mark, awarded for a valid method applied to the problem. Method marks are not lost for numerical errors, algebraic slips or errors in units. However, it is not usually sufficient for a candidate just to indicate an intention of using some method or just to quote a formula; the formula or idea must be applied to the specific problem in hand, e.g. by substituting the relevant quantities into the formula. Correct application of a formula without the formula being quoted obviously earns the M mark and in some cases an M mark can be implied from a correct answer.
- A** Accuracy mark, awarded for a correct answer or intermediate step correctly obtained. Accuracy marks cannot be given unless the associated method mark is earned (or implied).
- B** Mark for a correct result or statement independent of method marks.
- DM or DB** When a part of a question has two or more ‘method’ steps, the M marks are generally independent unless the scheme specifically says otherwise; and similarly, when there are several B marks allocated. The notation DM or DB is used to indicate that a particular M or B mark is dependent on an earlier M or B (asterisked) mark in the scheme. When two or more steps are run together by the candidate, the earlier marks are implied and full credit is given.
- FT** Implies that the A or B mark indicated is allowed for work correctly following on from previously incorrect results. Otherwise, A or B marks are given for correct work only.
- A or B marks are given for correct work only (not for results obtained from incorrect working) unless follow through is allowed (see abbreviation FT above).
 - For a numerical answer, allow the A or B mark if the answer is correct to 3 significant figures or would be correct to 3 significant figures if rounded (1 decimal place for angles in degrees).
 - The total number of marks available for each question is shown at the bottom of the Marks column.
 - Wrong or missing units in an answer should not result in loss of marks unless the guidance indicates otherwise.
 - Square brackets [] around text or numbers show extra information not needed for the mark to be awarded.

Abbreviations

AEF/OE	Any Equivalent Form (of answer is equally acceptable) / Or Equivalent
AG	Answer Given on the question paper (so extra checking is needed to ensure that the detailed working leading to the result is valid)
CAO	Correct Answer Only (emphasising that no ‘follow through’ from a previous error is allowed)
CWO	Correct Working Only
ISW	Ignore Subsequent Working
SOI	Seen Or Implied
SC	Special Case (detailing the mark to be given for a specific wrong solution, or a case where some standard marking practice is to be varied in the light of a particular circumstance)
WWW	Without Wrong Working
AWRT	Answer Which Rounds To

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Question	Answer	Marks	Guidance
1	$0.2 \times 6 + 0 = 0.2 \times 1 + 0.5v$ or $0.2 \times 6 + 0 = 0.2 \times -1 + 0.5v$	M1	For attempt at use of conservation of momentum in at least one case. Must have three non-zero terms. Allow sign errors. Must have correct masses with relevant velocities. <i>Their</i> v may be in opposite direction.
	Speed = 2 ms^{-1}	A1	Do not allow negative.
	Speed = $2.8[0] \text{ ms}^{-1}$ or $\frac{14}{5} \text{ ms}^{-1}$ or $2\frac{4}{5} \text{ ms}^{-1}$	A1	OE Do not allow negative.
		3	

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Question	Answer	Marks	Guidance
2	$X \cos 30 - T \sin 30 = 0$	M1	Must have correct number of relevant terms (forces must have components as required). Allow sin/cos mix. Allow sign errors.
	$X \sin 30 + T \cos 30 - 0.2g = 0$	M1	Must have correct number of relevant terms (forces must have components as required). Allow sin/cos mix but must be consistent with their other equation. Allow sign errors.
	$X = 1$, Tension = 1.73 N [1.7320..] or $\sqrt{3}$ N	A1	For both.
	Alternative Method for Question 2: Resolving in directions of X and T or triangle of forces		
	$X - 0.2g \cos 60 = 0$	(M1)	Must have correct number of relevant terms (forces must have components as required). Allow sin/cos mix. Allow sign errors.
	$T - 0.2g \sin 60 = 0$	(M1)	Must have correct number of relevant terms (forces must have components as required). Allow sin/cos mix but must be consistent with their other equation. Allow sign errors.
	$X = 1$, Tension = 1.73 N [1.7320..] or $\sqrt{3}$ N	(A1)	For both.
	Alternative Method for Question 2: Using Lami's theorem		
	$\frac{0.2g}{\sin 90} = \frac{X}{\sin 150} = \frac{T}{\sin 120}$	(M1M1)	First M1 for any two fractions. Second M1 for all three fractions or another pair of fractions. Allow $\frac{X}{\sin 120}$ and $\frac{T}{\sin 150}$ for M1 marks.
	$X = 1$, Tension = 1.73 N [1.7320..] or $\sqrt{3}$ N	(A1)	For both.
		3	

