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General Certificate of Education (A-level)
January 2011

Mathematics MM1B

(Specification 6360)

Mechanics 1B

Mark Scheme

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Key to mark scheme abbreviations

M	mark is for method
m or dM	mark is dependent on one or more M marks and is for method
A	mark is dependent on M or m marks and is for accuracy
B	mark is independent of M or m marks and is for method and accuracy
E	mark is for explanation
√or ft or F	follow through from previous incorrect result
CAO	correct answer only
CSO	correct solution only
AWFW	anything which falls within
AWRT	anything which rounds to
ACF	any correct form
AG	answer given
SC	special case
OE	or equivalent
A2,1	2 or 1 (or 0) accuracy marks
–*x* EE	deduct *x* marks for each error
NMS	no method shown
PI	possibly implied
SCA	substantially correct approach
c	candidate
sf	significant figure(s)
dp	decimal place(s)

No Method Shown

Where the question specifically requires a particular method to be used, we must usually see evidence of use of this method for any marks to be awarded.

Where the answer can be reasonably obtained without showing working and it is very unlikely that the correct answer can be obtained by using an incorrect method, we must award **full marks**. However, the obvious penalty to candidates showing no working is that incorrect answers, however close, earn **no marks**.

Where a question asks the candidate to state or write down a result, no method need be shown for full marks.

Where the permitted calculator has functions which reasonably allow the solution of the question directly, the correct answer without working earns **full marks**, unless it is given to less than the degree of accuracy accepted in the mark scheme, when it gains **no marks**.

Otherwise we require evidence of a correct method for any marks to be awarded.

MM1B

Q	Solution	Marks	Total	Comments
1	$5\times 6=(m+5)\times 2.4$ $30=2.4m+12$ $m=\dfrac{30-12}{2.4}=7.5$	M1A1 A1	3	M1: Equation for conservation of momentum with correct number of terms. A1: Correct equation. A1: Correct mass CAO Consistent use of weight instead of mass penalise final A1 mark.
	Total		**3**	
2(a)	$s=\dfrac{1}{2}\times 10\times 4+10\times 4+\dfrac{1}{2}\times(4+7)\times 10+\dfrac{1}{2}\times 7\times 10$ $(=20+40+55+35)$ $=150$ m **OR** $s=\dfrac{1}{2}\times(10+20)\times 4+\dfrac{1}{2}\times(4+7)\times 10+\dfrac{1}{2}\times 7\times 10$ $(=60+55+35)$ $=150$ m **OR** $s=\dfrac{1}{2}\times 10\times 4+10\times 4+10\times 4+\dfrac{1}{2}\times 10\times 3+\dfrac{1}{2}\times 7\times 10$ $(=20+40+40+15+35)$ $=150$ m	M1M1A1 A1 (M1M1A1) (A1) (M1M1A1) (A1)	4	M1: Any one term correct. M1: A second term correct. A1: Correct expression for total distance. A1: Total distance correct.
(b)	Average Speed $=\dfrac{150}{40}=3.75$ ms^{-1}	M1 A1F	2	M1: Their total distance divided by 40. A1F: Correct average speed based on their distance from part (a). Must be correct to three or more significant figures.
(c)	$a=\dfrac{4}{10}=0.4$ ms^{-2}	M1 A1	2	M1: Any division involving the numbers 10 and 4. A1: Correct acceleration. CAO **Note on use of constant acceleration equations:** award M1 for correct equation with correct values and A1 for correct final answer.
(d)	$F=200000\times 0.4=80000$ N	M1A1F	2	M1: Multiplication of , 2×10^n , for any integer n, by candidate's acceleration from part (c). A1F: Correct force based on their answer to part (c) multiplied by 200000. Note: use of $a = 2.5$ gives 500000 N Accept 80kN
	Total		**10**	

MM1B (cont)

Q	Solution	Marks	Total	Comments
3(a)(i)	$P - 500 = 2200 \times 0.8$ $P = 1760 + 500$ $= 2260$	M1A1 A1	3	M1: Equation of motion for car and caravan as a single body. Must see 2200 (or 1200+1000) multiplied by 0.8, and 500 (or 200+300). Allow sign errors. A1: Correct equation. A1: Correct value for *P*. (Award full marks for: (*P* =) 1760 + 500 = 2260 or similar to obtain correct final answer.)
	OR (If finding the tension first)			
	$P - 1100 - 200 = 1200 \times 0.8$ $P = 960 + 1100 + 200$ $= 2260$	(M1A1) (A1)		M1: Equation of motion for car with their value for the tension. Must see 1200 multiplied by 0.8, 200 and their tension. Allow sign errors. A1: Correct equation. A1: Correct value for *P*. (Award full marks for: (*P* =) 960 + 200 + 1100 = 2260 or similar to obtain correct final answer.)
(a)(ii)	$T - 300 = 1000 \times 0.8$ $T = 300 + 800$ $= 1100$	M1A1 A1	3	M1: Equation of motion for caravan. Must see 300 and 1000 multiplied by 0.8. Allow sign errors. A1: Correct equation. A1: Correct tension. CAO
	OR			
	$2260 - 200 - T = 1200 \times 0.8$ $T = 2260 - 200 - 960$ $= 1100$ N	(M1A1) (A1)		M1: Equation of motion for car. Must see 2260 (or candidate's *P*), 200 and 1200 multiplied by 0.8. Allow sign errors. A1: Correct equation. A1: Correct tension. CAO If candidates find tension first it must be stated in part (a)(ii) to gain any marks. The working does not have to be repeated if seen in part (a)(i).

