AQA Maths Mechanics 2

Mark Scheme Pack

2006-2015

Version 1.0: 0106

ASSESSMENT and QUALIFICATIONS ALLIANCE

General Certificate of Education

Mathematics 6360

MM2A Mechanics 2

Mark Scheme

2006 examination – January series

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A2,1	2 or 1 (or 0) accuracy marks	NOS	not on scheme
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PI	possibly implied	sf	significant figure(s)
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MM2A

Q	Solution	Marks	Total	Comments
1	$5T_A = 20\times 9.8\times 1.5$	M1		Moment equation.
		A1		Correct equation
	$T_A = \dfrac{20\times 9.8\times 1.5}{5} = 58.8$ N	A1		Correct tension
		M1		Vertical equation with T or moments equation.
	$T + 58.8 = 20\times 9.8$	A1		Correct equation
	$T = 137.2$ N	A1	6	Correct tension
	Total		**6**	
2(a)	$T\cos 30° = 2\times 9.8$	M1		Resolving vertically with two terms
		A1		Correct equation
	$T = \dfrac{2\times 9.8}{\cos 30°}$			
	$T = 22.6$ N AG	A1	3	Correct T from correct working
(b)	$T\cos 60° = 2\times \dfrac{v^2}{0.6}$	M1		Resolving horizontally.
		A1		Correct equation
		dM1		Solving for v
	$v = 1.84$ ms^{-1}	A1	4	Correct v
	Total		**7**	
3(a)(i)	$a = 2 + 12e^{-t}$	M1A1	2	Differentiating, with at least one term correct. Correct velocity
(ii)	$2 < a \leq 14$	B1,B1		For 2, For 14
		B1	3	Correct inequalities
(b)	$s = t^2 + 12e^{-t} + c$	M1		Integrating, with at least one term correct.
		A1		Correct expression with or without c
	$s = 0, t = 0 \Rightarrow c = -12$	dM1		Finding c
	$s = t^2 + 12e^{-t} - 12$	A1	4	Correct final expression
	Total		**9**	
4(a)	$P = (30\times 42)\times 42$ AG	M1		Finding force
	$= 52920$ W	A1	2	Correct answer from $P = Fv$
(b)(i)	$F = 1200\times 9.8\sin 5° + 30v$	M1A1		Finding force. Correct force
	$52920 = (1200\times 9.8\sin 5° + 30v)v$	dM1		Using $P = Fv$
	$v^2 + 392\sin 5°v - 1764 = 0$	A1	4	Correct equation from correct working AG
(ii)	$v = \dfrac{-392\sin 5° \pm \sqrt{(392\sin 5°)^2 - 4\times 1\times(-1764)}}{2\times 1}$	M1		Solving quadratic
	$v = 28.3$ or -62.4			
	v $= 28.3$ ms^{-1}	A1	2	Correct solution
	Total		**8**	

Q	Solution	Marks	Total	Comments
5		M1		Applying Newton's second law with $40v$ and $\frac{dv}{dt}$.
	$1600\frac{dv}{dt} = -40v$	A1		Correct equation
	$\int \frac{1}{v}dv = \int -\frac{1}{40}dt$	dM1		Separating variables
	$\ln v = -\frac{t}{40} + c$	dM1		integrating to get ln$v$ term.
	$v = Ae^{-\frac{t}{40}}$	A1		Correct integral with or without c
	$t = 0, v = 20 \Rightarrow c = 20$	dM1		Finding constant
	$v = 20e^{-\frac{t}{40}}$	A1	7	Correct final result
	Total		**7**	
6(a)	$\frac{1}{2}mv^2 = \frac{1}{2}m \times 2^2 + mg(3 - 3\cos\theta)$	M1		Three term energy equation
		A1		Correct equation
	$v^2 = 4 + 6g(1 - \cos\theta)$ AG	dM1	4	Solving for v^2.
		A1		Correct result from correct working
(b)	$mg\cos\theta = m\frac{v^2}{3}$	M1		Resolving towards the centre
		A1		Correct equation
	$3g\cos\theta = 4 + 6g - 6g\cos\theta$	dM1		Solving for $\cos\theta$
	$\cos\theta = \frac{4 + 6g}{9g}$	A1		Correct $\cos\theta$
	$\theta = 44.6°$	A1	5	Correct angle
	Total		**9**	

MM2A (cont)

Q	Solution	Marks	Total	Comments
7(a)	$\frac{100}{0.4}\ e = 10 \times 9.8$	M1		Use of Hookes law and equilibrium
	$e = 0.392$ m	A1	2	Correct length
(b)	$EPE = \frac{1}{2} \times \frac{100}{0.4} \times 0.6^2 = 45$ J AG	M1 A1	2	Use of EPE formula Correct value from correct working
(c)(i)	$45 = \frac{1}{2} \times \frac{100}{0.4}(x - 0.4)^2 + \frac{1}{2} \times 10v^2 + 10 \times 9.8(1 - x)$	M1 A1 M1		Expression for EPE with $(x \pm 0.4)^2$ Correct EPE Four term energy equation
	$45 = 125(x - 0.4)^2 + 5v^2 + 98(1 - x)$	B1 A1		Correct GPE Correct equation
	$5v^2 = 98x - 98 + 45 - 125x^2 + 100x - 20$	dM1		Solving for v^2
	$v^2 = 39.6x - 25x^2 - 14.6$ AG	A1	7	Correct result from correct working
(ii)	$39.6x - 25x^2 - 14.6 = 0$ $25x^2 - 39.6x + 14.6 = 0$			
	$x = \frac{39.6 \pm \sqrt{39.6^2 - 4 \times 25 \times 14.6}}{2 \times 25}$	M1		Solving quadratic
	$= 1$ or 0.584	A1		Correct solutions
	$x = 0.584$	A1	3	Appropriate value selected **SC** Only correct answers given, award M1A1.
	Total		**14**	
	TOTAL		**60**	

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Mathematics 6360

MM2B Mechanics 2B

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2006 examination – June series

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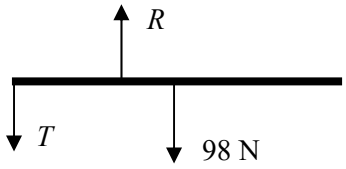
MM2B

Q	Solution	Marks	Total	Comments
1(a)	$\mathbf{v} = (6t^2 - 2t)\mathbf{i} + (1 - 12t^2)\mathbf{j}$	M1 A1 A1	3	differentiating both components one component correct second component correct
(b)(i)	$\mathbf{v}\left(\frac{1}{3}\right) = \left(\frac{6}{9} - \frac{2}{3}\right)\mathbf{i} + \left(1 - \frac{12}{9}\right)\mathbf{j} = -\frac{1}{3}\mathbf{j}$	M1 A1	2	substituting the value for t into their $\mathbf{v}$ correct velocity
(ii)	Travelling due south	A1ft	1	correct description (Follow through from $\mathbf{v} = \pm k\mathbf{j}$)
(c)	$\mathbf{a} = (12t - 2)\mathbf{i} - 24t\mathbf{j}$ $\mathbf{a}(4) = 46\mathbf{i} - 96\mathbf{j}$	M1 A1 A1	3	differentiating their velocity correct acceleration at time t correct acceleration at $t = 4$
(d)	$\mathbf{F} = 6(46\mathbf{i} - 96\mathbf{j}) = 276\mathbf{i} - 576\mathbf{j}$ $F = \sqrt{276^2 + 576^2} = 639$ N or $a = \sqrt{46^2 + 96^2} = 106.45$ $F = 6 \times 106.45 = 639$ N	M1 M1 A1	3	apply Newton's second law correctly finding magnitude correct magnitude
	Total		**12**	
2(a)	$\text{KE} = \frac{1}{2} \times 0.6 \times 14^2 = 58.8$ J	M1 A1	2	use of KE formula correct energy
(b)	$0.6 \times 9.8h = 58.8$ $h = \frac{58.8}{0.6 \times 9.8} = 10$ m	M1 A1 A1	3	two term energy equation involving PE and previous energy correct equation correct height Note: Constant acceleration methods not accepted.
(c)(i)	WD against resistance $= 58.8 - 0.6 \times 9.8 \times 8$ $= 11.76 = 11.8$ J (to 3 sf)	M1 A1 A1	3	three term energy equation correct equation correct value
(ii)	$8F = 11.76$ $F = 1.47$ N	M1 A1ft	2	using work done = Fd with $d = 8$ correct force accept 1.48
(d)	The magnitude of the force would <u>vary</u> with the speed of the ball.	B1	1	appropriate explanation
	Total		**11**	

MM2B (cont)

Q	Solution	Marks	Total	Comments
3(a)		B1	1	correct force diagram, with labels and arrows.
(b)	$2T = 0.5 \times 98$ $T = 24.5$ N AG	M1 A1 A1	3	moment equation correct equation correct positive value for the tension from correct working
(c)(i)	$2 \times 2 \times 24.5 = 3 \times 9.8 \times m + 0.5 \times 98$ $m = \frac{98-49}{3 \times 9.8} = \frac{5}{3} = 1.67$ kg (to 3 sf) **Or** $2 \times 2.45 = 3 \times 9.8m$ $m = \frac{49}{29.4} = \frac{5}{3} = 1.67$ kg	B1 M1 A1 A1 (M1A1) (M1A1)	4	tension doubled moment equation correct equation correct mass for equation for finding m
(ii)	$R = 24.5 \times 2 + 98 + \frac{5}{3} \times 9.8 = 163$ N	M1 A1 A1	3	considering vertical equilibrium with 3 terms correct equation correct reaction must be consistent with 3(c)(i) if awarding accuracy marks
(d)	This allows the centre of mass to be placed at the <u>centre of the rod</u> for the moment calculations.	B1	1	correct explanation
	Total		**12**	

MM2B (cont)

Q	Solution	Marks	Total	Comments
4(a)	$\frac{1}{2}mU^2 = \frac{1}{2}mv^2 + mgl(1-\cos 60°)$	M1		three/four term energy equation with a trig term
	$U^2 = v^2 + gl$	A1		correct equation
	$v = \sqrt{U^2 - gl}$	dM1		solving for v or v^2
		A1	4	correct v in a simplified form
(b)	$T - mg\cos 60° = m\frac{v^2}{l}$	M1		resolving towards the centre of the circle with three terms
	$T = m\left(\frac{U^2 - gl}{l} + \frac{g}{2}\right) = m\left(\frac{U^2}{l} - \frac{g}{2}\right)$	dM1		substituting for v^2
		A1		correct equation
		dM1		making T the subject
		A1	5	correct expression for T . Simplification not necessary.
(c)	$T - mg = m\frac{U^2}{l}$	M1		considering the vertical forces and using Newton's second law with $\frac{U^2}{l}$
	$T = m\left(\frac{U^2}{l} + g\right)$	A1	2	correct T
	Total		**11**	
5(a)	$F = 800 + \frac{1200}{20}t = 800 + 60t$	M1		finding the gradient of the line
	$1200a = 800 + 60t$	A1		correct gradient
		B1		correct intercept
	$a = \frac{800}{1200} + \frac{60}{1200}t = \frac{2}{3} + \frac{t}{20}$	dM1		using Newton's second law on two terms
	AG	A1	5	correct result from correct working
(b)	$v = \int \frac{2}{3} + \frac{t}{20}\mathrm{d}t = \frac{2t}{3} + \frac{t^2}{40} + c$	M1		integrating
	$v = 0, t = 0 \Rightarrow c = 0$	A1		correct integral with or without c
	$v = \frac{2t}{3} + \frac{t^2}{40}$	A1	3	showing $c = 0$
(c)	$s = \int_0^{20} \frac{2t}{3} + \frac{t^2}{40}\mathrm{d}t$	M1		integrating
		A1		correct integral, with or without c.
	$= \left[\frac{t^2}{3} + \frac{t^3}{120}\right]_0^{20}$	dM1		use of both limits or finding c
	$= 200$ m	A1	4	correct distance
(d)	The $\frac{2t}{3}$ term would change, because only the constant term in the force would change. When integrated this becomes the t term in the velocity.	B1		correct term
		B1	2	correct explanation
	Total		**14**	

MM2B (cont)

Q	Solution	Marks	Total	Comments
6(a)	$a = \frac{14^2}{50} = 3.92$	M1		finding acceleration
		A1		correct acceleration
	$F = 1200 \times 3.92$ AG	dM1		use of $F = ma$
	$= 4704$ N	A1	4	correct force from correct working
(b)	$R = 1200 \times 9.8 = 11760$	B1		normal reaction
	$4704 \leq \mu \times 11760$	M1		applying $F \leq \mu R$ or $F = \mu R$
	$\mu \geq \frac{4704}{11760}$ AG			
	$\mu \geq 0.4$	A1	3	correct result from correct working
	Total		**7**	
7(a)	$20\frac{\mathrm{d}v}{\mathrm{d}t} = -10\sqrt{v}$	M1		applying Newton's second law with $\frac{\mathrm{d}v}{\mathrm{d}t}$
	$\frac{\mathrm{d}v}{\mathrm{d}t} = -\frac{\sqrt{v}}{2}$	A1		correct differential equation
		dM1		separating variables
	$\int \frac{1}{\sqrt{v}}\mathrm{d}v = \int -\frac{1}{2}\mathrm{d}t$ AG			
	$2\sqrt{v} = -\frac{t}{2} + c$	dM1		integrating
	$t = 0, v = 25 \Rightarrow c = 10$	A1		correct integrals with or without c
		dM1		finding the constant of integration
	$v = \left(\frac{20 - t}{4}\right)^2$	A1	7	correct final result from correct working
(b)	$t = 20$	B1	1	correct time
	Total		**8**	
	TOTAL		**75**	

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Dr Michael Cresswell Director General

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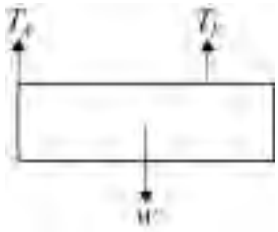
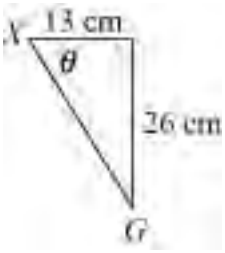
1(a)	$\frac{1}{2}\times 35\times v^2 = 35\times 9.8\times 10$	M1 A1		Energy method
	$v = 14$ (ms^{-1})	A1	3	
(b)	Air resistance or friction	B1	1	
(c)	Energy lost =			
	$35\times 9.8\times 10 - \frac{1}{2}\times 35\times 12^2 \quad (=910)$	M1 A1		Difference attempted ±
	Work done: $F\times 20 \quad (=910)$	m1		
	$20F = 910 \quad F = 45.5$(N)	A1	4	$F > 0$
	Total		**8**	
2(a)		B1	1	Arrows + labels, w in centre
(b)	M(A) $0.4W = 0.6T_B$	M1		Moments equation
	$T_B = \frac{2W}{3}$	A1		Accept 2 dp for each A1
	Res$\uparrow$ or M (B) $T_A = \frac{W}{3}$	M1 A1	4	
(c)	Lamina is uniform $\Rightarrow$ weight acts at centre	B1	1	
	Total		**6**	
3(a)	$mg\ 2a = \frac{1}{2}\ mv^2$	M1 A1		Energy equation
	$v = 2\sqrt{ga}$	A1	3	
(b)	$T - mg = \frac{mv^2}{2a}$	M1 A1		All terms for M1, no component
	$T = 3mg$	A1F	3	ft if $T > 0$
	Total		**6**	

MM2B (cont)

Q	Solution	Marks	Total	Comments
4(a)	$(10\times 40)\rho\times 5+(10\times 60)\rho\times 40$	M1		
	$=(10\times 40+10\times 60)\rho\,\bar{y}$	M1 A1		
	$\bar{y}=26$ cm	A1	4	
(b)	Symmetry of shape	B1	1	
(c)		M1		Attempting subtraction leading to 13 cm
	$\tan\theta=\frac{26}{"13"}$	M1 A1		Or inverted, must see 26 Or inverted
	$\theta=63^\circ$ (63.4)	A1	4	Accept 117°
	Total		**9**	
5(a)(i)	$t=0,\ \mathbf{r}=2\mathbf{i}+10\mathbf{k}$	B1	1	
(ii)	$t=2\pi,\ \mathbf{r}=2\mathbf{i}+7.49\mathbf{k}$	B1	1	Or $\mathbf{r}=2\mathrm{i}+(10-0.8\pi)\mathbf{k}$ accept $7.5\mathbf{k}$
(iii)	$t=2\pi,\qquad t=4\pi$	B1 B1	2	
(b)	$\mathbf{v}=-2\sin t\,\mathbf{i}+2\cos t\,\mathbf{j}-0.4\mathbf{k}$	M1 A1 A1	3	Differentiation Trig **k**
(c)	$\mathbf{a}=-2\cos t\,\mathbf{i}-2\sin t\,\mathbf{j}$	M1A1		
	$\mathbf{F}=-50\cos t\,\mathbf{i}-50\sin t\,\mathbf{j}$	M1		
	$\lvert\mathbf{F}\rvert=\sqrt{50^2\cos^2 t+50^2\sin^2 t}$	M1		No unit vectors
	$\lvert\mathbf{F}\rvert=50$(N)	A1	5	
	Total		**12**	

MM2B (cont)

Q	Solution	Marks	Total	Comments
6(a)	$\frac{40\times 2\pi}{60} = \frac{4\pi}{3}$ (rad/sec)	M1 A1	2	
(b)	$a=\omega^2 r = \left(\frac{4\pi}{3}\right)^2 \times 0.2$ $= \frac{16\pi^2}{45}$	M1 A1	2	Accept $0.356\,\pi^2\,(3\text{sf})$
(c)(i)		B1	1	
(ii)	**Vertically** No acceleration, forces balance $mg = T\cos\theta$	B1	1	
(iii)	**Horizontally** $T\sin\theta = m\times\frac{16\pi^2}{45}$	M1 A1F		ft acceleration
	$T\cos\theta = mg$	m1		SC $\tan\theta = \frac{\omega^2 r}{g}$ 1st 3 marks for quoting and using correctly
	$\tan\theta = \frac{16\pi^2}{45g}$ or $\tan\theta = 0.358(08)$	A1F		ft provided M1
	$\theta = 20^\circ$	A1F	5	earned in (b)
	Total		**11**	

MM2B (cont)

Q	Solution	Marks	Total	Comments
7(a)	Max speed ≡ zero acceleration used	M1		Implied
	$\frac{72000}{60}$	M1		
	$\frac{72000}{60} = k \times 60$			
	$k = 20$	A1	3	
(b)(i)	$20v = -500\frac{dv}{dt}$	M1		see $\frac{dv}{dt}$, ±
	$\frac{dv}{dt} = -\frac{v}{25}$	A1	2	
(ii)	$25\int\frac{dv}{v} = -\int dt$	M1 A1		M1 separating variables
				Alternative
	$[25\ln v]_{20}^{10} = -[t]_0^t$	A1		$25\ln v = -t\ (+c)$ A1
	$25\ln 10 - 25\ln 20 = -t$	m1 A1		$t = 0, v = 20, c = 25\ln 20$ m1 $t = t, v = 10,$ $25\ln 10 = -t + 25\ln 20$ A1
	$t = 25\ln 2$ or 17.3 or $-25\ln\frac{1}{2}$	A1	6	$t = 25\ln 2$ or 17.3 A1
	Total		**11**	
8(a)	$2g = \frac{49 \times x}{0.5}$	M1 A1		
	$\underline{x = 0.2}$	A1	3	
(b)	EPE $= \frac{49 \times (0.2)^2}{2 \times 0.5}$	M1		
	= 1.96 (J)	A1	2	
(c)(i)	$1.96 = \frac{49 \times x^2}{2 \times 0.5} + 0.8 \times 9.8 \times (0.2 + x)$	M1 A3		All terms attempted for M1 -1 EE from A3
	$x^2 + 0.16x - 0.008 = 0$	A1	5	
(ii)	$x = \frac{0.16 \pm \sqrt{0.16^2 + 4 \times 0.008}}{2}$	M1		
	$x = 0.04$	A1	2	$x = 0.04$ only identified
	Total		**12**	
	TOTAL		**75**	

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ASSESSMENT and QUALIFICATIONS ALLIANCE

General Certificate of Education

Mathematics 6360

MM2B Mechanics 2B

Mark Scheme

2007 examination - June series

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Dr Michael Cresswell Director General

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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	MC	mis-copy
CAO	correct answer only	MR	mis-read
CSO	correct solution only	RA	required accuracy
AWFW	anything which falls within	FW	further work
AWRT	anything which rounds to	ISW	ignore subsequent work
ACF	any correct form	FIW	from incorrect work
AG	answer given	BOD	given benefit of doubt
SC	special case	WR	work replaced by candidate
OE	or equivalent	FB	formulae book
A2,1	2 or 1 (or 0) accuracy marks	NOS	not on scheme
–*x* EE	deduct *x* marks for each error	G	graph
NMS	no method shown	c	candidate
PI	possibly implied	sf	significant figure(s)
SCA	substantially correct approach	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. However, there are situations in some units where part marks would be appropriate, particularly when similar techniques are involved. Your Principal Examiner will alert you to these and details will be provided on the mark scheme.

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.