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Question	Answer	Marks	Guidance
3(a)	$AB: [s =] u \times 8 + \frac{1}{2} a \times 8^2$ $[= 8u + 32a]$ or $\frac{u + u + 8a}{2} \times 8$ $BC: [2s =] (u + 8a) \times 10 + \frac{1}{2} a \times 10^2 \quad [= 10u + 130a]$ or $\frac{u + 8a + u + 8a + 10a}{2} \times 10$ $AC: [3s =] u \times 18 + \frac{1}{2} a \times 18^2$ $[= 18u + 162a]$ or $\frac{u + u + 18a}{2} \times 18$	B1B1	For use of $s = ut + \frac{1}{2} at^2$ or $s = \frac{u+v}{2} t$. B1 for any one correct expression, B2 for two correct expressions.
	Attempt to solve simultaneously $(u + 8a) \times 10 + \frac{1}{2} a \times 10^2 = 2 \left(u \times 8 + \frac{1}{2} a \times 8^2 \right)$ $[\Rightarrow 10u + 130a = 2(8u + 32a)]$ OR $u \times 18 + \frac{1}{2} a \times 18^2 = 3 \left(u \times 8 + \frac{1}{2} a \times 8^2 \right)$ $[\Rightarrow 18u + 162a = 3(8u + 32a)]$ $u \times 18 + \frac{1}{2} a \times 18^2 = \frac{3}{2} \left((u + 8a) \times 10 + \frac{1}{2} a \times 10^2 \right)$ $[\Rightarrow 18u + 162a = \frac{3}{2} (10u + 130a)]$	M1	To obtain an equation in u and a only. Must have come from correct expressions but allow $\times \frac{1}{3}$ instead of $\times 3$ or $\times \frac{1}{2}$ instead of $\times 2$ or $\times \frac{2}{3}$ instead of $\times \frac{3}{2}$. Note: M0 for $u \times 10 + \frac{1}{2} a \times 10^2 = 2 \left(u \times 8 + \frac{1}{2} a \times 8^2 \right)$ leading to $u = -\frac{7}{3} a$. Note: M0 for distance $AC = 2AB$ leading to $u = -49a$.
	$u = 11a$	A1	

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Question	Answer	Marks	Guidance
3(a)	Alternative Method for Question 3(a): Using $v^2 = u^2 + 2as$		
	$[s =] \frac{(u + 8a)^2 - u^2}{2a}$ or $[2s =] \frac{(u + 18a)^2 - (u + 8a)^2}{2a}$ or $[3s =] \frac{(u + 18a)^2 - u^2}{2a}$	(B1B1)	B1 for any one correct expression, B2 for two correct expressions.
	$\frac{(u + 18a)^2 - u^2}{2a} = 3 \left(\frac{(u + 8a)^2 - u^2}{2a} \right)$ or $\frac{(u + 18a)^2 - (u + 8a)^2}{2a} = 2 \left(\frac{(u + 8a)^2 - u^2}{2a} \right)$ or $\frac{(u + 18a)^2 - u^2}{2a} = \frac{3}{2} \left(\frac{(u + 18a)^2 - (u + 8a)^2}{2a} \right)$	(M1)	To obtain an equation in u and a only.
	$u = 11a$	(A1)	
		4	

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Question	Answer	Marks	Guidance
3(b)	$v = 11a + a \times 18$	M1	For use of $v = u + at$ or other complete suvat method Using <i>their</i> u in terms of a , e.g. $v^2 = (11a)^2 + 2a(18 \times 11a + 162a) \left[= 841a^2 \right]$, $v = \sqrt{(11a)^2 + 2a(18 \times 11a + 162a)} \left[= \sqrt{841a^2} \right]$.
	Speed = $29a$	A1FT	FT <i>their</i> expression for v so <i>their</i> $u + 18a$. Note: If answer to part (a) is $u = -\frac{7}{3}a$, then speed = $\frac{47}{3}a$.
		2	