MM1B (cont)

Q	Solution	Marks	Total	Comments
3(b)(i)	$15 = 7 + 0.8t$ $t = \frac{15-7}{0.8} = 10$ seconds	M1A1 A1	 3	M1: Use of a constant acceleration equation to find t, with 7, 15 and 0.8. A1: Correct equation. A1: Correct time. CAO
(b)(ii)	$15^2 = 7^2 + 2\times 0.8s$ $s = \frac{15^2 - 7^2}{1.6} = 110$ m **OR** $s = \frac{1}{2}(7+15)\times 10 = 110$ m **OR** $s = 7\times 10 + \frac{1}{2}\times 0.8\times 10^2 = 110$ m	M1A1 A1 (M1A1F) (A1F) (M1A1F) (A1F)	 3	M1: Use of a constant acceleration equation to find s, with 7, 15 and 0.8. A1: Correct equation A1: Correct distance. CAO M1: Use of a constant acceleration equation to find s, with 7, 15 and candidate's time. A1F: Correct equation. A1F: Correct distance. M1: Use of a constant acceleration equation to find s, with 7, 0.8 and candidate's time. A1F: Correct equation. A1F: Correct distance. If candidates find distance first it must be stated in part (b)(ii) to gain any marks. The working does not have to be repeated if seen in part (b)(i).
(c)	Resistance forces <u>vary with speed</u> (or velocity) **OR** Speed (or velocity) changes (or increases) **OR** It accelerates	B1	1	B1: Correct explanation. Must not mention friction in main argument
	Total		**13**	

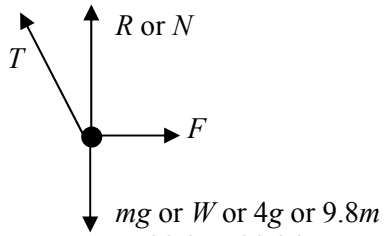
MM1B (cont)

Q	Solution	Marks	Total	Comments
4(a)	$(V=)\sqrt{2^2+4^2}=\sqrt{20}$ $=2\sqrt{5}$ $=4.47\ \text{ms}^{-1}$	M1A1	2	M1: Equation or expression to find V based on Pythagoras. Must be +. A1: Correct velocity. Accept $\sqrt{20}$, $2\sqrt{5}$, 4.47 or more accurate answer from 4.472135…
(b)	$\tan\alpha=\frac{4}{2}$ $\alpha=63.4°$ **OR** $\sin\alpha=\frac{4}{2\sqrt{5}}$ or $\frac{4}{4.47}$ $\alpha=63.4°$ **OR** $\cos\alpha=\frac{2}{2\sqrt{5}}$ or $\frac{2}{4.47}$ $\alpha=63.4°$	M1 A1F (M1) (A1F) (M1) (A1F)	2	M1: Trigonometric equation to find angle. Can be any of those as shown. For tan, fraction can be inverted. For sin, 2 can be used instead of 4. For cos, 4 can be used instead of 2. Can use their V from part (a). A1F: Correct angle. Accept 63 or AWRT 63.4 or 63.5.
(c)	$t=\frac{20}{4}=5\ \text{seconds}$ **OR** $t=\frac{\sqrt{500}}{\sqrt{20}}=5\ \text{seconds}$	M1 A1	2	M1: Division of distance by speed (for example, $\frac{10}{2}$ or $\frac{20}{4}$ or $\frac{\sqrt{500}}{\sqrt{20}}$ or $\frac{22.4}{4.47}$) Do not award M1 if distance and speed don't correspond (eg $\frac{10}{4}$ or $\frac{20}{2}$ or $\frac{20}{4.47}$) A1: Correct time CAO. Accept 5.00 or 5.0
	Total		**6**	

MM1B (cont)