MM2B

Q	Solution	Marks	Total	Comments
1(a)	Kinetic energy = $\frac{1}{2} \times 5 \times 10^2$	M1		Full method
	= 250 J	A1	2	
(b)	Using conservation of energy: KE when box hits ground = Initial KE + Change in potential energy	M1		Could have sign errors
	$= 250 + 5 \times 30 \times g$	A1ft		
	= 1720 J	A1	3	AG; SC2 $5 \times 35.1 \times g = 1720$. ...
(c)	$\frac{1}{2}mV^2 = 1720$	M1		
	$V^2 = 688$	A1		
	∴ Speed is 26.2 m s^{-1}	A1	3	CAO; accept $\sqrt{688}$ or $4\sqrt{43}$; SC2 26.3
(d)	No air resistance	E1		Or no resistance forces
	Box is a particle	E1	2	Deduct 1 mark for unacceptable third reason
	Total		**10**	
2(a)	Symmetry of the lamina about *PQ*	E1	1	Accept 'mirror line'
(b)	Taking moments about *AB*:			
	$600\rho \times 15 + 100\rho \times 35$	M1A1		Condone lack of ρ
	$= 700\rho\bar{x}$	A1		
	$\bar{x} = 17.857 = 17.9$ cm	A1	4	SC3 17.8
(c)	$\tan\theta = \frac{10}{17.857}$	M1A1		M1 for use of $\tan\theta$
	$= 0.56$			
	Angle is 29.2488…	M1		
	$= 29°$	A1	4	
	Total		**9**	

MM2B (cont)

Q	Solution	Marks	Total	Comments
3(a)	Using $F = ma$:			
	$2400\mathbf{i} - 4800t\mathbf{j} = 800\mathbf{a}$	M1		
	$\mathbf{a} = 3\mathbf{i} - 6t\mathbf{j}$	A1	2	
(b)	$\mathbf{v} = \int \mathbf{a}\, dt$	M1		
	$= 3t\mathbf{i} - 3t^2\mathbf{j} + \mathbf{c}$	A1		Condone no '+ **c**'
	When $t = 0$, $\mathbf{v} = 6\mathbf{i} + 30\mathbf{j}$			
	$\therefore\ \mathbf{c} = 6\mathbf{i} + 30\mathbf{j}$	M1		Needs '+ **c**' above
	$\therefore\ \mathbf{v} = (3t + 6)\mathbf{i} + (30 - 3t^2)\mathbf{j}$	A1	4	AG
(c)	$\mathbf{r} = \int \mathbf{v}\, dt$	M1		
	$= (\frac{3}{2}t^2 + 6t)\mathbf{i} + (30t - t^3)\mathbf{j} + \mathbf{d}$	A1,A1		A1 **i** term, A1 **j** term; condone no '+ **d**'
	When $t = 0$, $\mathbf{r} = 2\mathbf{i} + 5\mathbf{j}$			
	$\therefore\ \mathbf{d} = 2\mathbf{i} + 5\mathbf{j}$	M1		
	$\therefore\ \mathbf{r} = (\frac{3}{2}t^2 + 6t + 2)\mathbf{i} + (30t - t^3 + 5)\mathbf{j}$	A1	5	
	Total		**11**	
4(a)	Centre of mass of rod is 3 m from river bank	B1		Use of centre of mass is centre of rod
	Taking moments about A, edge of bank:			Or resolve $R = 65g$ B1
	$3 \times 15 = 50x$	M1		Moments about any point (correct) M1
	$x = 0.9$	A1	3	0.9 A1
(b)	Taking moments about A:			
	$50 \times 2 = 15 \times 3 + m \times 8$	M1A1		M1 3 terms, 2 correct
	$55 = 8m$	A1		
	$m = 6\frac{7}{8}$			
	Mass is $6\frac{7}{8}$ kg	A1	4	Accept 6.88 and 6.87
(c)	Centre of mass of rod is 3 m from river bank	E1	1	Centre of mass is at centre of rod
(d)	eg Woman is a particle The mass is a particle The plank is a rigid rod	E1	1	
	Total		**9**	

MM2B (cont)

Q	Solution	Marks	Total	Comments
5(a)	Using conservation of energy (lowest and highest points):	M1		
	$\frac{1}{2}m(7v)^2 = \frac{1}{2}mv^2 + 2mga$	A1A1		A1 for $7v$ and v
	$\frac{48}{2}v^2 = 2ga$	M1		Needs 48 or 24
	$\therefore v = \sqrt{\frac{ag}{12}}$	A1	5	AG
(b)	Velocity at A is $\sqrt{\frac{ag}{12}}$			
	Resolving vertically at A:	M1		3 terms
	$m\frac{v^2}{a} + R = mg$	A1,A1		A1 correct 3 terms, A1 correct signs
	$R = mg - \frac{m}{a}\times\frac{ag}{12}$			$\left(1-\frac{1}{12}\right)mg$ M1A2
	$= \frac{11}{12}mg$	A1	4	Condone $-\frac{11}{12}mg$
	Total		**9**	
6(a)	EPE is $\frac{\lambda x^2}{2l}$			
	$= \frac{200(0.5)^2}{2\times 2}$	M1		
	= 12.5 J	A1	2	
(b)	When string becomes slack,			
	using $\frac{1}{2}mv^2$ = loss in EPE:	M1		NB Using $\sqrt{5}$ to answer (a) and thus (b) $\Rightarrow$ no marks
	$\frac{1}{2}\times 5 \times v^2 = 12.5$	A1		
	Speed is $\sqrt{5}$ m s^{-1}	A1	3	AG
(c)	Resolving vertically, $R = 5g$	B1		
	$F = \mu R$	M1		
	$0.4 \times 5g = 2g$	M1		
	Using change in energy = work done:			
	$2g \times 0.5 =$	M1		M1 for force × distance
	$\frac{1}{2}\times 5\times\left(\sqrt{5}^2\right) - \frac{1}{2}\times 5\times v^2$	A1,A1		A1 first term (or 12.5) A1 second term (inc $-$)
	$9.8 = 12.5 - \frac{5}{2}v^2$			
	$v^2 = 1.08$			
	Speed is 1.04 m s^{-1}	A1	7	
	Total		**12**	

MM2B (cont)

Q	Solution	Marks	Total	Comments
7(a)	Using $F = ma$:			
	$-\lambda mv = ma = m\dfrac{\mathrm{d}v}{\mathrm{d}t}$	M1		Condone no ' – '
	$\therefore \dfrac{\mathrm{d}v}{\mathrm{d}t} = -\lambda v$	A1	2	AG Note: no use of $m \Rightarrow$ no marks in (a)
(b)	$\int \dfrac{\mathrm{d}v}{v} = -\lambda \int \mathrm{d}t$	M1		
	$\ln v = -\lambda t + c$ $v = C\mathrm{e}^{-\lambda t}$	A1		Needs '+ c'
	When $t = 0$, $v = U \Rightarrow C = U$	M1		Needs correct working
	$v = U\,\mathrm{e}^{-\lambda t}$	A1	4	AG
	Total		**6**	
8(a)	Q is in equilibrium	E1		Q at rest, or not moving
	$T = 5g = 49$ N	B1	2	AG
(b)	Resolving vertically for P:			
	$T\cos\theta = 3g$	M1A1		
	$\cos\theta = \dfrac{3}{5}$			
	$\theta = \cos^{-1}\dfrac{3}{5} = 53.1°$	A1	3	Do not condone 53°
(c)	$\therefore \sin\theta = \dfrac{4}{5}$	B1		
	Resolving horizontally for P:			
	$\dfrac{mv^2}{r} = T\sin\theta$	M1A1		M1 2 terms: 1 term correct, other term includes sin or cos
	$\dfrac{3v^2}{r} = \dfrac{4}{5} \times 5g$			
	$\dfrac{3\times 4^2}{r} = 4g$			
	$r = \dfrac{48}{4g}$			
	$= 1.22$	A1	4	SC3 1·23
	Total		**9**	
	TOTAL		**75**	

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General Certificate of Education

Mathematics 6360

MM2B Mechanics 2B

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2008 examination - January series

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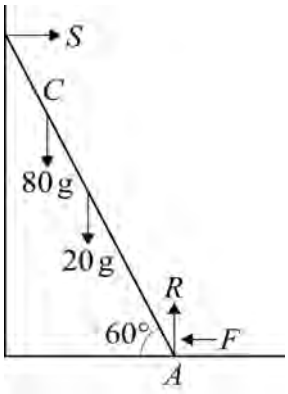
MM2B

Q	Solution	Marks	Total	Comments
1(a)	Kinetic energy = $\frac{1}{2} \times 0.6 \times 15^2$	M1		
	= 67.5 J	A1	2	
(b)	Using $mgh = \frac{1}{2}mv^2$:	M1		
	$67.5 = 0.6 \times g \times h$	A1		
	$\Rightarrow h = \frac{67.5}{0.6g}$			
	= 11.5 m	A1	3	
(c)	When 3 m above ground level: Change in PE is $0.6 \times g \times 3$ = 17.64 J			
	∴ KE of ball is 67.5 – 17.64	M1		
	= 49.86 J	A1		
	Speed of ball is $\sqrt{\frac{49.86}{\frac{1}{2} \times 0.6}}$	m1		Dep on M1
	= 12.9 m s^{-1}	A1	4	No KE given: speed = 12.9 SC3
(d)	eg ball is a particle, no air resistance, weight is the only force acting etc	E1	1	Accept no spin, no wind
	Total		**10**	
2(a)(i)	$a = \frac{dv}{dt} = 6t - 6\cos 3t$	M1A1	2	M1 for at least one term correct
(ii)	When $t = \frac{\pi}{3}$, $a = 6 \times \frac{\pi}{3} - 6\cos(3.\frac{\pi}{3})$	M1		
	$= 2\pi + 6$	A1	2	AG
(b)	$r = t^3 + \frac{2}{3}\cos 3t + 6t + c$	M1A1		M1 for 3 terms including $\cos 3t$ term Condone no '+ *c*'
	When $t = 0$, $r = 0$ ∴ $c = -\frac{2}{3}$	M1		
	∴ $r = t^3 + \frac{2}{3}\cos 3t + 6t - \frac{2}{3}$	A1	4	
	Total		**8**	

MM2B (cont)

Q	Solution	Marks	Total	Comments
3(a)		B2	2	B1 for any 4 correct
(b)	Resolve vertically: $R = 20g + 80g$			Must see $20g + 80g$ or $100g$ to obtain any marks in (b)
	$= 100g$	B1		
	Using $F = \mu R$:	m1		Dep on B1
	$F = 0.4 \times 100g$ $= 40g$ or 392 N	A1	3	AG
(c)	Resolve horizontally: $S = 40g$	B1		
	Moments about A: $80gx\cos 60 + 20g.2\cos 60 = S.4\cos 30$	M1A1 A1		M1 for 3 terms, all moments
	$40gx + 20g = 138.56g$ $x = \frac{118.56}{40}$	m1		Dep on M1
	$= 2.96$ m	A1	6	Accept $2\sqrt{3} - \frac{1}{2}$
	Total		**11**	
4(a)	$\mathbf{v} = \frac{\mathrm{d}r}{\mathrm{d}t}$ $\mathbf{v} = (3t^2 - 6t)\mathbf{i} + (4 + 2t)\mathbf{j}$	M1A1	2	
(b)(i)	$\mathbf{a} = (6t - 6)\mathbf{i} + 2\mathbf{j}$	M1 A1ft		
	Using $\mathbf{F} = m\mathbf{a}$: $\mathbf{F} = (18t - 18)\mathbf{i} + 6\mathbf{j}$	A1ft	3	
(ii)	When $t = 3$, $\mathbf{F} = 36\mathbf{i} + 6\mathbf{j}$			
	Magnitude is $\sqrt{36^2 + 6^2}$	M1		
	$= 36.5$	A1ft	2	Accept $6\sqrt{37}$; ft from (b)(i)
(c)	When **F** acts due north: Component of **F** in the **i** direction is 0	M1		
	$18t - 18 = 0$ $t = 1$	A1ft	2	ft from (b)(i)
	Total		**9**	

MM2B (cont)

Q	Solution	Marks	Total	Comments
5(a)	Acceleration is $\frac{v^2}{r}$			
	$= \frac{2^2}{0.2}$	M1		
	$= 20\ \text{m s}^{-2}$	A1	2	
(b)	$\theta = 30°$	B1		
	Resolve vertically:			
	$T_1 \cos\theta = mg$	M1		
	$T_1 \cos\theta = 4g$	A1		
	$T_1 = 45.3$ N	A1	4	AG
(c)	Resolve horizontally:			
	$T_1 \sin\theta + T_2 = \frac{mv^2}{r}$	M1A1		M1 for 3 terms, 2 correct
	$45.3\sin\theta + T_2 = 4 \times 20$			
	$T_2 = 57.4$ N	A1	3	Condone 57.3 N
	Total		**9**	
6(a)	EPE $= \frac{\lambda x^2}{2l}$			
	$= \frac{300 \times (1.5)^2}{2 \times 4}$	M1		
	$= 84.375$			
	$= 84.4$ J	A1	2	
(b)	When string is slack, gain in PE is mgh			
	$= 6 \times g \times 1.5\sin 30$	M1		
	$= 44.1$ J	A1		
	KE = EPE – gain in PE	m1		
	$= 84.375 - 44.1$			
	$= 40.275$	A1		
	$\frac{1}{2}.6.v^2 = 40.275$			
	$v = 3.66$	A1	5	AG
(c)	At A, PE gained above initial position is			
	$6 \times g \times 5.5 \sin 30$			Or PE above position string slack is 117.6
	$= 161.7$J	B1		KE at A is –77.3
	This is more than initial elastic potential energy	B1		
	$\therefore$ particle will not reach A	E1	3	**Or**
				Using $v^2 = u^2 + 2as$
				$a = 0.5g$ B1
				$s = 1.37$ or 1.366 B1 [or 2.87 above starting point]
				Hence stops before A E1
				Vertical height above sling slack is 0.683
				Vertical height above starting point is 1.435
	Total		**10**	

MM2B (cont)

Q	Solution	Marks	Total	Comments
7(a)	Conservation of energy:			
	$\frac{1}{2}m\left(3\sqrt{ag}\right)^2 + mg2a = \frac{1}{2}mv^2$	M1A1		M1 for 3 terms: 2 KE and PE
	$\frac{9}{2}mga + 2mga = \frac{1}{2}mv^2$	A1		
	$v = \sqrt{13ag}$	A1	4	
(b)	At A, consider vertical forces:			
	$T - mg = \frac{mv^2}{a}$	M1A1		M1 for 3 terms, 2 correct
	$T = mg + 13mg$	m1		
	$T = 14mg$	A1ft	4	ft from (a)
	Total		**8**	
8(a)	Power of engine is 8kW			
	$\therefore$ Force exerted by engine $= \frac{8000}{v}$	M1A1		M1 for Power = Fv
	Using $F = ma$:	m1		
	$\frac{8000}{v} - kv^2 = 600\frac{\mathrm{d}v}{\mathrm{d}t}$			
	$600\frac{\mathrm{d}v}{\mathrm{d}t} - \frac{8000}{v} + kv^2 = 0$	A1	4	AG
(b)(i)	When engine is turned off, power is zero:			
	$-kv^2 = 600\frac{\mathrm{d}v}{\mathrm{d}t}$	B1	1	AG
(ii)	$\int 600\frac{\mathrm{d}v}{v^2} = -\int k\,\mathrm{d}t$	M1		
	$-\frac{600}{v} = -kt + c$	A1		Need '+ c'
	When $t = 0$, $v = 20$:			
	$\therefore c = -\frac{600}{20} = -30$	A1		
	$\therefore \frac{600}{v} = kt + 30$			
	When $v = 10$, $kt = 30$:	M1		
	$\therefore t = \frac{30}{k}$	A1	5	$-\frac{30}{k}$ SC3
	Total		**10**	
	TOTAL		**75**	

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General Certificate of Education

Mathematics 6360

MM2B Mechanics 2B

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√or ft or F	follow through from previous incorrect result	MC	mis-copy
CAO	correct answer only	MR	mis-read
CSO	correct solution only	RA	required accuracy
AWFW	anything which falls within	FW	further work
AWRT	anything which rounds to	ISW	ignore subsequent work
ACF	any correct form	FIW	from incorrect work
AG	answer given	BOD	given benefit of doubt
SC	special case	WR	work replaced by candidate
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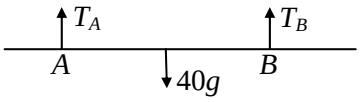
Otherwise we require evidence of a correct method for any marks to be awarded.

MM2B

Q	Solution	Marks	Total	Comments
1(a)	$a = \frac{dv}{dt} = 12t + 4$	M1 A1	2	
(b)	Using $F = ma$, Force $= 3 \times (12t + 4)$ When $t = 4$, force $= 3\,(12 \times 4 + 4)$ Force $= 156$ N	M1 A1	2	
(c)	$r = 2t^3 + 2t^2 - 7t + c$ When $t = 0$, $r = 5$, $\therefore c = 5$ $\therefore r = 2t^3 + 2t^2 - 7t + 5$	M1 A1 M1 A1	4	SC3 if no '+c' seen
	Total		**8**	
2(a)		B1	1	
(b)	Taking moments about A $2.1 \times 40g = T_B \times 4$ $T_B = 21$g	M1 B1 A1	3	B1 for 2.1
(c)	Resolve vertically $T_A + T_B = 40g$ $T_A = 19g$ or 186 N	M1 A1	2	
(d)	Gravitational force acts through mid point of the rod	E1	1	
	Total		**7**	
3	$\bar{X} = \frac{25\times1+12\times4+4\times5}{1+4+5}$ $= \frac{93}{10}$ or 9.3 $\bar{Y} = \frac{10\times1+7\times4+18\times5}{10}$ $= \frac{128}{10}$ or 12.8 $\therefore$ Centre of mass is at (9.3, 12.8)	M1 A1 M1 A1	4	Two terms on top correct (+third) and denominator correct SC3 for interchanged $\bar{X}$ and $\bar{Y}$
	Total		**4**	

MM2B (cont)

Q	Solution	Marks	Total	Comments
4(a)	Using power = force × velocity			
	Power = (40 × 50) × 50	M1		
	∴ = 100,000 watts	A1	2	
(b)	When speed is 25,			
	max force exerted is $\frac{100000}{25}$			
	= 4000N	B1		
	∴Accelerating force is 3000N			
	Using $F = ma$			
	$3000 = 1500\ a$	M1		Need 3 terms eg '4000' ± 1000 = *ma* or 2000 ± 1000 = *ma* M0 for 1000 = *ma*
	$a = 2\ \text{ms}^{-2}$	A1	3	
(c)	When van is at maximum speed			
	force against gravity is $mg\sin 6$ (parallel to slope)	B1		
	Force against gravity and resistance is			
	$mg\sin 6 + 40\ v$	M1		
	$= 1536.6 + 40\ v$	A1		
	Speed is maximum			
	when $1536.6 + 40v = \frac{100000}{v}$	M1		For 3 terms; $\frac{100000}{v}$ and 1 other term correct
	$40\ v^2 + 1536.6\ v - 100\ 000 = 0$	A1		CAO
	Speed is $34.4\ \text{ms}^{-1}$	A1	6	
	Total		**11**	
5(a)	$\mathbf{v} = \frac{\mathrm{d}\mathbf{r}}{\mathrm{d}t}$			
	$\mathbf{v} = -2\sin\frac{1}{4}t\,\mathbf{i} - 2\cos\frac{1}{4}t\,\mathbf{j}$	M1 A1	2	No **i**, **j**: no marks
(b)	Speed is $\{(-2\sin\frac{1}{4}t)^2 + (-2\cos\frac{1}{4}t)^2\}^{\frac{1}{2}}$	M1		
	$= 2\left(\sin^2\frac{1}{4}t + \cos^2\frac{1}{4}t\right)^{\frac{1}{2}}$	m1		clear use of $\sin^2\theta + \cos^2\theta = 1$
	= 2 which is a constant	A1	3	Use of 2 values SC1
(c)	Magnitude of **r** is			
	$\{(8\cos\frac{1}{4}t)^2 + (8\sin\frac{1}{4}t)^2\}^{\frac{1}{2}}$	M1		$\mathbf{a} = -k\mathbf{r} \Rightarrow$ circle SC2
	= 8 which is a constant	A1	2	
	∴ Particle is moving in a circle			
(d)	Using $v = a\omega$	M1		M1 for their $\frac{b}{c}$ if both found
	Angular speed is 0.25	A1	2	
(e)	$\boldsymbol{a} = -\frac{1}{2}\cos\frac{1}{4}t\,\mathbf{i} + \frac{1}{2}\sin\frac{1}{4}t\,\mathbf{j}$	M1 A1	2	
(f)	Magnitude of acceleration is $\frac{1}{2}$	B1	1	
	Total		**12**	

MM2B (cont)