Question	Answer	Marks	Guidance
4(a)	For attempt at integration	M1*	The power of t must increase by 1 with a change of coefficient in the same term. Use of $s = vt$ scores M0.
	$\frac{1}{2+1}kt^{2+1} - \frac{4}{2}t^{1+1} + 3t \left[= \frac{1}{3}kt^3 - 2t^2 + 3t \right] [+c]$	A1	Allow unsimplified.
	$\frac{1}{3}k \times 2^3 - 2 \times 2^2 + 3 \times 2[-0] = 6$	DM1	Use of limits 0 and 2 with 6 to form an equation in k only (without c but allow with $+c - c$).
	$k = 3$	A1	
		4	

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Question	Answer	Marks	Guidance
4(b)	$2 \times 3t - 4$ Or at min value $t = \frac{-b}{2a} = \frac{4}{2 \times 3}$	M1	For attempt at differentiation. Must have expression of the form $at + b$ with $a \neq 3$, unless their $k = \frac{3}{2}$. Allow $2kt - 4$.
	$[2 \times 3t - 4 = 0 \Rightarrow] t = \frac{2}{3}$	A1FT	OE FT <i>their k</i> $t = \frac{2}{\text{their } k}$. Allow without working.
	$v \left[= 3 \times \left(\frac{2}{3} \right)^2 - 4 \times \frac{2}{3} + 3 \right] = \frac{5}{3} \text{ m s}^{-1}$	A1	OE Allow 1.67 or better for v .
	Alternative Method for Question 4(b): Using completing the square		
	Attempt at completing the square	(M1)	Must have $\left(t - \frac{2}{3} \right)^2$ OE, or $\left(t - \frac{2}{\text{their } k} \right)^2$.
	$3 \left(t - \frac{2}{3} \right)^2 - \frac{4}{3} + 3$	(A1FT)	FT <i>their k</i> $k \left(t - \frac{2}{k} \right)^2 - \frac{4}{k} + 3$.
	$v = \frac{5}{3} \text{ m s}^{-1}$	(A1)	OE Allow 1.67 or better.
		3	

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Question	Answer	Marks	Guidance
5(a)	Use of Newton's second law for van or trailer or system Note: Trailer has 4 terms Van has 5 terms System has 7 terms (or 5 if counting van and trailer as one body)	M1*	Must have correct number of relevant terms. Allow sign errors. Allow sin/cos mix. Allow g missing. Masses must be correct for their equation(s). Forces must have components (or not) as required. Must have either 0.05 or $\sin 2.86\dots$ or $\sin 2.9$, not just $\sin \theta$.
	Trailer: $450 + 750g \times 0.05 - 300 = 750a$ [$525 = 750a$] Van: $D + 4500g \times 0.05 - 2500 - 450 = 4500a$ [$D - 700 = 4500a$] System: $D + 4500g \times 0.05 + 750g \times 0.05 - 2500 - 300 = (4500 + 750)a$ [$D - 175 = 5250a$]	A1	For any two correct equations.
	For attempt to solve for a or D	DM1	Must get to ' $a =$ ' or ' $D =$ '. Must have correct number of relevant terms in the equation(s) which they are using to find a or D . g must be present. Allow sign errors. Allow sin/cos mix. If no working shown to solve their equations, then their answers should be correct for their equations.
	$a = 0.7 \text{ ms}^{-2}$ and $D = 3850 \text{ N}$	A1	
		4	

