

MARK SCHEME for the May/June 2011 question paper
for the guidance of teachers

9709 MATHEMATICS

9709/51

Paper 5, maximum raw mark 50

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1	$0 = (15\sin 40^\circ)t - gt^2/2$ $t = 1.93$	M1 A1 [2]	Accept quoting the formula $T = 2V\sin \theta/g$ for the time of flight
2	(i) $x = 2 \times 0.6\sin(\pi/4)/(3\pi/4) [= 0.36(0)]$ $d^2 = 0.6^2 + 0.36^2 - 2 \times 0.6 \times 0.36\cos(\pi/4)$ $d = 0.429$	B1 M1 A1 [3]	Centre of mass from O
	(ii) $\sin \alpha / 0.36 = \sin(\pi/4)/0.429$ $\alpha = 36.4^\circ$ or 0.635°	M1 A1 A1 [3]	
3	(i) EE gain $= 2 \times 24[\sqrt{(0.6^2 + 0.25^2)} - 0.6]/(2 \times 0.6)$ $m \times 0.5^2/2 = 0.1$ $m = 0.8$ (kg) AG	B1 M1 A1 [3]	EE gain = 0.1 KE loss = EE gain
	(ii) $T = 24 \times (0.65 - 0.6)/0.6 (= 2)$ $2 \times 2 \times 0.25/0.65 = 0.8a$ $a = 1.92$	B1 M1 A1 [3]	Newton's Second Law with attempt to resolve 2T
4	(i) $a = 0$ when $x = 2.5$ $v dv/dx = 15 - 6x$ $\int v dv = \int (15 - 6x) dx$ $v^2/2 = [15x - 3x^2] (+ c)$ $v = 6.12$	B1 M1 A1 M1 A1 [5]	For use of limits 0 and 2.5 or evaluating $c(=0)$
	(ii) Solves $15x - 3x^2 = 0$ $a (= 15 - 6 \times 5) = -15\text{ms}^{-2}$	M1 A1 [2]	$x = 5$. Accept assumption $c = 0$.

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5	(i) $19 \times 0.6/3 + T \times 0.22 = T \times 0.6$ $T = 10$ AG	M1 A1 A1 [3]	Moments about A, 3 terms
	(ii) $10 = \lambda (0.11 + 0.6 - 0.7)/0.7$ $\lambda = 700$	M1 A1 [2]	
	(iii) $F^2 = 10^2 + (19 - 10)^2$ $F = 13.5$ $\alpha = \tan^{-1}(9/10) = 42.(0)^\circ$ (with horizontal)	M1 A1 B1 [3]	Or for $a = \tan^{-1}(10/9) = 48^\circ$ (with vertical)
6	(i) $5 = 0.4(V \sin \alpha) - g \times 0.4^2/2$ $V \sin \alpha = 14.5$ $0.4(V \cos \alpha) = 12$ hence $V \cos \alpha = 30$ $V = \sqrt{30^2 + 14.5^2}$ $V = 33.3$ $\alpha = 25.8^\circ$	M1 A1 B1 M1 A1 B1 [6]	α is the angle of projection Or $\tan \alpha = 14.5/30$ $\alpha = 25.8^\circ$ $V = 33.3$
	(ii) $v = 14.5 - 0.4g$ $\tan \theta = (14.5 - 0.4g)/30$ $\theta = \tan^{-1} 0.35 = 19.3^\circ$ with the horizontal OR $dy/dx = x \tan \alpha - gx^2 \sec^2 \alpha / (2V^2)$ $\tan \theta = \tan 25.8^\circ - 10 \times 12 \sec^2 25.8^\circ / 33.3^2$ $\theta = 19.3^\circ$ with the horizontal	B1 M1 A1 [3] M1 M1 A1	$v = \sqrt{14.5^2 - 2g \times 5}$ $\tan \theta = \sqrt{14.5^2 - 2g \times 5} / 30$ For differentiating the trajectory equation For attempting to substitute x , α and v
7	(i) $0.3 \omega^2 \times 0.5 = T + 0.36 \times 0.3g$ $0.2 \omega^2 \times 0.5 = T - 0.36 \times 0.2g$ $0.1 \omega^2 \times 0.5 = 0.36 \times 0.5g$ $\omega = 6$ $T = 0.3 \times 6^2 \times 0.5 - 0.36 \times 0.3 \times 10$ $T = 4.32$	M1 A1 M1 A1 M1 A1 [6]	Newton's Second Law, 3 terms Both correct
	(ii) (a) $0.2 \omega^2 r = 0.3 \omega^2 (1 - r)$ $r = 0.6$ $r_P = 0.6$ m and $r_Q = 0.4$ m	M1 A1 A1ft [3]	$0.3 \omega^2 R = 0.2 \omega^2 (1 - R)$ $R = 0.4$
	(ii) (b) $0.48 = 0.2v_P^2/0.6$ or $0.48 = 0.3v_Q^2/0.4$ $v_P = 1.2$ $v_Q = 0.8$	M1 A1 A1 [3]	Newton's Second Law radially