Q	Solution	Marks	Total	Comments
6(a)	Using $F = ma$			
	$-0.05mv = m\frac{dv}{dt}$			
	$\therefore \frac{dv}{dt} = -0.05v$	B1	1	Need to see m terms
(b)	$\int \frac{dv}{v} = -\int 0.05\, dt$	B1		
	$\ln v = -0.05t + c$	M1		Need first 2 terms
	$v = Ce^{-0.05t}$			
	When $t = 0$, $v = 20$,			
	$\therefore C = 20$	M1		} fully correct solutions
	$v = 20e^{-0.05t}$	A1	4	
(c)	When $v = 10$, $10 = 20e^{-0.05t}$	M1		
	$e^{0.05t} = 2$	A1		
	$\therefore t = \frac{1}{0.05}\ln 2$			
	$= 13.9$	A1	3	Accept $20 \ln 2$
	Total		**8**	
7(a)	At top, for complete revolutions:			
	$\frac{mv^2}{a} = mg$ where v is speed at top	M1		
	$\therefore v^2 = ag$	A1		
	Conservation of energy from B to top :			
	$\frac{1}{2}mv^2 + mg2a = \frac{1}{2}mu^2$	M1 A1		3 terms, 2 KE and PE
	$u^2 = 4ag + v^2$			
	$= 5ag$			
	$u = \sqrt{5ag}$	A1	5	AG
(b)	At C, speed of particle is $\sqrt{3ag}$	B1		
	Resolving horizontally at C:			
	$T = \frac{mv^2}{a}$	M1		Needs 2 correct terms
	$T = m\frac{3ag}{a}$			
	$T = 3mg$	A1	3	
(c)	No air resistance Bead is a particle	B1	1	
	Total		**9**	

MM2B (cont)

Q	Solution	Marks	Total	Comments
8(a)	Work done = $\int_0^e \frac{\lambda x}{l} \mathrm{d}x$	M1		
	$= \left[\frac{\lambda x^2}{2l}\right]_0^e$	A1		Needs limit of 0
	$= \frac{\lambda e^2}{2l}$	A1	3	AG
	Or			
	Area under a straight line = average force × distance = $\frac{\lambda e^2}{2l}$			
(b)(i)	Using $T = \frac{\lambda x}{l}$			
	$5g = \frac{150 \times x}{0.6}$	M1		
	Extension is 0.196 m	A1	2	
(ii)	EPE $= \frac{\lambda x^2}{2l}$			
	$= \frac{150 \times (0.3)^2}{2 \times 0.6}$	M1		
	= 11.25 J	A1	2	
(iii)	When x above P,			
	EPE $= \frac{150 \times (0.3 - x)^2}{2 \times 0.6}$	M1 A1		for $\frac{150 \times (... - x)^2}{2 \times 0.6}$
	PE[relative to P] = (–)5 × g × x	M1		for 5 × g × distance
	KE + EPE [at new point] = EPE [at P] – gain in PE	M1		4 terms, all signs correct, 2 terms correct
	$\frac{1}{2}mv^2 + \frac{150 \times (0.3 - x)^2}{2 \times 0.6} = \frac{150 \times (0.3)^2}{2 \times 0.6} - 5gx$	A1		
	$\frac{1}{2}mv^2 + \frac{150 \times (x^2 - 0.6x)}{2 \times 0.6} = -5gx$	m1		Equation involving terms in v^2, x^2 and x only
	$\frac{1}{2}.5.v^2 + 125x^2 - 75x = -49x$ $v^2 = 10.4x - 50x^2$	A1	7	
(iv)	Particle is at rest when $v = 0$ $10.4x - 50x^2 = 0$ $x = 0$ [not required]	M1		
	Or $x = \frac{10.4}{50}$ = 0.208 m above P.	A1	2	
	Total		**16**	
	TOTAL		**75**	

Version 1.0: 0109

General Certificate of Education

Mathematics 6360

MM2B Mechanics 2B

Mark Scheme

2009 examination - January series

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Registered address: AQA, Devas Street, Manchester M15 6EX
Dr Michael Cresswell Director General

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MM2B

Q	Solution	Marks	Total	Comments
1	$r = \int v \, dt$	M1		
	$= t^4 + 4\cos 2t + 5t \ (+c)$	A1		
	When $t = 0$, $r = 0 \Rightarrow c = -4$	M1		Finding c correctly
	$\therefore r = t^4 + 4\cos 2t + 5t - 4$	A1ft	4	
	Total		**4**	
2(a)	Initial KE = $\frac{1}{2}mv^2$			
	$= \frac{1}{2} \times 6 \times 12^2$	M1		Allow one of m and v incorrect
	= 432 J	A1	2	
(b)(i)	When it hits the ground, conservation of energy gives KE = Initial KE + loss in PE			
	$= 432 + 6 \times g \times 4$	M1		Need $6 \times g \times 4$ or 235.2
	= 667.2 = 667 J (3sf)	A1	2	AG
(ii)	$667.2 = \frac{1}{2} \times 6 \times v^2$	M1A1		
	Speed is 14.9 m s^{-1}	A1	3	
(iii)	Stone is a particle	B1		Not g constant
	No air resistance	B1	2	No other forces acting
	Total		**9**	

MM2B (cont)

Q	Solution	Marks	Total	Comments
3(a)	$\mathbf{v} = \frac{d\mathbf{r}}{dt}$	M1		
	$\mathbf{v} = (e^{\frac{1}{2}t} - 8)\mathbf{i} + (2t - 6)\mathbf{j}$	A1 A1	3	**i** terms **j** terms
(b)(i)	When $t = 3$, $\mathbf{v} = -3.52\mathbf{i}$	B1		Accept $(e^{\frac{3}{2}} - 8)\mathbf{i}$
	Speed is 3.52 m s $^{-1}$	B1	2	3.5 does not give 2nd B mark
(ii)	West	B1	1	
(c)	$\mathbf{a} = \frac{1}{2}e^{\frac{1}{2}t}\mathbf{i} + 2\mathbf{j}$	M1A1		
	When $t = 3$, $\mathbf{a} = \frac{1}{2}e^{\frac{3}{2}}\mathbf{i} + 2\mathbf{j}$ or $2.24\mathbf{i} + 2\mathbf{j}$	A1	3	
(d)	Using $\mathbf{F} = m\mathbf{a}$:	M1		Accept $\mathbf{F} = 7\mathbf{a}$
	$\mathbf{F} = 7(\frac{1}{2}e^{\frac{3}{2}}\mathbf{i} + 2\mathbf{j})$ $\therefore$ Magnitude of force is			
	$7\left((\frac{1}{2}e^{\frac{3}{2}})^2 + 2^2\right)^{\frac{1}{2}}$	M1		
	$\mathbf{F} = 21.025$ $\mathbf{F} = 21.0$	A1	3	Accept 21
	Total		**12**	
4(a)	Taking moments about *AD*:			
	$8 \times 10 + 2 \times 15 = 10\,\bar{x}$	M1A1		M1 for moments and 1 term on left correct and 1 term on right
	$\bar{x} = \frac{110}{10}$ $= 11$ cm	A1	3	
(b)	5 cm	B1	1	
(c)	$(\tan)\,\theta = \frac{1}{5}$ ie $\frac{(a)-10}{(b)}$	M1		From areas; $\frac{1.4}{5} \Rightarrow \theta = 15.6$ or 15.7
	$= 0.2$	A1ft		
	Angle is $\tan^{-1}(0.2)$	M1		
	$= 11.3°$	A1ft	4	
(d)	Centre of mass is at middle of lamina	E1	1	
	Total		**9**	

MM2B (cont)

Q	Solution	Marks	Total	Comments
5(a)	40 revolutions per minute			
	= 80π radians per minute	B1		or $\frac{2}{3}$ rev per second
	= $\frac{4\pi}{3}$ radians per second	B1	2	AG
(b)	Resolve vertically:			
	$T \cos 30 = 6g$	M1A1		M1 1 term each side, 1 correct
	$T = 67.9$ N	A1	3	AG
(c)	Resolve horizontally:			
	$T \sin 30 = m\omega^2 r$	M1 A1		M1 1 term each side, 1 correct A1 $T \sin 30$
	$67.9 \sin 30 = 6 \times r \times \left(\frac{4\pi}{3}\right)^2$	A1		A1 RHS
	$r = 0.322$ m	A1	4	Condone 0.323 (using π as 3.14)
	Total		**9**	
6(a)	At maximum speed, tractive force = resistance force Using power = force × velocity:	M1		
	800 000 = F × 40	M1		
	F = 20 000 N	A1	3	
(b)	Using force × distance = work done = change in energy:			
	20 000 s = $\frac{1}{2} \times 60\,000 \times (40^2 - 36^2)$	M1 A1 A1		M1 Fs = change of KE A1 2 of 3 terms correct A1 all 3 terms correct
	Distance = 456 m	A1	4	
	Total		**7**	
7(a)	$\frac{1}{2}mv^2 = \frac{1}{2}m \times 8^2 - mg2$	M1 A1		M1 3 terms, 2 KE and 1 PE
	$v^2 = 64 - 39.2$ $= 24.8$			
	$v = 4.98$	A1	3	Accept $\sqrt{24.8}$
(b)	Using $F = ma$ radially:			
	$R = mg \cos 60 + \frac{mv^2}{r}$	M1 A1 B1		M1 3 correct terms (not necessarily correct signs) B1 for 60°
	$= 6g \cos 60 + \frac{6 \times 24.8}{4}$			
	= 66.6 N	A1	4	
	Total		**7**	

MM2B (cont)

Q	Solution	Marks	Total	Comments
8(a)	Using $F = ma$:			
	$-0.08v^2 = 0.05a$	B1		
	$\therefore \frac{dv}{dt} = -1.6v^2$	B1	2	AG; condone sign error in first B1
(b)	$\int \frac{dv}{v^2} = -1.6\int dt$	M1		
	$-\frac{1}{v} = -1.6t\ (+c)$	A1		Condone $-\frac{1}{v} = -1.6t + c \Rightarrow \frac{1}{v} = 1.6t + c$
	When $t = 0$, $v = 3 \Rightarrow\ c = -\frac{1}{3}$	M1		
	$\frac{1}{v} = \frac{1}{3} + 1.6t$ *	A1		
	$\frac{1}{v} = \frac{1}{3} + \frac{8}{5}t$			
	$\frac{1}{v} = \frac{5 + 24t}{15}$			
	$v = \frac{15}{5 + 24t}$	A1	5	AG; all working lines correct from *
	Total		**7**	
9(a)	When acceleration is zero, tension = gravitational force			
	$\frac{784x}{16} = 80g$	M1		Both terms correct
	$x = 16,\ \ x + 16 = 32\,\text{m}$	A1		A1 for $x = 16$
	Length of cord is 32 m	A1	3	
(b)(i)	When bungee jumper comes to rest,			
	EPE = $\frac{784 \times x^2}{2 \times 16}$	M1		
	$= \frac{49x^2}{2}$			
	Change in PE = $80 \times g \times (16 + x)$	M1		Or $80 \times g \times 65 - \left(80g\left[16 + x\right]\right)$ $\left(\text{or } 80g\left(49 - x\right)\right)$
	$\frac{49x^2}{2} = 80 \times 9.8 \times (16 + x)$	A1		
	$x^2 = 32x + 512$			
	$x^2 - 32x - 512 = 0$	A1	4	AG
(ii)	$x = \frac{32 \pm \sqrt{32^2 + 2048}}{2}$	M1		
	$x = 43.7128$	A1		
	Distance below point of jump is 43.7 + 16 = 59.7 m			
	Distance between jumper and ground is 65 – 59.7	M1		
	= 5.29 m	A1	4	Accept 5.287, 5.3
	Total		**11**	
	TOTAL		**75**	

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General Certificate of Education

Mathematics 6360

MM2B Mechanics 2B

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2009 examination - June series

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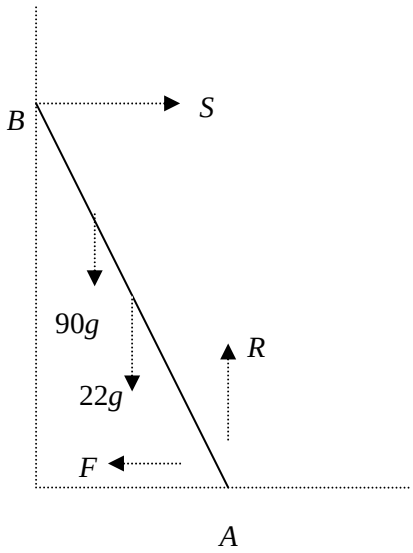
1(a)	$\mathbf{a} = \frac{d\mathbf{v}}{dt} = (3t^2 - 15)\mathbf{i} + (6 - 2t)\mathbf{j}$	M1A1 A1	3	A1 (**i** terms) A1 (**j** terms)
(b)(i)	Using $\mathbf{F} = m\mathbf{a}$:			
	Force $= 4 \times \{(3t^2 - 15)\mathbf{i} + (6 - 2t)\mathbf{j}\}$	M1		
	$= (12t^2 - 60)\mathbf{i} + (24 - 8t)\mathbf{j}$	A1	2	AG
(ii)	When $t = 2$, force $= -12\mathbf{i} + 8\mathbf{j}$	M1A1		
	Magnitude of force $= \sqrt{12^2 + 8^2}$ N	M1		
	$= 14.4$ (N)	A1	4	
	Total		**9**	
2(a)	KE $= \frac{1}{2} \times 55 \times 3^2$	M1		
	$= 247.5$ J	A1	2	
(b)	Change in PE as slides down:			
	$mgh = 55 \times 9.8 \times 20 \cos 30$	M1		Need cos 30 or sin 30
	$= 9335.7\ldots$	A1		
	Using Conservation of Energy:			
	KE at end of slide $= 247.5 + 9335.7$	m1		'a' + '9335.7'
	$= 9580$ J	A1		accept 9583
	Speed of Anne is $\sqrt{\frac{9583}{\frac{1}{2} \times 55}}$	m1		
	$= 18.7$ m s^{-1}	A1	6	
(c)	Anne is a particle; no air resistance	E1	1	
	Total		**9**	

MM2B (cont)

Q	Solution	Marks	Total	Comments
3(a)				
	Resolve vertically: $R = 22g + 90g$ $= 112g$	B1		
	Using $F = \mu R$: $F = 0.6R$ $F = 0.6 \times 112g$	M1 A1		[Needs $0.6\times112g$ or 0.6×1097.6 NOT 0.6×1097 unless 658.56 seen]
	$= 67.2g$ or 658.56 $F = 659$ N	A1	4	AG (659 must be shown from correct working)
(b)	Resolve horizontally: $S = F$	B1		
	Moments about A: $90g \times 5 \times \cos\theta + 22g \times 3 \times \cos\theta$	M1A1		M1 (one term, force × distance × cos or sin)
	$= 67.2g \times 6 \times \sin\theta$ $450g + 66g = 403.2g \tan\theta$ $\tan\theta = \frac{516}{403.2}$	A1		
	$\theta = 52.0°$	A1	5	accept 52 **Alternative**: or moments about B: M1 A2, 1 or 0 for four-term moment equation + M1 for rearranging etc (dep on 4 term) + A1 for answer
	Total		**9**	

MM2B (cont)

Q	Solution	Marks	Total	Comments
4(a)	Resolving vertically:			
	$T\cos 60 + T\cos 40 = mg$	M1A1		
	$1.266\,T = 6g$	M1		
	$T = 46.4$ N	A1	4	AG no marks if g deleted
(b)	Radius of circle is $0.6\tan 60$	B1		$r = 1.039$ or 1.04
	Horizontally:			
	$\frac{mv^2}{r} = T\cos 50 + T\cos 30$	M1		Accept sin instead of cos for M1
	$\frac{6v^2}{1.039} = 46.4\cos 50 + 46.4\cos 30$ or 70.01	A1		
	$v^2 = 12.123$			
	Speed is 3.48 m s^{-1}	A1	4	
	Total		**8**	
5	Force acting against gravity is $mg\sin\theta$	M1		Or 147000
	Force acting against gravity and resistance is $mg\sin\theta + 200\,000$	m1		200 000 + 'mg sin θ'
	$= 600\,000g\sin\theta + 200\,000$			
	$= 347\,000$	A1		
	Using power = force × velocity	M1		
	= 347000 × 24	A1F		
	= 8330 kW	A1	6	
	Total		**6**	
6(a)	$\text{EPE} = \frac{\lambda x^2}{2l}$			
	$= \frac{180\times 0.8^2}{2\times 1.2}$	M1		
	= 48 J	A1	2	
(b)	Using initial EPE = KE when string becomes slack:	M1		
	$48 = \frac{1}{2}\times 5\times v^2$	A1F		
	$v = \sqrt{\frac{96}{5}}$			
	= 4.38 m s^{-1}	A1F	3	ft $\sqrt{\frac{'a'}{2.5}}$
(c)	Normal reaction is $5g$ or 49	M1		
	Frictional force is $5g\times\mu$	m1A1		
	Work done by frictional force is $5\mu g\times 2$	m1		
	$= 10\mu g$	A1		
	Stops at wall $\Rightarrow 10\mu g = 48$	m1		m1 $10\mu g = 'a'$
	$\mu = 0.490$	A1	7	accept $\frac{24}{49}$ OE
	Total		**12**	

MM2B (cont)

Q	Solution	Marks	Total	Comments
7(a)	By conservation of energy to point where *QP* makes an angle θ with upward vertical:			
	$\frac{1}{2}mv^2 = \frac{1}{2}mu^2 - mga(1+\sin\theta)$	M1 A1		for 3 terms, 2 KE and 1 PE $mga\ (1+\sin\theta)$ term
	$v^2 = u^2 - 2ag(1+\sin\theta)$	A1		
	Resolve radially			
	$R = \frac{mv^2}{a} - mg\sin\theta$	M1A1		M1 for 3 terms, include $\sin\theta$ or $\cos\theta$
	$= \frac{mu^2}{a} - 3mg\sin\theta - 2mg$	A1	6	AG
(b)	When particle leaves the track, $R = 0$	M1		
	$0 = 3mg - 3mg\sin\theta - 2mg$	A1		
	$\sin\theta = \frac{1}{3}$	M1		SC3 $\sin^{-1}\frac{1}{3}$
	θ = 19.5°	A1	4	accept 19.4° or $\theta = 0.340^c$
	Total		**10**	
8(a)	Using $F = ma$:			
	$-\lambda m v^{\frac{3}{2}} = m\frac{dv}{dt}$	M1		
	$\therefore \frac{dv}{dt} = -\lambda v^{\frac{3}{2}}$	A1	2	AG
(b)	$\int \frac{dv}{v^{\frac{3}{2}}} = -\lambda\int dt$	M1		
	$-\frac{2}{v^{\frac{1}{2}}} = -\lambda t + c$	A1		Condone no '+c'
	When $t = 0$, $v = 9 \Rightarrow c = -\frac{2}{3}$	M1 A1		Dep. on correct integration (accept sign or '$\frac{1}{2}$' error)
	$\frac{2}{\sqrt{v}} = \lambda t + \frac{2}{3}$	A1		
	$\frac{\sqrt{v}}{2} = \frac{1}{\lambda t + \frac{2}{3}}$			
	$v = \left(\frac{6}{2+3\lambda t}\right)^2$	m1		Needs correct algebra
	$v = \frac{36}{(2+3\lambda t)^2}$	A1	7	AG
(c)	When $v = 4$,			**or** $\frac{36}{(2+3\lambda t)^2} = 4$ M1
	$\frac{2}{\sqrt{v}} = \lambda t + \frac{2}{3} \Rightarrow 1 = \lambda t + \frac{2}{3}$	M1A1		$(2+3\lambda t)^2 = 9$ A1
	$t = \frac{1}{3\lambda}$	A1	3	$t = \frac{1}{3\lambda}$ A1 needs statement why $2+3\lambda t \neq -3$
	Total		**12**	
	TOTAL		**75**	

Version 1.0: 0110

General Certificate of Education

Mathematics 6360

MM2B Mechanics 2B

Mark Scheme

2010 examination - January series

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Set and published by the Assessment and Qualifications Alliance.

The Assessment and Qualifications Alliance (AQA) is a company limited by guarantee registered in England and Wales (company number 3644723) and a registered charity (registered charity number 1073334).
Registered address: AQA, Devas Street, Manchester M15 6EX *Dr Michael Cresswell Director General*

Key to mark scheme and abbreviations used in marking

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	MC	mis-copy
CAO	correct answer only	MR	mis-read
CSO	correct solution only	RA	required accuracy
AWFW	anything which falls within	FW	further work
AWRT	anything which rounds to	ISW	ignore subsequent work
ACF	any correct form	FIW	from incorrect work
AG	answer given	BOD	given benefit of doubt
SC	special case	WR	work replaced by candidate
OE	or equivalent	FB	formulae book
A2,1	2 or 1 (or 0) accuracy marks	NOS	not on scheme
–*x* EE	deduct *x* marks for each error	G	graph
NMS	no method shown	c	candidate
PI	possibly implied	sf	significant figure(s)
SCA	substantially correct approach	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. However, there are situations in some units where part marks would be appropriate, particularly when similar techniques are involved. Your Principal Examiner will alert you to these and details will be provided on the mark scheme.

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**.

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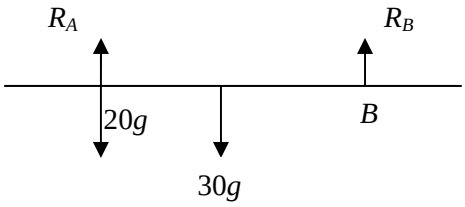
Where the permitted calculator has functions which reasonably allow the solution of the question directly, the correct answer without working earns **full marks**, unless it is given to less than the degree of accuracy accepted in the mark scheme, when it gains **no marks**.