Q	Solution	Marks	Total	Comments
5(a)	$\mathbf{v} = (4\mathbf{i} + 0.5\mathbf{j}) + (-0.4\mathbf{i} + 0.2\mathbf{j})t$	M1A1	2	M1: Use of constant acceleration equation to find **v** with $\mathbf{u} \neq 0\mathbf{i} + 0\mathbf{j}$ A1: Correct **v**. (Could be done as a column vector.)
(b)(i)	$\mathbf{v} = (4\mathbf{i} + 0.5\mathbf{j}) + (-0.4\mathbf{i} + 0.2\mathbf{j}) \times 22.5$ $= -5\mathbf{i} + 5\mathbf{j}$	M1 A1	2	M1: Substitution of 22.5 into their expression for the velocity, even if no marks awarded in part (a). A1: Correct velocity CAO (Could be done using column vectors.)
(b)(ii)	North-west	B1	1	B1: Correct statement of direction. Accept 315°. Must follow from correct answer to (b)(i).
(c)	$(\mathbf{v} =)(4 - 0.4t)\mathbf{i} + (0.5 + 0.2t)\mathbf{j}$ $5^2 = (4 - 0.4t)^2 + (0.5 + 0.2t)^2$ $0.2t^2 - 3t - 8.75 = 0$ $t^2 - 15t - 43.75 = 0$ $t = 17.5$ or $t = -2.5$ $t = 17.5$	B1 M1A1 A1 dM1 A1	6	B1: Grouping **i** and **j** components at some point in the solution. (Could be done as column vectors.) Allow $5 = (4 - 0.4t)\mathbf{i} + (0.5 + 0.2t)\mathbf{j}$ M1: Seeing both components of their velocity squared and added A1: Correct equation. (Condone including **i** and **j**.) For example: $5 = (4 - 0.4t)\mathbf{i}^2 + (0.5 + 0.2t)\mathbf{j}^2$ scores B1M1A0 $5^2 = (4 - 0.4t)\mathbf{i}^2 + (0.5 + 0.2t)\mathbf{j}^2$ scores B1M1A1 A1: Any correct simplified quadratic equation, with exactly three terms. dM1: Solving the quadratic equation. (Allow one substitution error in correctly quoted formula) Candidates with an incorrect quadratic equation must show method to get dM1. A1:Correct positive solution stated.
	Total		**11**	

MM1B (cont)

Q	Solution	Marks	Total	Comments
6(a)	$T = 2\times 9.8 = 19.6$ N	M1A1	2	M1: Equating tension and weight. A1: Correct tension CAO Accept $2g$ Accept 19.62 from $g = 9.81$
(b)		B1 B1	2	B1: R, F (not μR) and mg correct B1: T correct, must be in roughly correct direction. If more than four forces shown, do not award more than one mark. Note all forces must be shown as arrows and have labels. Note some candidates may draw the force diagram in the section with the question. Components can be ignored if shown in a different notation eg dashed arrows.
(c)	$T\cos 30° + R = 4\times 9.8$ $(R =) 39.2 - 19.6\cos 30°$ $= 39.2 - 16.9741...$ $= 22.2259....$ $= 22.2$ N (to 3sf) AG	M1 A1 A1	3	M1: Resolving vertically to form a three term equation. (May be implied) A1 Correct expression for R or equation for R. Must see 19.6cos30 or equivalent (eg $2g\sin 60$) A1: Correct force. Must see intermediate working, for example third or fourth line of working in solution opposite. Example: $19.6\sin 30° - R = 4\times 9.8$ scores M1A0A0. Use of $g = 9.81$ still gives 22.2 N as the final answer.
(d)	$T\cos 60° = F$ $F = 19.6\cos 60° = 9.8$ $19.6\cos 60° \le \mu(39.2 - 19.6\cos 30°)$ $\mu \ge \dfrac{19.6\cos 60°}{39.2 - 19.6\cos 30°}$ $\mu \ge 0.441$	M1 A1 dM1 A1	4	M1: Resolving horizontally A1: Correct expression for friction dM1: Use of $F = \mu R$ or $F \le \mu R$ (do not allow $F \ge \mu R$) A1: Final answer of $\mu = 0.441$ or $\mu \ge 0.441$ from correct working Use of $g = 9.81$ still gives 0.441 as the final answer.
	Total		**11**	

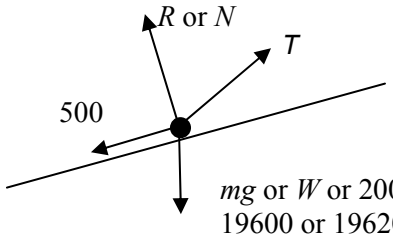
MM1B (cont)