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Question	Answer	Marks	Guidance
5(b)(i)	Use of Newton's second law for van or trailer or system Note: Trailer has 4 terms Van has 5 terms System has 7 terms (or 5 if counting van and trailer as one body)	M1*	Must have correct number of relevant terms Allow sign errors. Allow sin/cos mix. Allow g missing. Masses must be appropriate for their equation(s). Forces must have components (or not) as required. Must have either 0.09 or $\sin 5.16\dots$ or $\sin 5.2$ not just $\sin \theta$.
	Trailer: $T - 300 - 750g \times 0.09 = 750a$ [$T - 975 = 750a$] Van: $9100 - 2500 - 4500g \times 0.09 - T = 4500a$ [$2550 - T = 4500a$] System: $9100 - 2500 - 300 - (4500 + 750)g \times 0.09 = (4500 + 750)a$ [$1575 = 5250a$]	A1A1	A1 for one correct equation, second A1 for another correct equation. If using Van and Trailer equations, must be using the same T for both to get the second A1.
	For attempt to solve for a or T	DM1	Must get to ' $a =$ ' or ' $T =$ '. Must have correct number of relevant terms in the equation(s) which they are using to find a or T . g must be present. Allow sign errors. Allow sin/cos mix. If no working shown to solve their equations, then their answers should be correct for their equations.
	$T = 1200 \text{ N}$ and $a = 0.3 \text{ ms}^{-2}$	A1	
		5	

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Question	Answer	Marks	Guidance
5(b)(ii)	$v^2 = 20^2 + 2 \times \text{their } 0.3 \times 375$	M1	For use of $v^2 = 20^2 + 2a \times 375$ or other complete method to find v^2 or v . For info time taken $t = \frac{50}{3}$.
	$v = 25 \text{ ms}^{-1}$	A1FT	FT <i>their</i> value of a , i.e. $v = \sqrt{400 + 750 \times \text{their } a}$. Provided it does not lead to root of negative value.
	Alternative Method for Question 5(b)(ii): Using energy		
	System: $\frac{1}{2} \times (4500 + 750)(v^2 - 20^2) + (4500 + 750)g \times 375 \times 0.09 = (9100 - 2500) \times 375$ or Van: $\frac{1}{2} \times 4500(v^2 - 20^2) + 4500g \times 375 \times 0.09 = (9100 - 2500 - \text{their } 1200) \times 375$ OR Trailer: $\frac{1}{2} \times 750(v^2 - 20^2) + 750g \times 375 \times 0.09 = (\text{their } 1200 - 300) \times 375$	(M1)	Must include all appropriate terms. Allow sign errors. g must be present. Allow their value of T in place of 1200.
	$v = 25 \text{ ms}^{-1}$	(A1FT)	FT their value of T if using Van or Trailer.
		2	

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Question	Answer	Marks	Guidance
6(a)	$DF = \frac{P}{7}$	B1	For $P = DF \times 7$ OE seen at any point in working. Allow any force term or simply DF , e.g. $32,80 \times 0.1$, $32 - 80 \times 0.1$, 80×10 etc.
	$D - 32 = 80 \times 0.1$	M1	For use of Newton's second law. Must have correct number of terms. Allow sign errors.
	[Power =] 280 W	A1	
		3	
6(b)	[At steady speed driving force =] $32 = \frac{280}{v}$	M1	Attempt at equilibrium equation ($a = 0$) with their power.
	Steady speed = 8.75 ms^{-1} or $\frac{35}{4} \text{ ms}^{-1}$	A1FT	OE FT <i>their</i> power from part (a) $\frac{\text{their } 280}{32}$.
		2	

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Question	Answer	Marks	Guidance
6(c)	120×4 [480]	B1	Work done by cyclist.
	$\frac{1}{2} \times 80v^2$ [40v ²] or $\frac{1}{2} \times 80 \times 7.5^2$ [2250]	B1	For at least one KE term.
	$80g \times \frac{1}{20} \times 32.2$ [1288] [80 × 10 × 1.61]	B1	Change in PE.
	Attempt at work-energy equation	M1	Attempt at work energy equation with five relevant terms (four relevant terms plus work done against resistance); dimensionally correct. Allow sign errors. Allow sin/cos mix.
	$120 \times 4 + 80g \times \frac{1}{20} \times 32.2 - 1128 = \frac{1}{2} \times 80(v^2 - 7.5^2)$ [480 + 1288 - 1128 = 40v ² - 2250]	A1	For correct equation.
	Speed = 8.5[0]ms ⁻¹ or $\frac{17}{2}$	A1	OE Use of constant acceleration scores M0 and cannot score B marks if the method leading to their answer only uses constant acceleration.
		6	