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

MM2B

Q	Solution	Marks	Total	Comments
1	Work done = $Fs\cos\theta$	M1		Accept $Fs\sin\theta$ for M1
	$= 40 \times 5 \times \cos 30$	A1		
	= 173 J	A1	3	
	Total		**3**	
2	$\bar{X} = \frac{3\times15+1\times7+6\times8+10\times12}{3+1+6+10}$	M1A1		M1 for at least 3 multiplication & addition
	$= \frac{220}{20}$ or 11	A1		
	$\bar{Y} = \frac{3\times6+1\times14+6\times7+10\times9}{20}$	M1A1		
	$= \frac{164}{20}$ or 8.2	A1	6	SC 4 (10, 7.4) [omit lamina] ie: B2, B2
	$\therefore$ Centre of mass is at (11, 8.2)			
	Total		**6**	
3(a)		B2	2	B1 for four forces B2 for two different reactions and 30g and 20g marked
(b)	Taking moments about A:			
	$3.2\times30g = R_B \times 5$	M1B1		B1 for 3.2
	$R_B = 19.2g$	A1	3	AG
(c)	Resolve vertically: $R_A + R_B = 50g$	M1		Can be awarded in (b)
	$R_A = 30.8g$ or 302 N	A1	2	
(d)	Gravitational force acts through mid-point of the rod	E1	1	
	Total		**8**	

MM2B (cont)

Q	Solution	Marks	Total	Comments
4(a)	$\mathbf{r} = \int \mathbf{v}\,dt$	M1		M1 for at least one term correct
	$= \left(t^4 - 6t^2 + 3t\right)\mathbf{i} + 5t\mathbf{j} + 4t^2\mathbf{k} + \mathbf{c}$	A1m1		m1 for $+\,\mathbf{c}$
	When $t = 0$, $\mathbf{r} = -5\mathbf{i} + 6\mathbf{k}$ $\therefore \mathbf{c} = -5\mathbf{i} + 6\mathbf{k}$			
	$\therefore \mathbf{r} = \left(t^4 - 6t^2 + 3t - 5\right)\mathbf{i} + 5t\mathbf{j} + \left(6 + 4t^2\right)\mathbf{k}$	A1	4	
(b)	$\mathbf{a} = \left(12t^2 - 12\right)\mathbf{i} + 8\mathbf{k}$	M1A1	2	M1 for either component
(c)	Magnitude is $\left\{\left(12t^2 - 12\right)^2 + 64\right\}^{\frac{1}{2}}$	M1 A1F	2	
(d)	Magnitude is a minimum when $12t^2 - 12$ is zero	M1		M1 for correct differentiation of correct expression in (c)
	ie when $t = 1$	A1	2	
(e)	Minimum acceleration is 8			
	Using F = *ma*,	M1		*a* could be a vector
	$F = 7 \times 8 = 56$	A1	2	CAO
	Total		**12**	

MM2B (cont)

Q	Solution	Marks	Total	Comments
5(a)	Using $F = ma$,			
	$-0.2mv^{\frac{1}{2}} = m\dfrac{\mathrm{d}v}{\mathrm{d}t}$			
	$\therefore\ \dfrac{\mathrm{d}v}{\mathrm{d}t} = -0.2v^{\frac{1}{2}}$	B1	1	AG Must see equ'n containing m
(b)	$\int \dfrac{\mathrm{d}v}{v^{\frac{1}{2}}} = -\int 0.2\ \mathrm{d}t$	M1		
	$2v^{\frac{1}{2}} = -0.2t + c$	A1m1		m1 for + c
	When $t=0$, $v=16 \therefore C=8$	A1		
	$2v^{\frac{1}{2}} = -0.2t + 8$			
	$v = (4 - 0.1t)^2$	A1	5	AG
(c)	When $v=1, 1=(4-0.1t)^2$	M1		
	$4 - 0.1t = \pm 1$			
	$t=30$ or 50	A1		[if use $2v^{\frac{1}{2}} = 8 - 0.2t$ no need to see 50]
	$t=30$	A1	3	$t \neq 50$ as ball stops when $t = 40$
(d)	Integrating $v=(4-0.1t)^2$:			
	$v = 16 - 0.8t + 0.01t^2$			
	$x = 16t - 0.4t^2 + \dfrac{0.01}{3}t^3 + d$	M1		M1 for first 3 terms or $-\dfrac{10}{3}(4-01t)^3$
	When $t=0$, $x=0 \Rightarrow d=0$	A1		
	$x = 16t - 0.4t^2 + \dfrac{0.01}{3}t^3$			
	When speed is $1\,\mathrm{m\,s^{-1}}$, $t = 30$			
	$x = 480 - 360 + 90$	m1		dep on M1 above
	$= 210$	A1	4	[No 'd', 3 marks only]
	Total		**13**	

MM2B (cont)

Q	Solution	Marks	Total	Comments
6(a)	$r = 1.2\sin\theta$	B1	1	1.2 $\cos\theta$ 0 marks
(b)	Resolve horiz: $T\sin\theta = m\omega^2 r$	M1A1		$T\cos\theta = m\omega^2 r$ etc M1 (+ second M1)
	$T\sin\theta = 4\times 5^2 \times 1.2\sin\theta$			
	$T = 120$	A1		
	Resolve vert: $T\cos\theta = 4g$	M1A1		
	$\cos\theta = 0.32666$			M1 for $\tan\theta = \dfrac{30\sin\theta}{g}$
	$\theta = 70.9°$ or 1.24^c	A1	6	
	Total		**7**	
7(a)	Using conservation of energy:			
	$\frac{1}{2}mu^2 = \frac{1}{2}mv^2 - mgh$	M1A1		M1 for 3 terms, 2 KE and PE or 4 terms , 2 KE and 2 PE
	$\frac{1}{2}mu^2 = \frac{1}{2}mv^2 - mga(1-\cos\theta)$	M1A1		M1A1 for finding h
	$v^2 = u^2 + 2ga(1-\cos\theta)$			
	$v = \left(u^2 + 2ga[1-\cos\theta]\right)^{\frac{1}{2}}$	A1	5	AG
(b)	Using $F = ma$ radially,			
	$mg\cos\theta - \mathrm{N} = \dfrac{mv^2}{a}$	M1A1		M1 Correct 3 terms A1 Correct signs $(-\mathrm{N}$ or $+\mathrm{N})$
	Particle leaves surface of hemisphere when N = 0	B1		
	$mg\cos\theta = \dfrac{m}{a}\left(u^2 + 2ga[1-\cos\theta]\right)$	M1		
	$\cos\theta = \dfrac{u^2}{ga} + 2 - 2\cos\theta$			
	$\cos\theta = \dfrac{1}{3}\left(\dfrac{u^2}{ga} + 2\right)$	A1	5	
	Total		**10**	

MM2B (cont)

Q	Solution	Marks	Total	Comments
8(a)	When $x \geq 22$, KE is $\frac{1}{2}\times 49\times v^2$			
	EPE is $\frac{1078(x-22)^2}{2\times 22}$	M1A1		M1 for any $\frac{1078p^2}{2\times 22}$
	Change in PE is $49 \times g \times x$			
	Conservation of energy:			
	$\frac{1}{2}\times 49\times v^2 + \frac{1078(x-22)^2}{2\times 22} = 49\times g\times x$	M1A1 A1		M1 3 terms (KE, PE, EPE) A1 2 terms correct A1 all 3 terms correct
	$\frac{49}{2}v^2 + \frac{49}{2}(x-22)^2 = 49gx$			
	$v^2 + (x-22)^2 = 19.6x$			SC3 $\frac{49}{2}v^2 + \frac{49}{2}e^2 = 49g(e+22)$ [could use x for e]
	$5v^2 = 318x - 5x^2 - 2420$	A1	6	AG
(b)	If x is not greater than 22, cord is not stretched	B1	1	
(c)	At maximum value of x, $v = 0$ $\therefore 5x^2 - 318x + 2420 = 0$	M1		
	$x = \frac{318 \pm \sqrt{318^2 - 4\times 5\times 2420}}{2\times 5}$	m1		dep on M1 above
	$x = 54.76..$ or $8.84..$	A1		A1 for either solution
	$= 54.8$	E1	4	Needs to give a reason for deletion of second root. Both roots must be positive: one above 22, one below 22
(d)(i)	When speed is a maximum, $a = 0$ tension = gravitational force	M1		**or** $\frac{d(5v^2)}{dx} = 318 - 10x$
	$\frac{1078(x-22)}{22} = 49g$	A1		= 0 at maximum speed $\Rightarrow 318 - 10x = 0$
	$x - 22 = 9.8$ $x = 31.8$	A1	3	AG
(ii)	From part (a), $v^2 = 19.6\times 31.8 - 9.8^2$	M1		
	$v = 22.96$ Maximum speed is $23.0\,\text{m s}^{-1}$	A1	2	
	Total		**16**	
	TOTAL		**75**	

Version 1.0

General Certificate of Education
June 2010

Mathematics MM2B

Mechanics 2B

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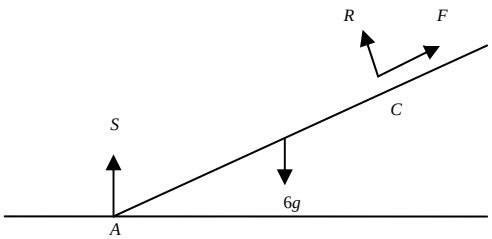
MM2B

Q	Solution	Marks	Total	Comments
1	$v = \frac{ds}{dt}$	M1		M1 for either $\frac{ds}{dt}$ or 1 of 2 terms correct (ignore signs)
	$= 10t - 12\sin 4t$	A1A1	3	
	Total		**3**	
2(a)	Kinetic energy $= \frac{1}{2} \times 3 \times 4^2$	M1		
	$= 24$ (J)	A1	2	
(b)	PE lost is			
	$= 3 \times g \times 51$	M1		
	$= 153g$ or 1499.4			
	= 1500 J	A1	2	Accept 1499, $153g$
(c)(i)	KE is $24 + 153g$	M1		M1 '(a)' + '(b)'
	= 1523.4			
	= 1520 J	A1		(if done (c)(i) in (b) 0 marks; if done (b) and then (c)(i) in (b) M1 only)
(ii)	Using KE $= \frac{1}{2}mv^2$			
	$v^2 = 1015.6$	M1		
	Speed of stone is 31.9 ms^{-1}	A1	4	Accept 31.8 from 1520
				If use constant acceleration formulae in 2D, possible 4 marks in (c) BUT **no marks** if initial speed is treated as being vertical
(d)	eg Stone is a particle	E1	1	
	No air resistance			Not no resistance; accept no wind resistance
	Total		**9**	
3(a)	Symmetry	E1	1	Only accept 'symmetry'
(b)	Moments about B:			
	$0.4 \times 4 + 0.1 \times 8 = 0.5 \times \bar{x}$	M1A1		M1 3 terms , 2 correct
	$\bar{x} = \frac{2.4}{0.5}$			
	= 4.8 cm	A1	3	
	Total		**4**	

MM2B (cont)

Q	Solution	Marks	Total	Comments
4(a)	Using **F** = *m***a**,			
	$400\cos\frac{\pi}{2}t\,\mathbf{i} + 600t^2\,\mathbf{j} = 200\,\mathbf{a}$	M1		
	$\mathbf{a} = 2\cos\frac{\pi}{2}t\,\mathbf{i} + 3t^2\,\mathbf{j}$	A1	2	
(b)	$\mathbf{v} = \int a\,\mathrm{d}t$	M1		M1 for either $\int a\,\mathrm{d}t$ or 1 of 2 terms correct
	$= \frac{4}{\pi}\sin\frac{\pi}{2}t\,\mathbf{i} + t^3\mathbf{j} + \mathbf{c}$	A1m1		m1 for + **c**
	When $t = 4$, $\mathbf{r} = -3\mathbf{i} + 56\mathbf{j}$, $64\mathbf{j} + \mathbf{c} = -3\mathbf{i} + 56\mathbf{j}$	m1		
	$\therefore \mathbf{c} = -3\mathbf{i} - 8\mathbf{j}$ $\therefore \mathbf{v} = (\frac{4}{\pi}\sin\frac{\pi}{2}t - 3)\mathbf{i} + (t^3 - 8)\mathbf{j}$	A1	5	Do not accept $\frac{2}{\frac{\pi}{2}}$ Accept 1.27 for $\frac{4}{\pi}$
(c)	When particle is moving due west, northerly component is zero	M1		
	$\therefore t^3 - 8 = 0$	A1√		
	$t = 2$	A1	3	
(d)	When $t = 2$, $\mathbf{v} = -3\mathbf{i} + 0\mathbf{j}$	B1√		
	Speed of particle is 3 m s^{-1}	B1	2	B1 for change –3 to +3
	Total		**12**	
5	$\frac{\mathrm{d}v}{\mathrm{d}t} = -\frac{\lambda}{v^{\frac{1}{4}}}$	M1		
	$\int v^{\frac{1}{4}}\mathrm{d}v = -\int \lambda\,\mathrm{d}t$	m1		Condone one of $v^{-\frac{1}{4}}$, $+\int\lambda\mathrm{d}t$, $\frac{1}{\lambda}$
	$\frac{4}{5}v^{\frac{5}{4}} = -\lambda t + c$	A1A1 m1		m1 for + *c*
	$t = 0$, $v = u$ $\therefore c = \frac{4}{5}u^{\frac{5}{4}}$	A1		
	$\therefore v^{\frac{5}{4}} = u^{\frac{5}{4}} - \frac{5}{4}\lambda t$			
	$v = \left(u^{\frac{5}{4}} - \frac{5}{4}\lambda t\right)^{\frac{4}{5}}$	A1	7	
	Total		**7**	

MM2B (cont)

Q	Solution	Marks	Total	Comments
6(a)	Using power = force × velocity Power = (30 × 48) × 48 = 69120 watts	 M1 A1	 2	 AG
(b)	When speed is 40 m s^{-1}, max force exerted is $\frac{69120}{40}$ = 1728 N Accelerating force is '1728' – 1200 N Using $F = ma$: 528 = 1200a a = 0.44 m s^{-2}	 B1 M1 m1 A1	 4	
(c)	Force exerted by engine is $\frac{69120}{v}$ Force exerted by the engine $= 30v - mg\sin 3$ $30v - 615.47$ (or $1200g\sin 3$)$= \frac{69120}{v}$ $30v^2 - 615.47v - 69120 = 0$ $v = \frac{615.47 \pm \sqrt{615.47^2 + 4\times 30\times 69120}}{2\times 30}$ Speed is 59.3 m s^{-1}	 M1 A1A1 A1 M1 A1	 7	 (Use of cos3 delete A1,A1 of 3 A terms) A2 All terms correct A1 Two terms correct SC3 for $30v^2 + 615.47v - 69120 = 0$
	Total		**13**	
7(a)		B2	2	B1 for S and $6g$ (in correct place) B1 for R and F or combined vertical force at C
(b)	Moments about C: 3 × S × cos 20 = 6g × 1 × cos 20 S = 19.6 N or 2g	 M1A1 A1	 3	 M1 2 terms, 1 term correct R, F not correct 0 marks in (c)(i) and (c)(ii)
(c)(i)	Moments about A: 2 × 6g × cos 20 = R × 3 R = 36.8 N (or resolving, R = 6g cos20 – S cos20 = 4g cos20)	 M1A1 A1	 	**Or** Moments about mid-point of rod: 2 × S × cos 20 = P × 1 × cos 20 P = 39.2 N or 4g (Or resolving vertically P = 4g)
(ii)	Resolve parallel to AB: S cos 70 + F = 6g cos 70 F = 4g cos 70 = 13.4 N (or F = 6g sin20 – S sin20 = 4g sin20)	 M1 A1	 5	$R = P \times \cos 20$ M1 A1 = 36.8 N A1 $F = P \times \sin 20$ M1 = 13.4 N A1
(d)	Using $F = \mu R$: 13.4 = μ × 36.8 μ = 0.364 or tan20	M1 A1√	 2	M1 '(c)(ii)' = μ '(c)(i)' (condone ≥)
	Total		**12**	

MM2B (cont)

Q	Solution	Marks	Total	Comments
8(a)	Using conservation of energy:			
	$\frac{1}{2}mv^2 = 3mg(1-\cos\theta)$	M1A1		M1 $\frac{1}{2}mv^2 = mgh$
	$v^2 = 6g(1-\cos 15)$	m1		
	$v = (6g[1-\cos 15])^{\frac{1}{2}}$			
	$= 1.42$	A1	4	SC3: 1.41
(b)	When particle is at rest,			
	resolve radially $T = mg\cos 15$	M1A1		M1 $T - mg\cos 15 = \frac{mv^2}{r}$ or $T = mg\sin 15$
	$22 = mg\cos 15$			
	$m = 2.32$	A1	3	
	Total		**7**	
9	As particle moves, $T = \frac{mv^2}{r}$	M1		**or** using unknown as extension:
	If radius is r, extension is $r - 1.2$	B1		If extension is x, radius is $1.2 + x$ B1
	Using $T = \frac{\lambda x}{l}$:			Using $T = \frac{\lambda x}{l}$:
	$T = \frac{192(r-1.2)}{1.2}$	M1		$T = \frac{192x}{1.2}$ M1
	$= 160(r-1.2)$	A1		$= 160x$ A1
	$T = \frac{mv^2}{r} \Rightarrow 160(r-1.2) = \frac{8\times 3^2}{r}$	M1		$T = \frac{mv^2}{r} \Rightarrow 160x = \frac{8\times 3^2}{1.2+x}$ M1
				M1
	$160r^2 - 192r = 72$ (or $192r^2 - 230.4r = 86.4$)	A1		$192x + 160x^2 = 72$ A1
	$20r^2 - 24r - 9 = 0$			$20x^2 + 24x - 9 = 0$
	$(10r+3)(2r-3) = 0$	M1		$(10x-3)(2x+3) = 0$ M1
	$r = 1.5$ or -0.3			$x = 0.3$ or -1.5
	Radius is 1.5	A1	8	Radius is 1.5 A1
	Total		**8**	
	TOTAL		**75**	

Version1.0

General Certificate of Education (A-level)
January 2011

Mathematics MM2B

(Specification 6360)

Mechanics 2B

Mark Scheme

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Registered address: AQA, Devas Street, Manchester M15 6EX.

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.