Q	Solution	Marks	Total	Comments
7(a)	$12\sin 30°t - 4.9t^2 = -0.5$	M1A1A1		M1: Three term equation for vertical motion, with $\pm g$, ± 0.5 (or ± 1 and ± 1.5) and $12\sin 30°t$ or $12\cos 30°t$.
	$4.9t^2 - 12\sin 30°t - 0.5 = 0$			A1: Correct terms. (one must be equivalent to ± 0.5)
	$t = 1.30281...or - 0.078323...$	dM1		A1: Correct signs.
	$t = 1.30$ seconds (to 3sf) AG	A1	5	dM1: Solving the quadratic to find t. Must see use of quadratic equation formula or can be implied by seeing 1.303 or 1.302 or similar.
				A1: Correct time from correct working. Must see more than 3 significant figures in candidate's working before the final answer or two correct solutions to the quadratic (eg 1.3 and –0.08). Accept 1.3
	OR			
	time up = 0.6122			M1:Adding time up to time down having used a quadratic.
	time down = 0.6122+0.0783=0.6905			A1: 0.6122
	total time = 0.6122+0.6905 = 1.30 (to 3sf)	(M1A1 dM1A1A1)		dM1: Finding time down with a quadratic
				A1: 0.6905
				A1: Correct answer Accept 1.3
	OR			M1:Forms an equation to find t having found v first
	$-6.767 = 12\sin 30° - gt$	(M1A1A1)		A1: Correct terms
	$t = \dfrac{12\sin 30° + 6.767}{g} = 1.30281 = 1.30$ (to 3sf)	(dM1A1)		A1: Correct signs
				dM1: Solving for t
				A1: Correct time from correct working. Must see more than 3 significant figures in candidate's working before the final answer. Accept 1.3
(b)	$12\cos 30° \times 1.303 = 13.5$ m	M1A1	2	M1: Finding horizontal displacement using 1.30 (or better) and $12\cos 30°$. Do not allow $12\sin 30°$.
				A1: Correct distance. AWRT 13.5.

MM1B (cont)

Q	Solution	Marks	Total	Comments
7(c)	$v_y = 12\sin 30° - 9.8\times 1.3028 \ (= -6.767)$ $v = \sqrt{(12\cos 30°)^2 + (-6.767)^2} = 12.4 \text{ ms}^{-1}$	M1A1 dM1A1	4	M1: Finding vertical component of velocity or velocity squared at impact. Must include $12\sin 30°$ or $12\cos 30$ and $\pm g$ A1: Correct expression for vertical component. May have 1.3 or 1.30 instead of 1.3028. (Accept +6.767 or similar) dM1: Finding speed from two components. May use 6.74. A1: Correct speed. Allow 12.3 or AWRT 12.4. Note using g = 9.81 still gives 12.4.
(d)	$\tan\theta = \dfrac{6.767}{12\cos 30°}$ $\theta = 33.1°$ **OR** $\sin\theta = \dfrac{6.767}{12.4}$ $\theta = 33.1°$ **OR** $\cos\theta = \dfrac{10.4}{12.4}$ $\theta = 33.1°$	M1 A1F	2	M1: Trigonometric equation to find angle. Can only be those shown opposite or described below. For tan, fraction can be inverted. For sin, 10.4 can be used instead of 6.767. For cos, 6.767 can be used instead of 10.4. Can use their values from part (c) (eg 6.74 or 6.77). A1F: Correct angle. Accept AWRT 33°. Follow though vertical component or final speed from part (c).
(e)	The weight is the only force acting. OR No air resistance.	B1	1	B1: Appropriate assumption.
	Total		**14**	

MM1B (cont)

Q	Solution	Marks	Total	Comments
8(a)	 mg or W or $2000g$ or 19600 or 19620 or $9.8m$	B1 B1	2	B1: R, 500 and mg correct B1: Tension in roughly correct direction. If more than four forces shown, do not award more than one mark. Note all forces must be shown as arrows and have labels. Note some candidates may draw the force diagram in the section with the question. Components can be ignored if shown in a different notation eg dashed arrows.
(b)	$2000\times 0.6 = T\cos 12° - 500 - 2000\times 9.8\sin 5°$ $T = \dfrac{1200+500+19600\sin 5°}{\cos 12°}$ $\left(=\dfrac{3408.25}{\cos 12°}\right)$ $(=3484.4)$ $=3480$ (to 3sf) AG	M1A1A1 dM1 A1	5	M1: Resolving parallel to the slope to obtain a four term equation of motion. The weight and tension terms must be resolved. A1: Correct terms. A1: Correct signs. dM1: Solving for T. A1: Correct tension. AWRT 3480. Allow AWRT 3490 from use of $g = 9.81$.
	Total		**7**	
	TOTAL		**75**	