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Question	Answer	Marks	Guidance
7(a)	For CD $R = mg \cos 30$	B1	May be seen in later working without.
	Use of $F = 0.1R$ for either BC or CD $F_{BC} = 0.1mg [= m]$ OR $F_{CD} = 0.1mg \cos 30 \left[= \frac{\sqrt{3}}{2}m \right]$	M1	Note: The first two marks are often gained in the work-energy equation.
	$0.1mg \cos 30d + mgd \sin 30 \left[\left(\frac{\sqrt{3}}{2} + 5 \right)md \right]$	A1	For sum of work done by friction and the change in PE. Note: Allow terms on different sides of a work energy equation as long as they have different signs.
	$mg \times 2 \sin 30 = 0.1mg \times 2 + 0.1mg \cos 30d + mgd \sin 30 + \frac{1}{2}m \times 1^2$ $\left[10m = 2m + m \cos 30d + 5md + \frac{1}{2}m \right]$	M1	Attempt at work energy equation with five relevant terms (dimensionally correct). Allow sign errors. Allow sin/cos errors but must be consistent. Note: Initial PE = mg .
	$d = 1.28 \text{ m}$ or $\frac{15(10 - \sqrt{3})}{97} [1.27854...]$	A1	ISW if go on to find total distance = $2 + 2 + 1.28$ having already found 1.28.

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Question	Answer	Marks	Guidance
7(a)	Alternative Method for Question 7(a): Using Newton's second law and equations of motion		
	For CD $R = mg \cos 30$	(B1)	May be seen in later working without m . If not seen in working check diagram but must be a reaction force, not a downward component of the weight.
	Use of $F = 0.1R$ for either BC or CD $F_{BC} = 0.1mg [= m]$ or $F_{CD} = 0.1mg \cos 30 \left[= \frac{\sqrt{3}}{2} m \right]$	(M1)	
	For a_{CD} $-mg \sin 30 - 0.1mg \cos 30 = ma$ $\left[a = -g \sin 30 - 0.1g \cos 30 = -5.866... = -\left(5 + \frac{\sqrt{3}}{2} \right) \right]$	(A1)	For correct equation for a or ma in section CD Note: Allow if acceleration in the opposite sense and both signs positive.
	For a_{AB} $mg \sin 30 = ma \Rightarrow a = 5 \Rightarrow v_B^2 = 0 + 2 \times 5 \times 2 [= 20]$ For a_{BC} $-0.1mg = ma$ $a = -1$ so $v_C^2 = 20 - 2 \times 1 \times 2 [= 16]$ $1^2 = 16 - 2 \times (g \sin 30 + 0.1g \cos 30)d \left[1 = 16 - 2 \left(5 + \frac{\sqrt{3}}{2} \right) d \right]$	(M1)	Attempt to find d . Allow sign errors in Newton's second law. Allow sin/cos errors but must be consistent. Should include a valid attempt at v_C^2 to get M1. Must get to final line of working. Note: this mark can be earned even if A0 above. Must have 2 term acceleration though could have sign error.
	$d = 1.28 \text{ m}$ or $\frac{15(10 - \sqrt{3})}{97} [1.27854...]$	(A1)	ISW if go on to find total distance = $2 + 2 + 1.28$ having already found 1.28.

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Question	Answer	Marks	Guidance
7(a)	Alternative Method for the last 2 marks: Using an energy method for the third phase		
	For a_{AB} : $mg \sin 30 = ma \Rightarrow a = 5 \Rightarrow v_B^2 = 0 + 2 \times 5 \times 2 [= 20]$ For a_{BC} : $-0.1mg = ma \quad a = -1$ so $v_C^2 = 20 - 2 \times 1 \times 2 [= 16]$ $\frac{1}{2}m(1^2 - 4^2) = -mgd \sin 30 - 0.1mg \cos 30 \times d$	(M1)	Attempt at work energy equation for the third phase with four relevant terms (dimensionally correct). Allow sign errors. Allow sin/cos errors but must be consistent. Must get to final line.
	$d = 1.28\text{m}$ or $\frac{15(10 - \sqrt{3})}{97}$ [1.27854...] ignore units	(A1)	ISW if go on to find total distance = 2 + 2 + 1.28 having already found 1.28.
		5	