MM2B

Q	Solution	Marks	Total	Comments
1(a)	$\mathbf{r} = \int v\,\mathrm{d}t$			
	$= (4t + t^3)\mathbf{i} + (12t - 4t^2)\mathbf{j} + \mathbf{c}$	M1A1		M1 either **i** or **j** term correct. Condone no **c**
	When $t = 0$, $\mathbf{r} = 5\mathbf{i} - 7\mathbf{j}$			
	$\mathbf{c} = 5\mathbf{i} - 7\mathbf{j}$	M1		Any attempt at **c**
	$\mathbf{r} = (5 + 4t + t^3)\mathbf{i} + (-7 + 12t - 4t^2)\mathbf{j}$	A1	4	
(b)	$\mathbf{a} = \frac{\mathrm{d}v}{\mathrm{d}t}$			
	$\mathbf{a} = 6t\,\mathbf{i} - 8\,\mathbf{j}$	M1A1	2	M1 either term correct
(c)	Using $\mathbf{F} = m\mathbf{a}$	M1		Or: using $\mathbf{F} = m\mathbf{a}$
	$\mathbf{F} = 2(6t\,\mathbf{i} - 8\,\mathbf{j})$			$\mathbf{F} = 2(6t\,\mathbf{i} - 8\,\mathbf{j})$
	$= 12t\,\mathbf{i} - 16\,\mathbf{j}$	A1		When $t = 1$, $\mathbf{F} = 12\,\mathbf{i} - 16\,\mathbf{j}$
	$\therefore$ Magnitude of force is			
	$(144t^2 + 256)^{\frac{1}{2}}$ when $t = 1$	M1		Magnitude of force is $(144 + 256)^{\frac{1}{2}}$
	= 20 N	A1	4	= 20 N
	Total		**10**	
2(a)	PE lost is			
	$= 4 \times g \times 5 \cos 70$	M1A1	2	M1 $4 \times g \times 5 \times \cos$ or $\sin 20$ or 70
	= 67.0 J			
(b)	KE is loss of PE $\Rightarrow$ KE is 67.0 J	B1	1	ft
(c)	Using KE = $\frac{1}{2}mv^2$			
	$v^2 = 33.5$	M1		
	Speed of particle is 5.79 m s^{-1}	A1	2	(ft from (b))
	Total		**5**	
3(a)	PE is $400 \times g \times 8$			
	$= 3200\,g$ [or 31 360]	B1	1	
(b)	KE is $\frac{1}{2} \times 400 \times 2^2$			
	= 800	B1	1	
(c)	Work done per minute is 32 160 J			
	Power = 32 160 ÷ 60	M1		$[(a) + (b)] \div 60$
	= 536 W	A1	2	CAO Accept 537 from 31 400 in (a)
	Total		**4**	

MM2B(cont)

Q	Solution	Marks	Total	Comments
4(a)	Moments about line *AD*: $5 \times 30 + 4 \times 10 = 9 \times \bar{x}$ $\bar{x} = \frac{190}{9}$ $= 21.1$ cm	M1A1 A1	 3	M1 2 of 3 terms correct
(b)	Moments about line *AB*: $5 \times 15 + 4 \times 25 = 9 \times \bar{y}$ $\bar{y} = \frac{175}{9}$ $\bar{y} = 19.4$ cm	M1A1 A1	 3	M1 2 of 3 terms correct If moments about *DC*; 10.6 found SC2
(c)	$\tan\theta = \frac{80}{175}$ or $\frac{8.9}{19.4}$ $= 0.4571$ Angle is $\tan^{-1} 0.4571$ $= 24.6°$	M1 A1 A1 A1	 4	M1 use of tan A1 use of 8.9 or 80 $\left(30-(a)\right)$ Or 0.45876 $65.4^\circ \Rightarrow$ M1A1 only
(d)	Moments about the line *PR*: (or *AD* or *BC*) $30m = 4 \times 20$ or $9 \times \frac{80}{9}$ $m = \frac{8}{3}$	M1 A1 A1	 3	
(e)	Centre of mass is at middle of lamina	E1	1	
	Total		**14**	

MM2B(cont)

Q	Solution	Marks	Total	Comments
5(a)	Resolve vertically $R = mg$ If the particle is on the point of sliding, $F = \mu R$	M1		Ignore all inequalities
	$\therefore F = 0.3R = 0.3mg$	A1		
	Resolving radially: $F = m\omega^2 r$ $0.3mg = m\omega^2 \times 0.8$ $\omega^2 = \dfrac{0.3\times g}{0.8}$	M1		
	$\omega = 1.92$	A1	4	
(b)(i)	45 revolutions per minute = $\dfrac{90\pi}{60}$	M1		
	$= \dfrac{3\pi}{2}$ or 4.71 radians per second	A1	2	
(ii)	Resolving radially: $F = m\omega^2 r$			
	$m\mu g = m\left(\dfrac{3\pi}{2}\right)^2 \times 0.15$	M1A1 A1		M1A1 either side correct A1 second side correct
	$\mu = \dfrac{\left(\dfrac{3\pi}{2}\right)^2 \times 0.15}{g}$			
	$\mu = 0.340$	A1	4	CAO (accept 0.339)
	Total		**10**	
6(a)	By conservation of energy			
	$\dfrac{1}{2}m(5v)^2 = \dfrac{1}{2}m(3v)^2 + mg\,2a$	M1 A1		M1 for 3 terms , 2 KE and PE
	$8v^2 = 2ag$	A1		
	$v = \sqrt{\dfrac{ag}{4}}$ or $\dfrac{1}{2}\sqrt{ag}$	A1	4	
(b)	Greatest and least values of tension are at the highest and lowest points of its path			
	At top, $T = \dfrac{m(3v)^2}{a} - mg$	M1		
	$= \dfrac{5}{4}mg$	A1ft		ft - must be positive tension
	At B, $T = \dfrac{m(5v)^2}{a} + mg$	M1		
	$= \dfrac{29}{4}mg$	A1ft		
	Ratio is 29 : 5	A1	5	CAO Condone 5 : 29 or 1 : 5.8
	Total		**9**	

MM2B(cont)

Q	Solution	Marks	Total	Comments
7(a)	Work done = $\int_0^e \frac{\lambda x}{l}\mathrm{d}x$	M1		Condone lack of limits and '*dx*'
	$= \left[\frac{\lambda x^2}{2l}\right]_0^e$	A1		Must include limits from integral
	$= \frac{\lambda e^2}{2l}$	A1	3	AG
(b)(i)	Using $T = \frac{\lambda x}{l}$, $7g = \frac{196x}{2}$	M1		M1 could use *3g* or *4g* – at least 1 side correct
	$x = \frac{14g}{196}$	A1		
	$= 0.7$	A1	3	
(ii)	By C of Energy, when next at rest, EPE (initial) = PE change (for platform) + EPE (when at rest)			
	$\frac{196\times0.7^2}{2\times2} = 4\times g\times(0.7-x)+\frac{196x^2}{2\times2}$	M1A1 A1		M1 3 terms (not including $\frac{1}{2}mv^2$) A1 2 of 3 terms correct A1 all correct
	$2.45 = 2.8 - 4x + 5x^2$ $100x^2 - 80x + 7 = 0$ $(10x - 7)(10x - 1) = 0$ $x = 0.1$	 m1 A1 A1	 6	 [last A1, must give 0.1, not 0.1 and 0.7]
	<u>Alternative</u>			
(b)(ii)	$\frac{196\times0.7^2}{2\times2} = 4gX + \frac{196(0.7-X)^2}{2\times2}$	(M1) (A1) (A1)		(where X is distance moved upwards)
	$4gX = 98\times0.7X + 49X^2$	(m1)		
	$X = 0,\ 0.6$	(A1A1)		
(iii)	Max speed when $T = mg$	M1		
	$4g = \frac{196x}{2}$	A1		
	$x = 0.4$	A1	3	Or mid-point of values 0.2 and 0.6 above SC2
	Total		**15**	

MM2B

Q	Solution	Marks	Total	Comments
8(a)(i)	$F = 65g - 260v$ $= 65(9.8 - 4v)$	B1	1	Accept $260v - 65g$ AG must see $65g$ or 260
(ii)	Using $F = ma$			
	$65\dfrac{\mathrm{d}v}{\mathrm{d}t} = 65(9.8 - 4v)$	M1		Need to see terms in m (condone $-$ sign)
	$\dfrac{\mathrm{d}v}{\mathrm{d}t} = -4(v - 2.45)$	A1	2	AG
(b)	$\dfrac{1}{v - 2.45}\dfrac{\mathrm{d}v}{\mathrm{d}t} = -4$	B1		
	$\int \dfrac{1}{v - 2.45}\,\mathrm{d}v = -\int 4\,\mathrm{d}t$			
	$\ln(v - 2.45) = -4t + c$	M1 A1		M1 log side correct $-4t + c$
	$v - 2.45 = C\mathrm{e}^{-4t}$ $t = 0,\ v = 19.6$ $\therefore C = 17.15$ or $e^{2.84}$	A1		Or $c = \ln 17.15$ or 2.84
	$\therefore v = 2.45 + 17.15\mathrm{e}^{-4t}$ $2.45 + 17.2e^{-4t}$	A1	5	
	Total		**8**	
	TOTAL		**75**	

Version 1.1

General Certificate of Education (A-level)
June 2011

Mathematics MM2B

(Specification 6360)

Mechanics 2B

Final

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MM2B

Q	Solution	Marks	Total	Comments
1(a)	KE = $\frac{1}{2}\times 58\times 2^2$	M1		M1: Correct fully substituted expression for KE.
	= 116 J	A1	2	A1: CAO
(b)	Change in PE: mgh = 58 × 9.8 × 7	M1		M1: Expression for PE with 58 and 9.8 or 9.81 with 6 or 7 for the height (or 11 and 4, 11 and 5 or 10 and 4).
	= 3978.8	A1		A1: Accept 3980 or 3970 or 3978 or 3979 or 3978.8. Accept 3982 or 3983 or 3980.
	KE = 3978.8 + 116 J = 4094.8 J	M1		M1: Adding their two previous answers.
	Speed of Kim is $\sqrt{\frac{4094.8}{\frac{1}{2}\times 58}}$	dM1		dM1: Seeing expression for v (not v^2), dependent on second M1
	= 11.88 m s^{-1} = 11.9 m s^{-1}	A1	5	A1: Accept 11.88 or 11.8 or 11.9 Accept 11.88 or 11.8 or 11.9 or AWRT 11.89 from g = 9.81.
				Obtaining $v=\sqrt{u^2+2gh}$ followed by incorrect substitution M0M1M1, unless h is 6 or 7, which is M1M1M1
				11.0 (from h = 6) M1M1M1
				$v=\sqrt{2^2+2\times g\times 7}$ M1M1M1 $=\sqrt{141.2}$ A1 $=11.9$ A1
				$v=\sqrt{4+14g}$ M1M1M1A1 $=11.9$ A1
				$v=\sqrt{2^2+12g}$ M1M1M1
	Total		**7**	

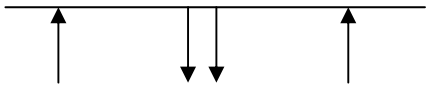
MM2B (cont)

Q	Solution	Marks	Total	Comments
2	$\bar{X} = \dfrac{2\times 9+3\times 2+8\times 3+7\times 6}{2+3+8+7}$	M1		M1: Expression for $\bar{X}$ with no more than one error in the numerator and correct denominator. A1: Correct distance.
	$= \dfrac{90}{20}$ or 4.5	A1		Accept $\dfrac{9}{2}$ or $\dfrac{90}{20}$ or equivalent.
	$\bar{Y} = \dfrac{2\times 6+3\times 4+8\times 8+7\times 11}{20}$	M1		M1: Expression for $\bar{Y}$ with no more than one error in the numerator and correct denominator. A1: Correct distance.
	$= \dfrac{165}{20}$ or 8.25	A1		Accept $\dfrac{33}{4}$ or $\dfrac{165}{20}$ or equivalent .
	$\therefore$ Centre of mass is at (4.5, 8.25)	A1F	5	A1: Correct coordinates; dependent on M1 M1 Do not accept $\dfrac{90}{20}$ etc at this stage. SC4: For final answer (8.25, 4.5) award 4 marks. Moments about *B*, (2.5, 4.25) SC2
	Total		**5**	

MM2B (cont)

Q	Solution	Marks	Total	Comments
3(a)	$\mathbf{a} = \frac{\mathrm{d}v}{\mathrm{d}t}$			
	$\mathbf{a} = -8\mathrm{e}^{-2t}\mathbf{i} + (6-6t)\mathbf{j}$	M1 A1 A1	3	M1: Differentiating with either of the two components correct. Do not need to see **i** or **j**. A1: Correct **i** component. A1: Correct **j** component.
(b)(i)	Using $\mathbf{F} = m\mathbf{a}$			
	$\mathbf{F} = 5\times\{-8\mathrm{e}^{-2t}\mathbf{i} + (6-6t)\mathbf{j}\}$	M1 A1	2	M1: Multiplying their acceleration by 5, even if not a vector. A1: Correct expression.
	$= -40\mathrm{e}^{-2t}\mathbf{i} + (30-30t)\mathbf{j}$			
(ii)	Magnitude of $\mathbf{F}$ is			
	$\{(-40)^2 + (30)^2\}^{\frac{1}{2}}$	M1		M1: Finding magnitude from two non-zero terms. Must add terms and square root. Condone $\{(40)^2 + (30)^2\}^{\frac{1}{2}}$
	$= 50$	A1	2	A1: Correct answer only. In this part, condone lack of negative signs in expression for force in (b) (i).
(c)	When **F** acts due west, **j** component is zero	M1		M1: Putting **j** component equal to zero.
	$30 - 30t = 0$ $t = 1$	A1	2	A1: Correct time.
(d)	$\mathbf{r} = -2\mathrm{e}^{-2t}\mathbf{i} + (3t^2 - t^3)\mathbf{j} + \mathbf{c}$	M1 A1 A1		M1: Integration with either of the two components correct. Do not need to see **i** or **j**. A1: Correct **i** component. A1: Correct **j** component. Condone lack of + **c**
	When $t = 0$, $\mathbf{r} = 6\mathbf{i} + 5\mathbf{j}$ $\therefore$ $\mathbf{c} = 8\mathbf{i} + 5\mathbf{j}$	dM1		dM1: Finding **c** using $6\mathbf{i} + 5\mathbf{j}$ and $\mathrm{e}^0 = 1$.
	$\therefore$ $\mathbf{r} = (8 - 2\mathrm{e}^{-2t})\mathbf{i} + (5 + 3t^2 - t^3)\mathbf{j}$	A1	5	A1: Correct position vector.
	Total		**14**	

MM2B (cont)

Q	Solution	Marks	Total	Comments
4(a)	 R_C or C or $38g$; $65g$ Or 637 ; $17g$ Or 166.6 ; R_D or D or $44g$	B1 B1	2	B1: Two weights correct and in correct relative positions. B1: Two upward reaction forces, labelled differently. Note all forces must be shown as arrows and have labels. Condone use of $g = 9.81$ for calculating weights.
(b)	Taking moments about C $3 \times 17g + 2.6 \times 65g = 44g \times d$	B1 M1 A1		B1: Seeing 2.6. M1: Three term moment equation including $17g$, $65g$ and $44g$ or 17, 65 and 44, with different distances for the $17g$ and $65g$. A1: Correct equation.
	$44d = 220$ $d = 5$			
	Distance is $5 - 4.6 = 0.4$ m	A1	4	A1: Correct final answer.
	Alternative $R_C = 38g$ Taking moments about D $38g(4.6 + x) = 65g(2 + x) + 17g(1.6 + x)$ $174.8 - 130 - 27.2 = 44x$ $x = 0.4$	(B1) (M1) (A1) (A1)		Could take moments about any other point
(c)	Gravitational force (centre of mass or weight) at mid-point (or centre) of the plank	E1	1	E1: Correct explanation.
	Total		**7**	
5(a)	$90\,\text{km h}^{-1} = 90 \times \frac{1000}{3600}\,\text{m s}^{-1}$ $= 25\ \text{m s}^{-1}$ **AG**	B1	1	B1: Must see $\frac{1000}{3600}$ or $\frac{1000}{60^2}$.
(b)	Resistance is 5000 N	B1		B1: Obtaining 5000.
	Using power = force × velocity = 5000 × 25	M1		M1: Using $P = Fv$ with 25 and their F.
	= 125 kW	A1	3	A1: Correct final answer, must be in kW. 125W or 125 000 W B1M1 125 B1M1A1
	Total		**4**	

MM2B (cont)

Q	Solution	Marks	Total	Comments
6(a)	Using $F = ma$ $-2mv^{\frac{5}{4}} = m\frac{dv}{dt}$			
	$\therefore \frac{dv}{dt} = -2v^{\frac{5}{4}}$ **AG**	B1	1	B1: Must see $-2mv^{\frac{5}{4}} = m\frac{dv}{dt}$ or $-2mv^{\frac{5}{4}} = ma$ and correct final answer.
(b)	$\int \frac{dv}{v^{\frac{5}{4}}} = -2\int dt$	M1		M1: Two integrals with one in the form $\int f(v)dv$ where $f(v) = v^{\pm\frac{5}{4}}$ or $v^{\pm\frac{4}{5}}$. The other integral must not contain v terms.
	$-\frac{4}{v^{\frac{1}{4}}} = -2t + c$	A1		A1: Correct expression. Condone lack of + c for this A1, but no subsequent marks if no c.
	When $t = 0$, $v = 16 \Rightarrow c = -2$	dM1 A1		dM1: Using $t = 0$ and $v = 16$ to find c. A1: Obtaining $c = -2$.
	$-\frac{4}{v^{\frac{1}{4}}} = -2t - 2$ $v^{\frac{1}{4}} = \frac{2}{1+t}$			
	$v = \left(\frac{2}{t+1}\right)^4$ **AG**	A1	5	A1: Correct final answer. Must see $v^{\frac{1}{4}} = \frac{2}{1+t}$ or $v^{-\frac{1}{4}} = \frac{1+t}{2}$ or $\frac{1}{v^{\frac{1}{4}}} = \frac{1+t}{2}$ Or if they obtain $v = \left(\frac{2}{t+c}\right)^4$ $v = 16, t = 0 \Rightarrow 16^{\frac{1}{4}} = \frac{2}{c}$, condone $c = 1$ (no other root considered)
	Total		**6**	

MM2B (cont)

Q	Solution	Marks	Total	Comments
7(a)	Resolving vertically $T\cos 30 + 20\cos 50 = 4g$	M1A1 A1		M1: Three terms, which must include $4g$, $T\cos\theta$ or $T\sin\theta$ and $20\cos\theta$ or $20\sin\theta$, where θ = 30, 40, 50 or 60. A1: Correct terms A1: Correct equation
	$T\cos 30 = 26.344$ $T = 30.4$ N	A1	4	A1: Correct final answer. Accept 30.4 or AWRT 30.42. Accept 30.4 or 30.5 or AWRT 30.45 from $g = 9.81$.
(b)	Horizontally: $\frac{mv^2}{r} = 20\cos 40 + T\cos 60$	M1 A1F		M1: Three terms, which must include $\frac{mv^2}{r}$ or $\frac{4\times 5^2}{r}$, $T\cos\theta$ or $T\sin\theta$ and $20\cos\theta$ or $20\sin\theta$, where θ = 30, 40, 50 or 60. A1F: Correct equation. May include T, m and v.
	$\frac{4\times 5^2}{r} = 30.53$	dM1		dM1: Substitution of values for T, m and v. Equation of form $\frac{4\times 5^2}{r}$ = number
	$r = 3.27537$ $= 3.28$	A1	4	A1: Correct answer. Accept 3.27 or 3.28 or AWRT 3.28. Accept 3.27 or AWRT 3.27 from $g = 9.81$. **Note: Do not accept $\frac{mv^2}{r} = 30.4$ or similar.**
	Total		**8**	

MM2B (cont)

Q	Solution	Marks	Total	Comments
8(a)	Using conservation of energy (lowest and highest points)			
	$\frac{1}{2}mu^2 = \frac{1}{2}mv^2 + mg(2a)$	M1A1		M1: Equation for conservation of energy with two KE terms and one or two PE terms. May see m or 0.3. A1: Correct equation.
	$u^2 = v^2 + 4ag$			
	For complete revolutions, $v > 0$			
	$\therefore u^2 > 4ag$			
	$u > 2\sqrt{ag}$ **AG**	A1	3	A1: Correct result with statement of $v > 0$ and some intermediate working including $4ag$ term.
	Or			
	Use of PE at top and KE at B	(M1)		
	Correct PE and KE	(A1)		
	Correct deduction including inequality	(A1)		
(b)(i)	C of Energy			
	$\frac{1}{2}mu^2 = \frac{1}{2}mv^2 + mga(1 + \sin\theta)$	M1A1		M1: Equation for conservation of energy with two KE terms and one or two PE terms including a $\sin\theta$. May see m or 0.3. A1: Correct equation.
	$v^2 = \left(\sqrt{\frac{9}{2}ag}\right)^2 - 2ga(1 + \sin\theta)$			
	$= \frac{5}{2}ag - 2ag\sin\theta$			
	Resolve radially			
	$\pm R = -mg\sin\theta + \frac{mv^2}{a}$	M1A1		M1: Three term equation from resolving radially. Correct three terms, but condone signs and replacement of sin by cos. A1: Correct equation. May see m or 0.3.
	$= -mg\sin\theta + \frac{5}{2}mg - 2mg\sin\theta$			
	$= -3mg\sin\theta + \frac{5}{2}mg$			
	$= \left(\frac{3}{4} - \frac{9}{10}\sin\theta\right)g$ **OE** (must include g)	A1	5	A1: Simplified correct final answer. Condone $\left(\frac{9}{10}\sin\theta - \frac{3}{4}\right)g$
(ii)	When this reaction is zero,			
	$\left(\frac{3}{4} - \frac{9}{10}\sin\theta\right)g = 0$	M1		M1: Putting their reaction equal to zero.
	$\sin\theta = \frac{5}{6}$			
	θ is 56.4° above horizontal	A1	2	A1: Correct angle. Accept AWRT 56.44.
	Total		**10**	

MM2B (cont)

Q	Solution	Marks	Total	Comments
9(a)	EPE $= \frac{\lambda x^2}{2l}$			
	$= \frac{1800\times(4)^2}{2\times 6}$	B1 M1		B1: Extension = 4. M1: Substitution of 6, 1800 and their extension into EPE formula.
	$= 2400$ J	A1	3	A1: Correct EPE
(b)				
	$\frac{1800\times(x)^2}{2\times 6} = \frac{1}{2}\times 200\times 8^2$	M1		M1: Equation with EPE and KE terms, both correct.
	$x^2 = 42.67$ $x = 6.53$ m	A1		A1: Correct extension. Accept $\frac{8\sqrt{6}}{3}$ or 6.53 or AWRT 6.532.
	Distance from O is 12.5 m	A1	3	A1: Correct distance. Accept 12.5 or AWRT 12.53.
(c)	Resistance force is 800 N Work done by resistance force is $800 \times (x + 6)$	B1		B1: Correct work done by resistance force.
	C of Energy gives $\frac{1800\times(x)^2}{2\times 6} + 800\times(x+6) = \frac{1}{2}\times 200\times 8^2$	M1A1 A1		M1: Three energy terms, KE, Work Done and EPE. A1: EPE correct. A1: Correct equation.
	$150x^2 + 800(x+6) = 6400$ $3x^2 + 16x - 32 = 0$ or $150x^2 + 800x - 1600 = 0$	A1		A1: Correct quadratic equation with no brackets.
	$x = \frac{-16 \pm \sqrt{16^2 + 4\times 3\times 32}}{2\times 3}$	dM1		dM1: Solving their quadratic equation with correct formula and correct substitution
	$x = 1.5497$	A1		A1: Correct positive solution stated. Accept 1.54 or 1.55 or AWRT 1.55.
	Distance from O is 7.55 m	A1	8	A1: Correct distance from O. Accept 7.55 or 7.54 or AWRT 7.55.
	OR Use d for distance: $800 \times d$	(B1)		B1: Correct work done by resistance force.
	C of Energy gives $\frac{1800\times(d-6)^2}{2\times 6} + 800\times d = \frac{1}{2}\times 200\times 8^2$	(M1A1) (A1A1)		M1: Three energy terms, KE, Work Done and EPE.
	$150d^2 - 1000d - 1000 = 0$ $3d^2 - 20d - 20 = 0$	(A1)		A1: Seeing $d - 6$ in EPE A1: EPE correct. A1: Correct equation.
	$x = \frac{-20 \pm \sqrt{20^2 + 4\times 3\times 20}}{2\times 3}$	(dM1)		A1: Correct quadratic equation with no brackets.
	$d = 7.55$	(A1)		dM1: Solving their quadratic equation. A1: Correct distance from O. Accept 7.55 or 7.54 or AWRT 7.55.
	Total		**14**	
	TOTAL		**75**	

Version 1.0

General Certificate of Education (A-level)
January 2012

Mathematics MM2B

(Specification 6360)

Mechanics 2B

Final

Mark Scheme

Mark schemes are prepared by the Principal Examiner and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation events which all examiners participate in and is the scheme which was used by them in this examination. The standardisation process ensures that the mark scheme covers the students' responses to questions and that every examiner understands and applies it in the same correct way. As preparation for standardisation each examiner analyses a number of students' scripts: alternative answers not already covered by the mark scheme are discussed and legislated for. If, after the standardisation process, examiners encounter unusual answers which have not been raised they are required to refer these to the Principal Examiner.