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1 (i) $16L\cos\theta = 4 \times 2L$ $\theta = 60^\circ$ or $\pi/3^\circ$ or 1.05°	M1 A1 [2]	Moments about A, accept $L = 1$
(ii) $X = 4\sin 60^\circ$ and $Y = 16 - 4\cos 60^\circ$ $= \sqrt{[(4\sin 60^\circ)^2 + (16 - 4\cos 60^\circ)^2]}$ $= 14.4 \text{ N}$ $\alpha = 76.1^\circ$	B1 M1 A1ft B1 [4]	$\tan\alpha = (16 - 4\cos 60^\circ)/(4\sin 60^\circ)$ ft cv(X,Y). $\alpha = 76.1^\circ$ $R = 14.4 \text{ N}$
2 (i) C of M semi-circle $= 4 \times 0.2/(3\pi)$ $\frac{\pi 0.2^2}{2} \times 4 \times \frac{0.2}{3\pi} = \frac{0.4h}{2} \times \frac{h}{3}$ $= 0.283$	B1 M1 A1 A1 [4]	(0.08488...) Moments about a relevant point.
(ii) $\tan\theta = 0.283/0.2$ $\cos\theta = XD/0.2 (= 0.5774)$ $XD = 0.115 \text{ m}$ OR $\tan\alpha = 0.2/0.283$ $\sin\alpha = XD/0.2 (= 0.5774)$ $XD = 0.115 \text{ m}$	M1 M1 A1 M1 M1 A1 [3]	$\tan\text{ADO} = h/0.2$, $\text{ADO} = 54.75^\circ$ For candidates ADO $\tan\text{DAO} = 0.2/h$, $\text{DAO} = 35.25$ For candidate's DAO
3 (i) $R\cos 30^\circ + T\cos 60^\circ = 0.5g$ $F = 0.5g/(\cos 30^\circ + \cos 60^\circ)$ $T\sin 60^\circ - R\sin 30^\circ = 0.5v^2/0.1$ $v = 0.518 \text{ ms}^{-1}$	M1 A1 M1 A1 [4]	or with $R = T = F$ $F = 3.660... = R = T$ Newton's Second Law with radial acceleration
(ii) $R = 0$ $T\cos 60^\circ = 0.5g$ $T\sin 60^\circ = 0.5 \times \omega^2 \times 0.1$ $\omega = 13.2 \text{ rads}^{-1}$ OR $R = 0$ $mv^2 \sin 30^\circ / r$ or $mr\omega^2 \sin 30^\circ$ $= mg\cos 30^\circ$ $\omega = 13.2 \text{ rad s}^{-1}$	B1 M1 M1 A1 B1 M1 M1 A1 [4]	Could be implied $T = 10 \text{ N}$ Newton's Second Law with radial acceleration Could be implied

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4 (i) $0.24g = 12(x)/0.5$ $x = 0.1$ EITHER $\frac{1}{2} \times 0.24 \times 3^2 + 12 \times (0.8 - 0.5)^2 / (2 \times 0.5) =$ $0.24v^2 / 2 + 12 \times 0.1^2 / (2 \times 0.5)$ $+ 0.24g(0.8 - 0.5 - 0.1)$ $v = 3.61 \text{ ms}^{-1}$ OR $0.24v dv/dx = mg - 12x/0.5$ $0.24v^2 / 2 = 2.4x - 12x^2 / 2 (+ c)$ $v = 3, x = 0.3, c = 1.44$ $x = 0.1, v = 3.61 \text{ ms}^{-1}$	M1	Finds position for equilibrium
	A1	
	M1	Energy balance, initial to equilibrium positions
	A1	
	A1	
	M1	Using Newton's Second Law
	A1	
	A1	Or uses limits
	[5]	
(ii) $0.24 \times 3^2 / 2 + 12 \times (0.8 - 0.5)^2 / (2 \times 0.5) =$ $0.24g(0.8 + x)$ $x = 0.1 \text{ m}$ $s = (0.5 + 0.1) = 0.6 \text{ m}$ OR $\frac{1}{2} \times 12 \times 0.3^2 / 0.5 + \frac{1}{2} \times 0.24 \times 3^2$ $= \frac{1}{2} \times 0.24v^2 + 0.24 \times 10 \times 0.3$ $v = \sqrt{12}$ <i>Either</i> $0 = 12 - 2 \times 10s$ $s = 0.6$ <i>Or</i> $\frac{1}{2} \times 0.24 \times 12 = 0.24 \times 10s$ $s = 0.6$ OR $\frac{1}{2} \times 12 \times 0.3^2 / 0.5 + \frac{1}{2} \times 0.24 \times 3^2$ $= 0.24 \times 10y$ $y = 0.9$ $s = 0.9 - 0.3 = 0.6$	M1	Initial KE + initial EE = Final PE
	A1	
	A1	
	A1	
	M1	Initial EE + Initial KE = (KE + PE) at equilibrium position
	A1	
	M1	Using $v^2 = u^2 + 2as$
	A1	
	M1	Using KE at equilibrium position = Final PE
	A1	
	A1	
	A1	
	[4]	