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Question	Answer	Marks	Guidance
7(b)	$mg \times 2 \sin 30 = 2\mu mg + 1 \times \mu mg \cos 30 + mg \times 1 \sin 30$ $[10m = 20m\mu + 10m \cos 30 \mu + 5m \text{ OR } 10m = 20m\mu + m5\sqrt{3}\mu + 5m]$	M1	Attempt at work energy equation with four relevant terms (dimensionally correct). Allow sign errors. Allow sin/cos errors but must be consistent.
	$\mu = 0.174 \text{ or } \frac{4 - \sqrt{3}}{13} [0.174457...]$	A1	
	$mg \times 1 \sin 30 - 1 \times \mu mg \cos 30$ $[5m - 5\sqrt{3}m\mu]$	M1	For difference between the change in PE and the work done by friction. Note: Allow terms on different sides of a work energy equation as long as both have the same sign. Allow sin/cos errors but must be consistent. Using μ , their μ or the correct value of μ to at least 2 sf. Must be as part of an attempt to find speed, not μ , although this could be the first step.
	$mg \times 1 \sin 30 - 1 \times \mu mg \cos 30 = \frac{1}{2}mv^2 [5m - 5\sqrt{3}m\mu = \frac{1}{2}mv^2]$ Speed = $2.64\text{ms}^{-1} [2.64164...]$	A1	

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Question	Answer	Marks	Guidance
7(b)	Alternative Method for Question 7(b): Newton's second law and equations of motion		
	For a_{AB} $mg \sin 30 = ma \Rightarrow a = 5 \Rightarrow v_B^2 = 0 + 2 \times 5 \times 2 [= 20]$ For a_{BC} $-\mu mg = ma$ $a = -\mu g$ so $v_C^2 = 20 - 2\mu g \times 2$ For a_{CD} $-mg \sin 30 - \mu mg \cos 30 = ma \left[a = -5.866... = -\left(5 + \frac{\sqrt{3}}{2}\right) \right]$ $0 = 20 - 2\mu g \times 2 - 2(g \sin 30 + \mu g \cos 30) \times 1$ $[20 - 40\mu - 10 - 10\sqrt{3}\mu = 0]$	(M1)	For attempt at equation for μ. Allow sign errors. Allow sin/cos errors but must be consistent. Must get to fourth line for M1.
	$\mu = 0.174$ or $\frac{4 - \sqrt{3}}{13}$ [0.174457...]	(A1)	
	$a = g \sin 30 - \mu g \cos 30 [= 5 - 5\sqrt{3}\mu]$	(M1)	For correct equation for a or ma in section CD down plane (weight component – friction). Allow sin/cos errors but must be consistent. Using μ, <i>their</i> μ or the correct value of μ to at least 2sf. Must be as part of an attempt to find speed, not μ, although this could be the first step.
	$v^2 = 0 + 2(g \sin 30 - \mu g \cos 30) \times 1 \Rightarrow \text{Speed} = 2.64 \text{ ms}^{-1}$ [2.64164...]	(A1)	

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Question	Answer	Marks	Guidance
7(b)	Alternative method for last 2 marks of Question 7(b): Using energy at the start – total work done against friction		
	$mg \times 2 \sin 30 - (\mu mg \times 2 + \mu mg \cos 30 \times 2) \left[= \frac{1}{2}mv^2 \right]$	(M1)	For PE_A – total work done against friction [= KE_C]. Allow sin/cos errors but must be consistent. Using μ , <i>their</i> μ or the correct value of μ to at least 2sf.
	$\left[10m - (20m\mu + 20m \cos 30 \mu = \frac{1}{2}mv^2 \right]$ $\left[10m - (20m\mu + 10m\sqrt{3}\mu = \frac{1}{2}mv^2 \right]$ Speed = 2.64ms ⁻¹ [2.64164...]	(A1)	
		4	