It must be stressed that a mark scheme is a working document, in many cases further developed and expanded on the basis of students' reactions to a particular paper. Assumptions about future mark schemes on the basis of one year's document should be avoided; whilst the guiding principles of assessment remain constant, details will change, depending on the content of a particular examination paper.

Further copies of this Mark Scheme are available from: aqa.org.uk

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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.

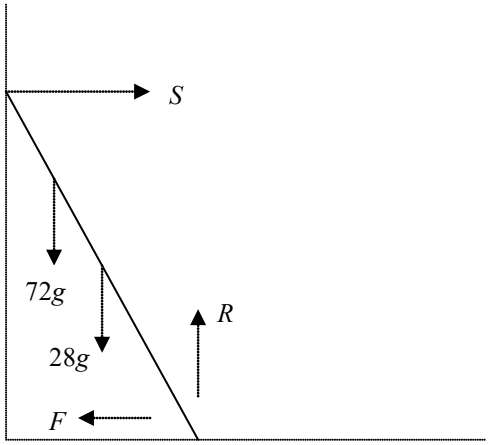
Where the permitted calculator has functions which reasonably allow the solution of the question directly, the correct answer without working earns **full marks**, unless it is given to less than the degree of accuracy accepted in the mark scheme, when it gains **no marks**.

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

MM2B

Q	Solution	Marks	Total	Comments
1(a)	KE at P = $\frac{1}{2} \times 25 \times 60^2$	M1		correct
	= 45 000 J	A1	2	
(b)	change in PE as it falls:			
	$mgh = 25 \times 9.8 \times 34$	M1		correct
	= 8330	A1	2	ISW
(c)(i)	using Conservation of Energy:			
	KE at ground = 8330 + 45 000	M1		ft C's (a) and (b)
	= 53 330 J	A1	2	ft if M1 gained in (a) and (b)
	(= 53 300 J to 3sf)			
(ii)	speed of packet is $\sqrt{\frac{53330}{\frac{1}{2} \times 25}}$	M1		ft C's (c)(i)
	= 65.3 m s^{-1}	A1	2	CAO
	Total		**8**	
2(a)	using **F** = *m***a**:	M1		ie dividing by 50
	$\mathbf{a} = (6t - 1.2\,t^2)\,\mathbf{i} + 2\,e^{-2t}\,\mathbf{j}$	A1	2	
(b)	$\mathbf{v} = \int \mathbf{a}\,dt$			
	$= (3\,t^2 - 0.4\,t^3)\,\mathbf{i} - e^{-2t}\mathbf{j} + \mathbf{c}$	M1A1		condone lack of + c; M1 one term correct
	when $t = 0$, $\mathbf{r} = 7\,\mathbf{i} - 4\,\mathbf{j}$			
	$\mathbf{c} = 7\,\mathbf{i} - 3\mathbf{j}$	m1A1	4	ft from ke $^{-2t}$ in (b); just adding 7**i** – 4**j**, m0
	$\mathbf{v} = (7 + 3\,t^2 - 0.4\,t^3)\,\mathbf{i} - (3 + e^{-2t})\,\mathbf{j}$			accept unsimplified. CAO
(c)	when $t = 1$, $\mathbf{v} = 9.6\,\mathbf{i} - 3.135\,\mathbf{j}$	M1A1		ft from (b)
	speed = $\sqrt{9.6^2 + 3.135^2}$	m1		
	= 10.1 ms^{-1}	A1	4	ft from (b)
	Total		**10**	

MM2B (cont)

Q	Solution	Marks	Total	Comments
3(a)				accept 'weight of man' or w_m etc for $72g$
	force diagram	B2	2	B1 for any error
(b)(i)	moments about P: $72g \times 6 \times \cos 69 + 28g \times 4 \times \cos 69$ $= S \times 8 \times \sin 69$ $(432g + 112g)\cos 69 = 8\ S \sin 69$	M1 A1A1		3 terms including distance and angles A1 2 correct terms
	$S = 255.8$	A1		accept division seen eg $\frac{544g}{8\tan 69}$
	$= 256$N		4	
(ii)	resolve vertically: $R = 28g + 72g$ $= 100g$	 B1		
	resolve horizontally: $S = F$	 B1		
	using $F = \mu R$: $\mu = 256 \div 100g$ $= 0.261$	 M1 A1	 4	
	Total		**10**	
4(a)	using power = force × velocity power = (25 × 42) × 42 ∴power is 44 100 watts	 M1 A1	 2	
(b)	when speed is 15 m s $^{-1}$, max force exerted is $\frac{44100}{15}$ $= 2940$N	 B1		
	resistance force is $25 \times 15 = 375$N accelerating force is 2940 – 375N $= 2565$	 M1		
	using $F = ma$ $2565 = 1500a$ $a = 1.71$ m s $^{-2}$	 m1 A1	 4	
	Total		**6**	

MM2B (cont)

Q	Solution	Marks	Total	Comments
5	$R = mg$ $F = 0.85\ mg$	M1 A1		
	$\frac{mv^2}{r} = 0.85\ mg$	M1A1		condone $\frac{mv^2}{r} = 0.85R$ (for M1A1)
	$v^2 = 34 \times 0.85 \times g$ $= 283.22$	m1		dependent on both M1s
	$v = 16.8\ \text{m s}^{-1}$	A1	6	
	Total		**6**	
6(a)	using $F = ma$ $0.4\ \frac{dv}{dt} = 2 - 4v$	M1		
	$\frac{dv}{dt} = -10\ (v - 0.5)$	A1	2	Needs line above
(b)	hence $\int \frac{1}{v - 0.5} dv = -\int 10 dt$			
	$\ln(v - 0.5) = -10t + c$	M1A1 m1		M1 for any side integrated correctly m1 for + c (and M1 gained)
	$v - 0.5 = Ce^{-10t}$ $t = 0,\ v = 1$			
	$\therefore C = 0.5$	A1		
	$\therefore v = 0.5 + 0.5e^{-10t}$	A1	5	condone $v = 0.5 + e^{-10t-0.693}$
(c)	when $v = 0.55$, $0.55 = 0.5 + 0.5e^{-10t}$	M1		substitute 0.55 into C's (b), after finding c, possible numerical error
	$10 = e^{10t}$	A1		
	$t = \ln 10 \div 10$ $= 0.230$	A1	3	
	Total		**10**	

MM2B (cont)

Q	Solution	Marks	Total	Comments
7(a)	by conservation of energy:			
	$\frac{1}{2}m(u)^2 = \frac{1}{2}m(v)^2 + mg2a$	M1		M1 for 3 terms, 2 KE and PE; not $v^2 = u^2 + 2as$
	$v^2 = u^2 - 4ag$	A1	2	
(b)(i)	at point A; $T_1 = \frac{m(v)^2}{a} - mg$	M1A1		both signs incorrect M1 either correct M1A1
	at point B; $T_2 = \frac{m(u)^2}{a} + mg$	A1		
	$\frac{T_1}{T_2} = \frac{2}{5}$	B1		or $5T_A = 2T_B$ or $T_1 = 2T$, $T_2 = 5T$
	$5\left(\frac{m(v)^2}{a} - mg\right) = 2\left(\frac{m(u)^2}{a} + mg\right)$	A1		CAO
	$5\left(\frac{m(u^2 - 4ag)}{a} - mg\right)$ $= 2\left(\frac{m(u)^2}{a} + mg\right)$			
	$5u^2 - 20ag - 5ag = 2u^2 + 2ag$	m1		from ratio 2 : 5 or 5 : 2 and one tension equation correct
	$3u^2 = 27ag$			
	$u = 3\sqrt{ag}$	A1	7	condone $\sqrt{9ag}$
(ii)	$u^2 = v^2 + 4ag \rightarrow v = \sqrt{5ag}$	B1		condone $v^2 = 5ag$
	ratio $u : v = 3 : \sqrt{5}$	B1	2	accept 1.34 : 1 or 1 : 0.745
	Total		**11**	

MM2B (cont)

Q	Solution	Marks	Total	Comments
8(a)	using $\text{EPE} = \frac{\lambda x^2}{2l}$,	M1		
	$\text{EPE} = \frac{32 \times 2.2^2}{2 \times 0.8}$	B1		B1 for 2.2
	= 96.8 J	A1	3	
(b)	by C of Energy, when next at rest, EPE (initial) = work done against friction + EPE (when at rest)	M1A1		M1A1 for work done by friction or $5F$
	$96.8 = F \times 5 + \frac{32 \times 1.2^2}{2 \times 0.8}$	M1A1		M1 3 terms; A1 all correct
	$5F = 96.8 - 28.8$	B1		B1 28.8
	frictional force is 13.6N	A1	6	
(c)	at B, tension is $\frac{32 \times 1.2}{0.8}$			
	= 48N	B1		
	tension > friction hence particle starts to move	E1	2	
(d)	when particle is next at rest, work done against friction is EPE at B			
	13.6 × distance = 28.8	M1		
	distance is 2.1176 = 2.12 m	A1	2	CAO
(e)	total distance is 5 + 2.1176	B1	1	ft from M1 in (d) or total distance × 13.6 = original EPE, 96.8
	= 7.12 m			total distance is 7.12 m
	Total		**14**	
	TOTAL		**75**	

Version 1.0

General Certificate of Education (A-level)
June 2012

Mathematics MM2B

(Specification 6360)

Mechanics 2B

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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.

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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.

MM2B

Q	Solution	Marks	Total	Comments
1(a)	KE = $\frac{1}{2}\times 76\times 28^2$	M1		All terms correct
	= 29 792 J	A1	2	
	= 29 800 J			
(b)	Change in PE: mgh = 76 × 9.8 × 31 J	M1		All terms correct
	= 23 088.8 J	A1	2	
	= 23 100 J			
(c)(i)	KE when touches down on ground			
	= 29 792 + 23 088.8J	M1		Their values, one correct
	= 52 881 J			
	= 52 900 J	A1	2	CAO
(ii)	Speed of Alan is $\sqrt{\frac{52881}{\frac{1}{2}\times 76}}$	M1		
	= 37.304 m s $^{-1}$			
	= 37.3 m s $^{-1}$	A1	2	CAO
	Total		**8**	
2(a)(i)	$a = \frac{dv}{dt}$			
	$= 12t + 8e^{-4t}$ m s^{-2}	M1A1	2	M1 for either term correct
(ii)	When t = 0.5, a = $6 + 8\times e^{-2}$	m1		
	= 7.08 m s^{-2}	A1	2	Condone 7.07 SC1 for 7.1 with no working
(b)	Using $F = ma$:			
	$F = 4 \times 7.08$			
	= 28.3 N	B1ft	1	Ft from value awarded A1
(c)	$r = \int v\,dt$	M1		At least two terms correct
	$= 2t^3 + \frac{1}{2}e^{-4t} + 8t + c$	A1		Does not need $+c$
	When $t = 0, r = 0 \rightarrow c = -\frac{1}{2}$	m1		Does not need $c = -\frac{1}{2}$
	$r = 2t^3 + \frac{1}{2}e^{-4t} + 8t - \frac{1}{2}$	A1	4	Need r, s (or words)
	Total		**9**	

MM2B

Q	Solution	Marks	Total	Comments
3(a)(i)	Moments about AB:			
	$1.6 \times 4 + 0.4 \times 8 = 2 \times x$	M1A1		M1 for 2 terms correct
	$x = 4.8$			
	Distance is 4.8 cm	A1	3	
(ii)	Moments about AD:			
	$1.6 \times 6 + 0.4 \times 12 = 2 \times y$	M1A1		M1 for 2 terms correct
	$y = 7.2$			
	Distance is 7.2 cm	A1	3	SC2+SC2 for (a)(i) and (a)(ii) reversed
(b)	Moments about A:			
	$1.6g \times 6 + 0.4\,g \times 12 = 12 \times T_B$	M1A1		M1 for 1 side of equation Or using above: moments about A $12 \times T_B = 7.2 \times 2g$ (ft for M marks)
	$T_B = 1.2g = 11.8$ N	A1		
	Resolve vertically: $T_A + T_B = 2g$	M1		
	$T_A = 0.8g = 7.84$ N	A1	5	1.2 and 0.8 is zero marks If 11.8 and 7.8 as final answer, must lose 1 mark somewhere
	Total		**11**	
4(a)	Distance of particle from the origin is			
	$\{(4\cos 3t)^2 + (4\sin 3t)^2\}^{\frac{1}{2}}$	M1		
	= 4 which is a constant	A1	2	
	$\therefore$ particle is moving in a circle centre the origin			
(b)	$\mathbf{v} = \frac{d\mathbf{r}}{dt}$			
	$\mathbf{v} = -12 \sin 3t\,\mathbf{i} - 12 \cos 3t\,\mathbf{j}$	M1A1	2	M1 for either term correct
(c)	$\mathbf{a} = \frac{d\mathbf{v}}{dt}$			
	$\mathbf{a} = -36 \cos 3t\,\mathbf{i} + 36 \sin 3t\,\mathbf{j}$	M1A1	2	M1 for either term correct
(d)	$\mathbf{a} = -9\,(4 \cos 3t\,\mathbf{i} - 4 \sin 3t\,\mathbf{j})$			
	$= -9\,\mathbf{r}$			
	$k = -9$	B2	2	B1 for 9
(e)	Acceleration is towards centre of circle (or origin)	E1	1	
	Total		**9**	

MM2B

Q	Solution	Marks	Total	Comments
5(a)	For particle *B*, tension in string = $2.1g$ N	B1		
	Resolve horizontally for particle *A*:			
	$m\omega^2 r = T$	M1		Or $m_1\omega^2 r = m_2 g$ or $\frac{m_1 v^2}{r} = m_2 g$ (condone lack of 1 and 2)
	$1.4\omega^2 \times 0.3 = 2.1g$ $\omega^2 = 49$	A1		
	Angular velocity is 7 rad/sec	A1	4	
(b)	Using $v = r\,\omega$: speed = 0.3×7 = 2.1 m s^{-1}	M1 A1	2	Part (b) marks can be awarded in (a)
(c)	Time taken is $2\pi / \omega$	M1		Or $\frac{2\pi r}{2.1}$
	$= \frac{2\pi}{7} = 0.898$ sec	A1	2	Accept $\frac{2\pi}{7}$ (0.895 M1A0)
	Total		**8**	
6(a)	Using conservation of energy:			
	$\frac{1}{2}mv^2 = mgh$	M1		M1 for 2 or 3 terms, 1 KE and 1 or 2 PE
	$\frac{1}{2}mv^2 = mg2.4(1-\cos 18)$	m1A1		m1A1 for finding *h*
	$v^2 = 4.8g(1 - \cos 18)$ $= 2.302$			
	$v = 1.52$ m s^{-1}	A1	4	Condone 1.51
(b)	Resolving vertically:			
	$T = mg + \frac{mv^2}{a}$	M1 A1		Correct 3 terms Correct signs
	$= 22g + \frac{22 \times 2.302}{2.4}$			
	= 236.7… N = 237 N	A1	3	Accept 236 N
	Total		**7**	

MM2B

Q	Solution	Marks	Total	Comments
7(a)	Using $F = ma$:			
	$m\frac{\mathrm{d}v}{\mathrm{d}t} = 49 - 9.8v$ or $5g - 9.8v$	M1		Need to see $m\frac{\mathrm{d}v}{\mathrm{d}t}$ or $5\frac{\mathrm{d}v}{\mathrm{d}t}$ or $a = \frac{49 - 9.81}{5}$
	$\therefore \frac{\mathrm{d}v}{\mathrm{d}t} = -1.96\,(v - 5)$	A1	2	Must see m terms (not a =…)
(b)	$\int \frac{\mathrm{d}v}{v-5} = -1.96 \int \mathrm{d}t$	M1		And one side integrated
	$\ln(v - 5) = -1.96t + c$	A1A1		Need + c, A1 each side
	When $t = 0$, $v = 7 \Rightarrow c = \ln 2$	A1		OE
	$\ln\frac{v-5}{2} = -1.96t$			
	$\frac{v-5}{2} = \mathrm{e}^{-1.96t}$			
	$v = 5 + 2\mathrm{e}^{-1.96t}$	A1	5	CAO
	Total		**7**	

MM2B

Q	Solution	Marks	Total	Comments
8(a)	Initial EPE = $\frac{\lambda x^2}{2l}$			
	$= \frac{120\times(0.5)^2}{2\times5}$	M1		M1 for formula with extension 0.5
	$= 3$ J	A1		
	Initial KE is $\frac{1}{2}\times0.4\times9^2 = 16.2$ J			
	When block is at A, $\frac{1}{2}mv^2 = 3 + 16.2$	M1		
	$v^2 = 19.2 \div 0.2 = 96$			
	Speed is 9.80 m s^{-1}	A1	4	Accept $4\sqrt{6}$; condone 9.79
(b)(i)	Normal reaction is $mg = 0.4g$	M1		
	Frictional force is $0.4\mu g$ N	A1		
	Work done by frictional force is $5.5 \times (0.4\mu g)$ or $2.2\mu g$	m1		
	C of Energy, when at A, gives $19.2 - 5.5 \times (0.4\mu g) = \frac{1}{2}\times0.4\times v^2$	M1		Three terms, eg initial energy in (a) (=3 or 19.2); work done; KE at A.
		A1		Fully correct
	$19.2 - 2.2\mu g = 0.2v^2$			
	$v = \sqrt{96 - 11\mu g}$	A1	6	Ft $v = \sqrt{(v^2 \text{ in (a)}) - 11\mu g}$
(ii)	Speed when rebounding is $\frac{1}{2}\sqrt{96 - 11\mu g}$	B1ft		
	Block is stationary at B			
	$\frac{1}{2}\times0.4\times\frac{1}{4}(96 - 11\mu g) - 2.2\mu g$	M1		Three terms
		A1		Two terms correct with sign
	$= \frac{120\times(0.5)^2}{2\times5}$	A1		Third term correct with sign
	$\frac{1}{2}\times0.1(96 - 11\mu g) - 2.2\mu g = 3$			
	$4.8 - 2.75\mu g = 3$	A1		Or $4.8 - 0.55\mu g - 2.2\mu g = 3$
	$\mu = 0.0668$	A1	6	
	Total		**16**	
	TOTAL		**75**	

Version

General Certificate of Education (A-level)
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Mathematics MM2B

(Specification 6360)

Mechanics 2B

Final

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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

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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.

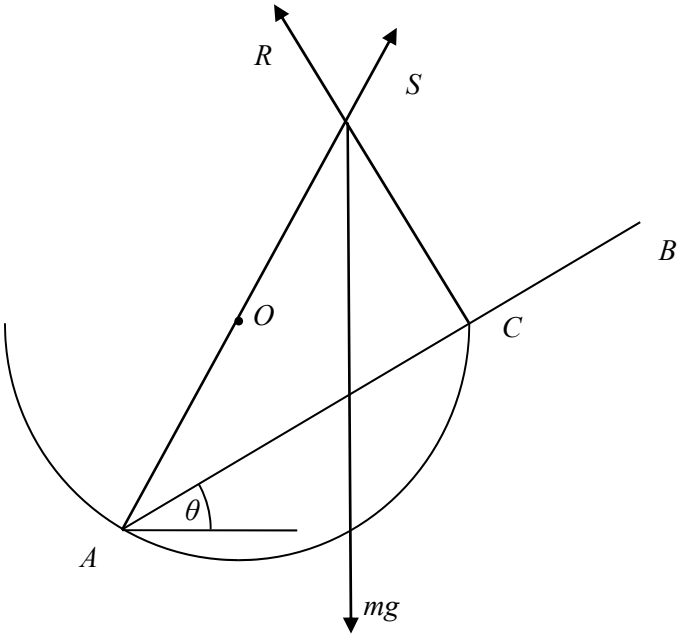
Q	Solution	Marks	Total	Comments
1(a)	KE = $\frac{1}{2}\times 0.16\times 11^2$	M1		
	= 9.68 J	A1	2	
(b)	Change in PE: mgh = 0.16 × 9.8 × 5	M1		
	= 7.84 J	A1	2	
(c)(i)	KE when reached point *B*			
	= 9.68 – 7.84 J	M1		**'(a)' – '(b)'**
	= 1.84 J	A1	2	cao
(ii)	Speed of ball is $\sqrt{\frac{1.84}{\frac{1}{2}\times 0.16}}$	M1		If added in **(c)(i)** 0 marks for **(c)(i)** 14.8 M1A1for **c(ii)**
	= 4.7958 m s^{-1}			
	= 4.80 m s^{-1}	A1	2	Condone 4.8,4.79
	Total		**8**	
2(a)	$\mathbf{a}=\frac{\mathrm{d}\mathbf{v}}{\mathrm{d}t}$	M1		
	$=-4\pi\sin\left(\frac{\pi}{3}t\right)\mathbf{i}-18t\mathbf{j}$	A1	2	M1 for either term correct Accept $-12\times\frac{\pi}{3}\sin\left(\frac{\pi}{3}t\right)\mathbf{i}-18t\mathbf{j}$ condone no **i** in **(a)**
(b)(i)	Using **F** = m**a**:			
	$\mathbf{F}=4\times\left[-4\pi\sin\left(\frac{\pi}{3}t\right)\mathbf{i}-18t\mathbf{j}\right]$	M1		Or either term correct
	$\mathbf{F}=-16\pi\sin\left(\frac{\pi}{3}t\right)\mathbf{i}-72t\mathbf{j}$	A1	2	
(ii)	When t = 3, $\mathbf{F}=4\times[-4\pi\sin(\pi)\mathbf{i}-54\mathbf{j}]$			
	$=-216\mathbf{j}$	B1		
	Magnitude is 216	B1ft	2	ft finding magnitude of their F
(c)	$\mathbf{r}=\int\mathbf{v}\,\mathrm{d}t$	M1		either term correct
	$=\frac{36}{\pi}\sin\left(\frac{\pi}{3}t\right)\mathbf{i}-3t^3\mathbf{j}+\mathbf{c}$	A1		No need for **c** (otherwise cao) Condone $\frac{12}{(\pi/3)}$
	When t = 3, **r** = 4**i** – 2**j**	M1		
	→ –81**j** + **c** = 4**i** – 2**j**			
	c = 4**i** + 79**j**	A1		
	$\mathbf{r}=\left\{\frac{36}{\pi}\sin\left(\frac{\pi}{3}t\right)+4\right\}\mathbf{i}+\{79-3t^3\}\mathbf{j}$	A1	5	cao
	Total		**11**	

Q	Solution	Marks	Total	Comments
3	Force acting against gravity is $mg\sin\theta$			
	Force acting against gravity and resistance is $mg\sin\theta + 8000$	M1		Condone $\cos\theta$ or -1 for M marks
	$= 1500 \times g \times \sin\theta + 8000$			
	$= 8588$ N or 8590 N	A1		
	Using power = force × velocity			
	$= 8588 \times 22$	M1 dep		
	$= 188\,936$ W	A1		
	$= 189$ kW	A1	5	Accept 188.9 or 188
	Total		**5**	
4(a)	Symmetry	E1	1	
(b)	Moments about AB:			
	$300\sigma.15 + 100\sigma.5 + 300\sigma.15 = 700\sigma.x$	M1A1		(condone lack of σ) M1 needs correct total marks
	$x = \frac{9500}{700}$			
	$= \frac{95}{7}$ or 13.6 cm	A1	3	
(c)	Distance from HG is 16.4 cm	B1		
	$\tan\theta = \frac{15}{16.42857}$	M1		Seeing both 15,16.4 and tan
	$= 0.913043$			
	$\theta = 42.3974°$	A1		
	$\theta = 42°$			[48° probably B1, M1]
		A1	4	NB $\frac{13.6}{15}$ etc $\Rightarrow 42°$ no marks
	Total		**8**	

Q	Solution	Marks	Total	Comments
5(a)	Using F = ma:			
	$-4v^{\frac{1}{3}} = 12\dfrac{\mathrm{d}v}{\mathrm{d}t}$	B1		
	$\therefore \dfrac{\mathrm{d}v}{\mathrm{d}t} = -\dfrac{1}{3}v^{\frac{1}{3}}$			
	$-3\int \dfrac{\mathrm{d}v}{v^{\frac{1}{3}}} = \int \mathrm{d}t$	M1		condone $-$, 3 incorrect side
	$-3\times\dfrac{v^{\frac{2}{3}}}{\frac{2}{3}} = t + c$	A1		condone lack of $+c$
	$-\dfrac{9}{2}v^{\frac{2}{3}} = t + c$			
	When $t = 0$, $v = 8 \Rightarrow c = -18$	M1A1		
	$-\dfrac{9}{2}v^{\frac{2}{3}} = t - 18$			
	$v^{\frac{2}{3}} = 4 - \dfrac{2}{9}t$			
	$v = \left(4 - \dfrac{2}{9}t\right)^{\frac{3}{2}}$	A1	6	
(b)	Particle is at rest when $4 - \dfrac{2}{9}t = 0$			
	The value of t is 18	B1	1	
	Total		**7**	
6(a)	Resolve vertically:			
	$T\cos\theta = mg$	M1		M1 for $T\cos\theta$ or $T\sin\theta$ and mg
	$34\cos\theta = 2\times 9.8$	A1		
	$\cos\theta = \dfrac{19.6}{34}$			
	$\theta = 54.8°$	A1	3	
(b)	Resolve horizontally for particle:			
	$\dfrac{mv^2}{r} = T\sin\theta$	M1		M1 for $T\cos\theta$ or $T\sin\theta$
	$v^2 = \dfrac{34\sin 54.8\times 0.8}{2}$	A1 ft from **(a)**		
	$v^2 = 11.113$			
	Speed is 3.33 m s^{-1}	A1	3	Accept 3.34
(c)	Time taken is $2\pi r / v$	M1		Or find ω and use $\dfrac{2\pi}{\omega}$
	$= 1.51$ sec	A1ft	2	
	Total		**8**	

Q	Solution	Marks	Total	Comments
7(a)	Using conservation of energy:			
	$\frac{1}{2}mv^2 = \frac{1}{2}mu^2 - mgh$	M1		for 3 terms, 2 KE and 1 PE
	$\frac{1}{2}\times 3\times v^2 = \frac{1}{2}\times 3\times 4^2 - 3\times g\times 1.2(1-\cos 25)$	M1 A1		M1A1 for finding h [M1 for $1.2(1-\cos 25 \text{ or } \sin 25)$]
	$v^2 = 4^2 - 2.4\times g(1-\cos 25)$			
	$v^2 = 16 - 2.2036$			
	$v = 3.71 \text{ m s}^{-1}$	A1	4	Accept 3.7, 3.70, 3.72
(b)	Resolving radially:			
	$T = mg\cos 25 + \frac{mv^2}{a}$	M1A1		M1 accept $\cos 25$ or $\sin 25$, + or − sign and $\neq 2$
	$= 26.645 + 34.491$			A1 fully correct and substituted
	$= 61.1$ N	A1	3	Accept 61.0 or 61
	Total		**7**	

Q	Solution	Marks	Total	Comments
8(a)	Work done = $\int_0^e \frac{\lambda x}{l}\,\mathrm{d}x$	M1		SC1 $\int_0^e \frac{\lambda e}{l}\,de$
	$= \left[\frac{\lambda x^2}{2l}\right]_0^e$	A1		SC1 $\int \frac{\lambda x}{l}\,dx$ with no limits
	$= \frac{\lambda e^2}{2l}$	A1	3	
(b)(i)	Using $T = \frac{\lambda x}{l}$:			
	$5g = \frac{392x}{1.6}$	M1		
	$x = \frac{5g \times 1.6}{392}$			
	$= 0.2$			
	Extension is 0.2 m	A1	2	
(ii)	When extension is 0.6 m, EPE $= \frac{\lambda x^2}{2l}$	B1		B1 for 0.6
	$= \frac{392 \times (0.6)^2}{2 \times 1.6}$	M1		
	$= 44.1$ J	A1	3	
(iii)	Let y metres be distance particle is above A.			
	C of energy, when particle has speed 0.8 m s^{-1}, gives			
	$5 \times g \times y + \frac{392 \times (0.6 - y)^2}{2 \times 1.6} + \frac{1}{2} \times 5 \times 0.8^2$	M1A1		M1 4 terms, 2 correct M1A1 4 terms, 3 correct M1A2 4 terms correct
	$= \frac{392 \times (0.6)^2}{2 \times 1.6}$	A1F		Ft answer to **(b)(ii)**
	$49y + 122.5(0.6 - y)^2 + 1.6 = 122.5 \times 0.6^2$ $49y - 147y + 122.5y^2 + 1.6 = 0$ $122.5y^2 - 98y + 1.6 = 0$			
	$y = \frac{98 \pm \sqrt{98^2 - 4 \times 122.5 \times 1.6}}{2 \times 122.5}$			
	$y = \frac{98 \pm 93.9148}{245}$			
	$= 0.016674$ and 0.7833	A1		if x used instead of $0.6 - y$, A1 here for $x = 0.5833...$
	Speed first becomes 0.8 when $y = 0.0167$	E1	5	
	Total		**13**	

Q	Solution	Marks	Total	Comments
9(a)	Smooth, hence reaction is perpendicular to possible movement	E1	1	
(b)		B2	2	B1 for 2 forces correct
(c)	Resolving along the rod:			Or geometrically:
	$S\cos\theta = mg\sin\theta$	M1A1		three forces act through a point B1 M1 is for 2 or 3 terms; 1 term correct (could be horizontal force at C used)
	Moment about C: $S\,2a\cos\theta\,.\sin\theta$			[forces act through point D]
	$= mg(2a\cos\theta - \frac{1}{2}l)\cos\theta$	M1A1		$AD\cos 2\theta = \frac{l}{2}\cos\theta$ M1A1
	$4a.S\sin\theta = mg(4a\cos\theta - l)$			$AD\cos\theta = 2a\cos\theta$ M1
	Dividing: $4a\tan\theta = \frac{4a\cos\theta - l}{\sin\theta}$			$l = \frac{4a\cos 2\theta}{\cos\theta}$ A1
	$l = 4a\cos\theta - 4a\sin\theta\tan\theta$			
	$l = \frac{4a\cos 2\theta}{\cos\theta}$	A1	5	

Q	Solution	Marks	Total	Comments
9 cont	**or** Resolving perpendicular to S: $R\cos\theta = mg\cos 2\theta$ Moments about A: $R\ 2a\cos\theta = mg\frac{1}{2}l\cos\theta$ $4a\ R = mgl$ $4amg\ \cos 2\theta = mgl\cos\theta$ $l = \dfrac{4a\cos 2\theta}{\cos\theta}$ **or** Resolving horizontally: $R\sin\theta = S\cos 2\theta$ Resolving vertically: $R\cos\theta + S\sin 2\theta = mg$ Moments about A: $R\ 2a\cos\theta = mg\frac{1}{2}l\cos\theta$ $4a\ R = mgl$ $R\cos\theta + R\dfrac{\sin\theta}{\cos 2\theta}\sin 2\theta = 4a\dfrac{R}{l}$ $l = \dfrac{4a\cos 2\theta}{\cos\theta}$	(M1A1) (M1A1) (A1) (M1A1) (M1A1) (A1)		Both attempted for M1 Both correct for A1
	Total		**8**	
	TOTAL		**75**	

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General Certificate of Education (A-level)
June 2013

Mathematics MM2B

(Specification 6360)

Mechanics 2B

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

Q	Solution	Marks	Total	Comments
1(a)	$v = \frac{ds}{dt}$	M1		
	$= 24t^2$	A1	2	
(b)	$a = \frac{dv}{dt}$			
	$= 48t$	B1		
	When $t = 2$, $a = 96$	B1		
	Using $F = ma$			
	$F = 3 \times 96$	M1		
	$= 288$ N	A1	4	
	Total		**6**	
2(a)	$\text{KE} = \frac{1}{2} \times 52 \times 7^2$	M1		
	$= 1274$ J	A1	2	
	$= 1270$ J			
(b)	Change in PE: $mgh = 52 \times 9.8 \times 8$	M1		
	$= 4076.8$	A1		
	Carol's KE when she reaches the net			
	$= 1274 + 4076.8$ J $= 5350.8$ J			
	$= 5350$ J	A1	3	
(c)	Speed of Carol is $\sqrt{\frac{5350.8}{\frac{1}{2} \times 52}}$	M1A1		
	$= 14.3457$ m s^{-1}			
	$= 14.3$ m s^{-1}	A1	3	
	Total		**8**	
3(a)	$v = \int a \, dt$			
	$= (20t^2 + t^3)\mathbf{i} - 5e^{-4t}\mathbf{j} + \mathbf{c}$	M1A1		M1 for either term correct Condone no '+ **c**'
	When $t = 1$,			
	$6\mathbf{i} - 5e^{-4}\mathbf{j} = 21\mathbf{i} - 5e^{-4}\mathbf{j} + \mathbf{c}$	M1		Finding '+ **c**'; not using $\mathbf{c} = 6\mathbf{i} - 5e^{-4}\mathbf{j}$
	$\mathbf{c} = -15\mathbf{i}$	A1		
	$\mathbf{v} = (20t^2 + t^3 - 15)\mathbf{i} - 5e^{-4t}\mathbf{j}$	A1	5	
(b)	When $t = 0$, $\mathbf{v} = -15\mathbf{i} - 5\mathbf{j}$	M1		
	Speed is $\sqrt{15^2 + 5^2}$	M1		
	$= 15.8$ m s^{-1}	A1	3	Accept $5\sqrt{10}$
	Total		**8**	

Q	Solution	Mark	Total	Comments
4(a)(i)	Moments about Q $2.2 \times 25g = T_P \times 4.2$ $T_P = 13.095 \times g$ $T_P = 128$ N Resolving vertically $T_P + T_Q = 25g$ or 245 $T_Q = 117$ N	M1 A1 A1 M1 A1	 5	**Or** Moments about any point M1A1 Moments about any other point M1 T_P A1 ; T_Q A1
(ii)	Weight of plank acts through its centre	E1	1	
(b)	Resolve vertically $T_P + T_Q = (25 + m)g = 2T_P$ Moments about B $T_P \times 5 + T_Q \times 0.8 = 25g \times 3$ $(25 + m)g \times 2.9 = 25g \times 3$ $2.9mg = 25g \times 0.1$ $29m = 25$ $m = 0.862$ or $\frac{25}{29}$	M1 A1 M1 A1 M1 A1	 6	Could use T rather than T_P, T_Q **Or** Moments about Q $T_P \times 4.2 = 25g \times 2.2 - mg \times 0.8$ $\frac{1}{2} \times (25 + m)g \times 4.2$ $= 25g \times 2.2 - mg \times 0.8$ $2.9mg = 25g \times 0.1$ $29m = 25$ **OR** Moments about any point M1A1 Moments about any other point M1A1 Solution M1A1
	Total		**12**	
5	In limiting equilibrium, using $F = \mu R$ Frictional force is $0.2 \times mg$ Resolve horizontally $\frac{m \times 15^2}{r} = 0.2 \times mg$ $r = \frac{15^2}{0.2 \times g}$ $= 114.79$ $= 115$	 M1A1 M1 A1	 4	
	Total		**4**	

Q	Solution	Marks	Total	Comments
6(a)	Using $F = ma$			
	$1600\frac{dv}{dt} = 4000 - 40v$	M1		
	$\frac{dv}{dt} = \frac{4000 - 40v}{1600}$			
	$\frac{dv}{dt} = \frac{100 - v}{40}$	A1	2	
(b)	$40\frac{dv}{100 - v} = dt$	B1		
	$40\int \frac{dv}{100 - v} = \int dt$	M1		
	$-40\ln(100 - v) = t + c$	A1		Condone lack of '+ c'
	When $t = 0$, $v = 0 \Rightarrow c = -40\ln 100$	M1A1		
	$-40\ln(100 - v) = t - 40\ln 100$			
	$t = 40\ln\frac{100}{100 - v}$			
	$e^{\frac{t}{40}} = \frac{100}{100 - v}$			
	$v = 100 - 100e^{-\frac{t}{40}}$ or $100(1 - e^{-\frac{t}{40}})$	A1	6	
	Total		**8**	
7	Using power = force × velocity			
	$240\,000 = F \times 20$	M1A1		
	$F = 12\,000$	A1		
	Accelerating force is $12\,000 - 5000$			
	$= 7000$ N	B1		
	Using $F = ma$	M1		
	$22\,000a = 7000$			
	$a = 0.318$ or $\frac{7}{22}$ m s^{-2}	A1	6	
	Total		**6**	

Q	Solution	Marks	Total	Comments
8(a)	Using conservation of energy:			
	$\frac{1}{2}m(5u)^2 = \frac{1}{2}m(2u)^2 + 2amg$	M1A1		M1 for 3 [or 4] terms: 2 KE and 1[or 2] PE
	$\frac{1}{2}\times 21\times u^2 = 2ag$	M1		M1A1 for finding h
	$u = \sqrt{\frac{4ag}{21}}$	A1	4	
(b)	Using conservation of energy with speed at point S to be V:			**Or**
	$\frac{1}{2}m(5u)^2 = \frac{1}{2}m(V)^2 + amg(1+\cos 60)$	M1		$\frac{1}{2}m(V)^2 = amg(1-\cos 60°) + \frac{1}{2}m\left(2\sqrt{\frac{4ag}{21}}\right)^2$
	$\frac{1}{2}mV^2 = \frac{1}{2}m(5u)^2 - 1\frac{1}{2}amg$			
	$V^2 = 25\times\left(\frac{4ag}{21}\right) - 3ag$			
	$V^2 = \frac{37ag}{21}$	A1		
	Resolving radially at point S:			
	$R = -mg\cos 60 + \frac{m(V)^2}{a}$	M1A1		
	$= -\frac{1}{2}mg + \frac{37mg}{21}$			
	$= \frac{53}{42}mg$ or $1.26mg$	A1	5	
	Total		**9**	

Q	Solution	Marks	Total	Comments
9(a)(i)	Using $T = \frac{\lambda x}{l}$			
	Tension in string is $\frac{60 \times 2.5}{3}$			
	$= 50$ N	B1		
	Frictional force on A [using $F = \mu R$] is $0.4 \times 8 \times g$			
	$= 31.36$ N	B1		
	which is less than tension in string			
	Thus particle A moves towards the hole	B1	3	
(ii)	Gravitational force on B is $3g = 29.4$	B1		
	which is less than tension in string			
	Thus particle B moves towards the hole	B1	2	
(b)	$\text{EPE} = \frac{\lambda x^2}{2l}$			
	$= \frac{60 \times (2.5)^2}{2 \times 3}$	M1		
	$= 62.5$ J	A1	2	
(c)	Let x be the distance B has moved upwards			
	Work done by friction [on A] is 31.36×0.46	M1		
	$= 14.4256$			
	$= 14.43$ J	A1		
	When B is at rest, extension is $2.04 - x$			
	$\text{EPE} = \frac{\lambda x^2}{2l}$			
	$= \frac{60 \times (2.04 - x)^2}{2 \times 3}$			
	$= 10(2.04 - x)^2$ J	B1		
	C of Energy, when particle B is at rest, gives			
	$3 \times g \times x + 10(2.04 - x)^2 + 14.4256$	M1A1		
	$= 62.5$	A1		
	$10x^2 - 11.4x - 6.4584 = 0$			Or $10x^2 - 11.4x - 6.454 = 0$
	$x = 1.555$ and -0.415			
	Particle B is first at rest when it has moved upwards 1.56 m	A1	7	Accept 1.55
	Total		**14**	
	TOTAL		**75**	

A-LEVEL
MATHEMATICS

Mechanics 2B – MM2B
Mark scheme

6360
June 2014

Version/Stage: Final V1.0

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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)

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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.

Q	Solution	Mark	Total	Comment
1 (a)	KE = $\frac{1}{2}\times 3\times 8^2$	M1		
	= 96 J	A1	2	
(b)	Change in PE;			
	mgh = 3 × 9.8 × 13	M1		
	= 382.2 J	A1	2	
	= 382 J			SC1 380
(c)(i)	Salmon's KE when it reaches the sea			(a) + (b)
	= 96 + 382.2J	M1		[both non zero]
	= 478 J	A1	2	Ft [one correct]
(ii)	Speed of salmon is $\sqrt{\frac{478.2}{\frac{1}{2}\times 3}}$	M1		
	= 17.8549 ms^{-1}			
	= 17.9 ms^{-1}	A1	2	Accept 17.8,17.85,17.855, 17.86
	Total		**8**	

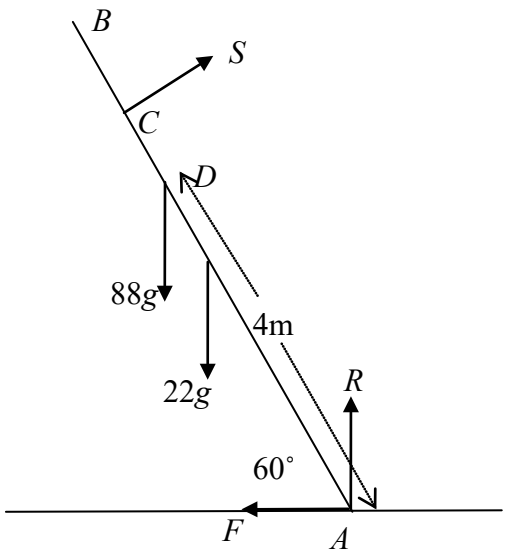
Q	Solution	Mark	Total	Comment
2 (a)	Using $F = ma$	M1		M1 either term correct oe
	$\boldsymbol{a} = 4e^{-2t}\,\mathbf{i} - 2t^3\mathbf{j}$	A1	2	
(b)	$v = \int a\,dt$	M1		M1 for either term correct
	$= -2\,e^{-2t}\,\mathbf{i} - \frac{1}{2}t^4\mathbf{j} + \mathbf{c}$	A1		Ft from (a) oe Condone no + **c**
	When t = 0, $-7\mathbf{i} - 4\mathbf{j} = -2\,\mathbf{i} + \mathbf{c}$	m1		
	$\mathbf{c} = -5\,\mathbf{i} - 4\,\mathbf{j}$			
	$\mathbf{v} = -(2\,e^{-2t} + 5)\mathbf{i} - (\frac{1}{2}t^4 + 4)\mathbf{j}$	A1	4	CAO
(c)	When $t = 0.5$,			
	$\mathbf{v} = -(2\,e^{-1} + 5)\mathbf{i} - (\frac{1}{2} \times 0.5^4 + 4)\mathbf{j}$	M1A1		
	$= -5.7357\mathbf{i} - 4.03125\,\mathbf{j}$			
	Speed is $\sqrt{5.736^2 + 4.031^2}$	M1		
	= 7.0106...	A1	4	
	or 7.01 ms^{-1}			MR A0 in (a) and last part of (c) Do not accept 7
	Total		**10**	

Q	Solution	Mark	Total	Comment
3	$\overline{X} = \frac{4\times11+3\times3+7\times5+1\times1+5\times7}{4+3+7+1+5}$	M1		M1 for at least 4 correct
	$= \frac{124}{20}$ or 6.2	A1		Accept $\frac{124}{20}$
	$\overline{Y} = \frac{4\times2+3\times6+7\times9+1\times4+5\times6}{20}$	M1		
	$= \frac{123}{20}$ or 6.15	A1		
	∴ Centre of mass is at (6.2, 6.15)	A1ft	5	Do not accept $\frac{124}{20}$ etc (6.15,6.2)M2A2 If lamina not used SC2; ie M1,M1
	Total		**5**	

Q	Solution	Mark	Total	Comment
4 (a)	20 revolutions per minute = 40π radians per minute	B1		or $\frac{1}{3}$ revolutions per second
	= $\frac{2\pi}{3}$ radians per second	B1	2	Accept 2.09
(b)	Resolve vertically $T\cos 35 = 0.8g$	M1 A1		M1 if Tsin35 used; need g
	T= 9.5708… = 9.57 N	A1	3	
(c)	Resolve horizontally $T \sin 35 = m\omega^2 r$	M1		M1 condone Tcos35 and $m\frac{v^2}{r}$
	$9.57 \sin 35 = 0.8 \times r \times \left(\frac{2\pi}{3}\right)^2$	A1 A1		A1 for either side
	$r = 1.564\ldots$	A1	4	
	Radius is 1.56 m			Condone 1.57
	Total		**9**	

Q	Solution	Mark	Total	Comment
5 (a)	Using conservation of energy :			
	$\frac{1}{2}mv_P^2 = \frac{1}{2}mv_Q^2 + 2amg$	M1 A1		M1 for 3 [or 4] terms 2 KE and 1[or 2] PE
	$v_Q^2 = 49ag - 4ag$	M1		
	$v_Q^2 = 45ag$			
	$v_Q = \sqrt{45ag}$	A1	4	$v_Q = 3\sqrt{5ag}$
(b)	At Q, T + mg = $\frac{mv_Q^2}{a}$	M1A1		M1 for correct 3 terms
	T = m. 45 g – mg = 44mg	A1	3	
	Total		**7**	

Q	Solution	Mark	Total	Comment
6 (a)	Using F = ma			
	$-0.3mv^{\frac{1}{3}} = m\frac{dv}{dt}$			
	$\therefore \frac{dv}{dt} = -0.3v^{\frac{1}{3}}$	B1		Need substitution for a
	$\int v^{-\frac{1}{3}}dv = -\int 0.3dt$	M1		
	$\frac{3}{2}v^{\frac{2}{3}} = -0.3\,t + c$	A1A1		A1 for each side no – sign [B0] could get M1A1
	When $t = 0$, $v = 8$,			
	$\therefore c = 6$	A1		
	$\frac{3}{2}v^{\frac{2}{3}} = -0.3\,t + 6$			
	$v^{\frac{2}{3}} = -0.2\,t + 4$			
	$v = (4-0.2t)^{\frac{3}{2}}$	A1	6	
(b)	When $v = 0$, $4 - 0.2\,t = 0$	M1		
	$t = 20$	A1	2	
(c)				
	Integrating $v = (4-0.2t)^{\frac{3}{2}}$,			
	$x = -2(4-0.2t)^{\frac{5}{2}} + d$	M1A1		M1 for power of 5/2 A1 correct [condone no d]
	When t = 0 , x = 0, $\Rightarrow d = 64$			
	$x = -2(4-0.2t)^{\frac{5}{2}} + 64$	A1		
	When speed is 0 ms^{-1}, $t = 20$	M1		
	$x = 64$	A1	5	
	Total		**13**	

Q	Solution	Mark	Total	Comment
7(a)		B2	2	Need 5 forces correct ignore labels B1 for 4 forces correct
(b)	Resolve horizontally F = S cos 30	B1		
	Resolve vertically R = 88g + 22g – S sin 30	B1		
	Moments about A 22g . 3 cos 60 + 88g. 4 cos 60 = 5 S 5S = 209g	M1		M1 for correct moments about any point Resolve once B1 moments twice is M1A1, B1
	S = 41.8g [409.64]	A1		
	Using F = μR; S cos 30 = μ(110g – S sin 30)	M1		R =873.18 F =354.758
	$\mu = \frac{S\sqrt{3}}{220g-S}$ $= \frac{41.8\sqrt{3}}{220-41.8}$ $= \frac{41.8\sqrt{3}}{178.2}$ $= \frac{19\sqrt{3}}{81} = 0.406$	A1	6	Accept 0.407, 0.4063..,0.41 not 0.4
	If S is horizontal, B1 in (a) In (b) M1 [moments], M1 for friction,B1 [2 resolve] 0.439 SC3			
	Total		**8**	

Q	Solution	Mark	Total	Comment
8 (a)	Resolve perpendicular to plane			
	$R = mg\cos 20$	M1		
	$F = \mu R = \mu mg\cos 20$	m1		
	$= 0.8 \times 4 \times g\cos 20$			or 0.8 x 36.8359
	$= 29.468..$	A1	3	
	$= 29.5$ N			
(b)(i)	As particle moves from C to B; Constant friction acts.			
	Work done by friction is $(x + 2) \times 29.468$	B1		
	Change in PE is $mg(x+2)\sin 20$	B1		
	Initial EPE $= \frac{\lambda x^2}{2l}$			
	$= \frac{120\times(x-1.5)^2}{2\times1.5}$			
	$= 40\,(x - 1.5)^2$	B1		
	Final EPE $= \frac{120\times(0.5)^2}{2\times1.5} = 10$	B1		
	$(x + 2) \times 29.468 + mg(x+2)\sin 20$	M1A1		M1 for 4 of these terms at least 2 correct
	$= 40\,(x - 1.5)^2 - 10$	A1		A1for 3 terms correct with correct signs A1 for equation totally correct
	$40x^2 - 162.875x - 5.75 = 0$			
	$x = 4.1069$ or -0.035			
	$\therefore\ x = 4.11$	A1	8	condone 4.10, 4.12, and anything in between,
(ii)	Using $T = \frac{\lambda x}{l}$			
	Tension when particle is at B is $\frac{120\times0.5}{1.5}$			
	$= 40$	B1		
	Frictional force is 29.468			
	Gravitational force is $mg\sin 20$			
	$= 13.407$	B1		For both 29.4. and 13.4.
	Using $F = ma$			
	$4a = 40 + 13.407 - 29.468$	M1		Need all terms & correct
	$= 23.938$			
	Acceleration is 5.984			
	$= 5.98\ ms^{-2}$	A1	4	condone 5.99,5.984..,5.985
	Total		**15**	
	TOTAL		**75**	

A-LEVEL
Mathematics
Mechanics 2B – MM2B
Mark scheme

6360
June 2015

Version/Stage: Version 1.0: Final

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Q	Solution	Mark	Total	Comment
1 (a) (i)	$\mathbf{a} = \frac{d\mathbf{v}}{dt}$ $\mathbf{a} = -8\sin 2t\,\mathbf{i} + 3\cos t\,\mathbf{j}$ Using $\mathbf{F} = m\mathbf{a}$ $\mathbf{F} = 4 \times \{-8\sin 2t\,\mathbf{i} + 3\cos t\,\mathbf{j}\}$ $= -32\sin 2t\,\mathbf{i} + 12\cos t\,\mathbf{j}$	 B1 M1 A1	 **3**	 All correct Multiplying their a by 4 [must be a vector with at least one trig term] CAO
(ii)	When $t = \pi$, $\mathbf{F} = -12\,\mathbf{j}$ Magnitude of $\mathbf{F}$ is 12	B1 B1	 **2**	CAO CAO
(b)	$\mathbf{r} = 2\sin 2t\,\mathbf{i} - 3\cos t\,\mathbf{j} + \mathbf{c}$ When $t = 0$, $\mathbf{r} = 2\mathbf{i} - 14\mathbf{j}$, $\therefore \mathbf{c} = 2\,\mathbf{i} - 11\,\mathbf{j}$ $\therefore \mathbf{r} = (2\sin 2t + 2)\mathbf{i} - (3\cos t + 11)\,\mathbf{j}$	M1 A1 m1 A1 A1	 **5**	M1 one term correct A1 another term correct Condone lack of + c m1 use of + c [$c \neq 0$] A1 CAO CAO [accept uncollected form and ISW [condone lack of brackets but must have – 11j]
	Total		**10**	

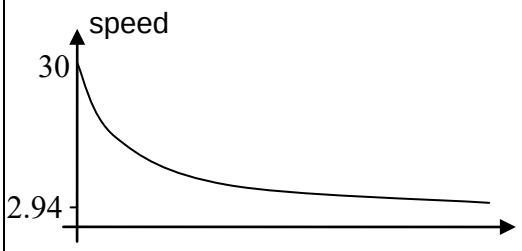
Q	Solution	Mark	Total	Comment
2	Resolve vertically $R = 3g + 4g + 5g + 8g$ $R = 20g$ Taking moments about A $3 \times 4g + AC \times 8g + 6 \times 5g = 4.3 \times 20g$ $42\,g + AC \times 8g = 86g$ $AC = \frac{44}{8}$ Distance AC is 5.5 m	 B1 M1 A1 A1	 4	 **Or** using $\bar{x}\sum m_i = \sum x_i m_i$ $\sum m_i = 20$ B1 **or** moments about any point need 4 non zero terms; could have 20 incorrect all terms either with/without g A1 for all terms correct CAO
	Total		**4**	

Q	Solution	Mark	Total	Comment
3 (a) (i)	P is 2 metres above QR. KE = change in PE = mgh = 32 × 9.8 × 2 = 64 g or 627.2 J = 627 J	B1 M1 A1	 **3**	Do not accept unsimplified expression Correct terms, any value of h used CAO AWRT
(ii)	Speed of Simon is $\sqrt{\frac{627.2}{\frac{1}{2}\times 32}}$ = 6.26 ms $^{-1}$	M1 A1	 **2**	Ft from their a CAO [AWRT] Accept square root 4g or 2 root g
(b)	Work done travelling Q to R is F × 5 R = 32 g Work done = change in energy μ × 32g × 5 = 64 g or 627.2 μ = 0.4	B1 B1 M1 A1	 **4**	Needs F times 5 CAO [or 313.6] Ft their 32g and their 64g [from a] condone incorrect distance [eg, 7, 9, 4, 2] **CAO** **Or** if constant acceleration; B1 for 32 g B1for acceleration = ± 2g/5 or ± 3.92 M1 for μg = 2g/5 A1 for 0.4
	Total		**9**	

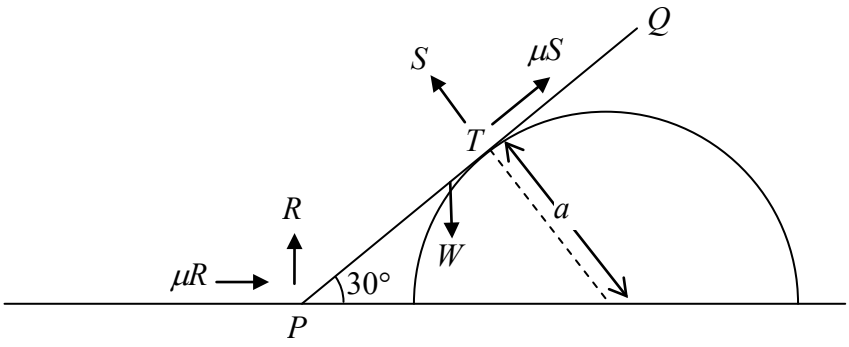
Q	Solution	Mark	Total	Comment
4 (a)	Resolve vertically $T_{AP}\cos 20 = 5g$ $T_{AP} = 52.1$ N	M1A1 A1	 **3**	M1 could be sin 20 A1 correct CAO AWRT
(b)	Resolve horizontally $T_{AP}\sin 20 + T_{BP} = m\frac{v^2}{r}$ $T_{BP} = 5\frac{v^2}{0.6} - \frac{5g}{\cos 20}\sin 20$ $= \frac{25}{3}v^2 - 5g\tan 20$ **AG**	M1 A1 A1	 **3**	Needs all the terms, could be cos 20 Needs sin 20 or cos 70
(c)	$T_{AP} = T_{BP}$ $\frac{25}{3}v^2 - 5g\tan 20 = 52.1$ or $\frac{5g}{\cos 20°}$ $\frac{25}{3}v^2 = 69.9$ $v^2 = 8.388$ or 8.3975 $v = 2.90$	M1A1 A1 A1	 **4**	ft from (a) **CAO PI** Or 2.896.. or 2.8978 CAO 2.9 not accepted
	Total		**10**	

Q	Solution	Mark	Total	Comment
5	900 rpm $= 900 \times \frac{2\pi}{60}$ radians per second $= 30\pi$ radians per second Minimum reactive force is $m\omega^2 r - mg$ $= 0.8 \times (30\pi)^2 \times 0.3 - 0.8g$ $= 2131.83 - 7.84$ Minimum magnitude is 2123.99 $= 2120$ Maximum reactive force is $m\omega^2 r + mg$ $= 0.8 \times (30\pi)^2 \times 0.3 + 0.8g$ $= 2131.83 + 7.84$ Maximum magnitude is 2139.67 $= 2140$	M1 A1 M1 A1 M1 A1		Use of $\frac{2\pi}{60}$ CAO or for v = 9π or 28.27 or 28.3 Needs both terms and correct signs could be using v CAO AWRT Needs both terms and correct signs CAO AWRT [must be clear which is min/max unless in this order]
	Total		**6**	

Q	Solution	Mark	Total	Comment
6	Gravitational force is $mg\sin\theta$	M1		Could accept cos θ
	$= 1400 \times g \times \sin\theta$	A1		CAO
	Accelerating force is *ma*			
	$= 1400 \times 0.2 = 280$	B1		CAO [do not need the 280]
	Total force exerted by engine is			
	$1400 \times g \times \sin\theta + 280 + 4000$			Need 3 terms [gravity, acc force, 4000 could be wrong sign];
	$= 1400 \times g \times \sin\theta + 4280$	B1		CAO
	Power $= 91100$			
	$= (1400 \times g \times \sin\theta + 4280) \times 20$	M1		Needs force [ft] times 20
		M1		M1 for equation need 4 terms 3 correct
	$1400 \times g \times \sin\theta + 4280 = 4555$	A1		or Total force exerted by engine is 91100/20 M1 = 4555 A1
	$1400 \times g \times \sin\theta = 275$			or using F = ma $1400\times0.2 = 91100/20 - 4000 - 1400g\sin\theta$ need 4 terms 3 correct [ignore signs] B1for 1400x0.2;91100/20M1A1 1400gsinθM1A1;form equation M1A1
	$\sin\theta = 0.0200$	**A1**		CAO
	$\theta = 1.15°$	**A1**	**9**	CAO
	Total		**9**	

Q	Solution	Mark	Total	Comment
7(a);	Using $F = ma$			
	$72\frac{dv}{dt} = 72g - 240v$	M1		CAO
	$-\frac{3}{10}\frac{dv}{dt} = v - 2.94$	A1	**2**	AG; Needs M1 above
(b)	Hence $\int \frac{1}{v-2.94}dv = -\frac{10}{3}\int dt$			
	$\ln(v-2.94) = -\frac{10}{3}t + c$	M1A1		M1 for either side integrated correctly A1 for all correct
		m1		m1 for + c
	$v - 2.94 = Ce^{-\frac{10}{3}t}$			
	$t = 0, v = 30$			
	$\therefore C = 27.06$	A1		CAO condone 1353/50 accept c = ln 27.06
	$\therefore v = 2.94 + 27.06e^{-\frac{10}{3}t}$	A1	**5**	CAO condone 27.1m
(c)		B2	**2**	B1 for starting at 30 and basic shape B1 for asymptote of 2.94
	Total		**9**	

Q	Solution	Mark	Total	Comment
8 (a)	When $x \geq 26$, KE is $\frac{1}{2} \times 70 \times v^2$ EPE is $\frac{1456 \times (x-26)^2}{2 \times 26}$ Change in PE is $70 \times g \times x$			
	Conservation of energy : $\frac{1}{2} \times 70 \times v^2 + \frac{1456 \times (x-26)^2}{2 \times 26} = 70\,g \times x$	M1A1 A1		M1 for 3 terms of correct items A1 for 2 of the 3 types of energy are correct [ignore signs] [treat all GPE terms as one term] A1 for all terms correct [70g is 686] Accept 4 terms if PE is on both sides
	$35v^2 + 28(x-26)^2 = 70gx$ $5v^2 + 4(x-26)^2 = 98x$ $5v^2 = 306x - 4x^2 - 2704$	A1	**4**	CAO
(b)	If x is not greater than 26, cord is not stretched. Hence EPE cannot be used unless x is greater than 26.	B1	**1**	Either statement, or cord not taut no EPE
(c)	At maximum value of x, $v = 0$ $\therefore 4x^2 - 306x + 2704 = 0$ $x = 66.3$	M1 A1	**2**	Correct use of v = 0 CAO [bod if give 2 values]
(d)(i)	When speed is a maximum, $a = 0$ tension = gravitational force $\frac{1456 \times (x-26)}{26} = 70\,g$ $x - 26 = 12.25$ $x = 38.25$	M1 A1	**2**	or differentiating (a) $306 - 8x = 0$ Accept 38.2 or 38.3 Could be seen with no working
(ii)	Using (a) and (d)(i) for maximum speed $5v^2 = 11704.5 - 5852.25 - 2704$ $v^2 = 629.65$ Maximum speed is 25.1 ms $^{-1}$	B1	**1**	CAO
	Total		**10**	

Q	Solution	Mark	Total	Comment
9				
	a / PT = tan 30 $PT = \frac{a}{tan30}$	B1		
	Resolve vertically R + S cos 30 + μS sin 30 = W (1)	M1A1		**Or** resolve along the rod μS+ Rsin30 + μRcos 30 =W sin 30 M1 for any 4 terms; must include at least 1 friction term and a trig term
	Resolve horizontally μR + μS cos 30 = S sin 30 (2)	M1A1		Resolve perpendicular to rod S + R cos 30 =μRsin 30 +W cos30 M1 for any 4 terms; must include at least 1 friction term and a trig term If resolve horizontally M1 for any 3 terms; must include a trig term
	Moments about P $PT \times S = W \times a \cos 30$ $\frac{acos30}{sin30} \times S = W \times a \cos 30$ S = W sin 30 or = $\frac{1}{2}$W	B1		Allow,bod, if moments taken about another point
	(2)→μR = W ($sin^2 30 - \mu sin30cos30$) or μR = W ($\frac{1}{4} - \frac{\sqrt{3}}{4}\mu$)			R(sin30 +μ cos 30) = Wsin 30 (1 - μ)
	(1)→ μR + μScos30 +μ^2S sin30 = μW W ($\frac{1}{4} - \frac{\sqrt{3}}{4}\mu$) + μ $\frac{1}{2}$W$\frac{\sqrt{3}}{2}$+$\mu^2 \frac{1}{2}$W $\frac{1}{2}$= μW μ = $sin^2 30 + \mu^2 sin^2 30$ **or** μ = $\frac{1}{4} + \frac{1}{4}\mu^2$ $\mu^2 - 4\mu + 1 = 0$ μ = 2 – √3 or 0.268	m1 A1	**8**	R(cos30 –μ sin 30) =W(cos30 –sin 30) Dividing $\frac{sin30+\mu cos30}{cos30-\mu sin30} = \frac{sin30(1-\mu)}{cos30-sin30}$ m1 for simplifying into a quadratic Dependent on both M1 above condone μ = 2 + √3
	Total		**8**	