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5 (i) $dv/dt = -2.5k\sqrt{v}$ $\int v^{-0.5} dv = -2.5k \int dt$ $v^{0.5}/0.5 = -2.5kt (+ c)$ $t = 0, v = 9$ hence $c = 6$ and $t = 2, v = 4$ hence $k = 0.4$ $v = (6 - t)^2/4 = (t - 6)^2/4$ AG	B1 M1 A1 M1 A1 [5]	$0.4dv/dt = -k\sqrt{v}$ LHS = $0.8\sqrt{v}$ $\sqrt{v} = (6 - t)/2$ Uses correct limits
(ii) $x = \int (t - 6)^2/4 dt$ $x = (t - 6)^3/(3 \times 4) (+ c)$ $t = 0, x = 0$ hence $c = 18$ $x(3) = 18 - (3 - 6)^3/12$ $x(3) = 15.75$ OR $\int v^{\frac{1}{2}} dv = \int -dx$ $\frac{2}{3} v^{\frac{3}{2}} = -x (+ c)$ $x = 18 - \frac{2}{3} v^{\frac{3}{2}}$ $x = 15.75$	M1 A1 M1 A1 M1 A1 [4]	$\int (6 - t)^2/4 dt$ $-(6 - t)^3/(3 \times 4) (+ c)$ Or uses limits 0, 3 Accept 15.7 or 15.8 From $mv dv/dx = -k\sqrt{v}$ Using $v = 9, x = 0$ so $c = 18$ Put $t = 3$ to find $v = 2.25$
6 (i) $x = (26\cos 30^\circ) \times 2.3$ $y = (26\sin 30^\circ) \times 2.3 + g \times 2.3^2/2$ $d^2 = 51.8^2 + 56.35^2$ $d = 76.5$ m	B1 B1 M1 A1 [4]	= 51.788.. = 56.35
(ii) $80 = (26\sin 30^\circ)t + 10t^2/2$ $t = 2.91$ s [or $(42.06 - 13)/10$] $x = (2.906 \times 26\cos 30^\circ) = 65.4$ m OR $80 = x \tan 30^\circ + 10x^2/(2 \times 26^2 \times \cos^2 30^\circ)$ $x = 65.4$	M1 A1 A1 M1 M1 A1 [3]	or $v^2 = (26\sin 30^\circ)^2 + 2 \times 10 \times 80$ with $v = 42.06$ = $26\sin 30^\circ + 10t$ solved for t Uses trajectory equation Attempts to solve the quadratic equation
(iii) $v^2 = (26\sin 30^\circ)^2 + 2g \times 80$ $V^2 = (26\sin 30^\circ)^2 + 2g \times 80 + (26\cos 30^\circ)^2$ $V = 47.7$ ms⁻¹ $\alpha = \tan^{-1} [(42.06)/(26\cos 30^\circ)] = 61.8^\circ$	B1 M1 A1 A1 [4]	$v = 42.06$. Accept $v = 26\sin 30^\circ + 10 \times 2.91$ or award correct method to find α Below horizontal (1.08)

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	(ii) $T \cos 30^\circ = 0.4v^2 / 0.2 (= 0.4 \omega^2 \times 0.2)$ $v = 1.86 \text{ ms}^{-1}$	M1 A1ft [2]	Newton's Second Law radially ft only on T from part (i)
2	(i) $20 = gt^2 / 2 \quad (t = 2)$ $x = 15 \times 2$ $x = 30$	M1 DM1 A1 [3]	$y = -gx^2 / (2 \times 15^2)$ use of trajectory equation $-20 = -10x^2 / (2 \times 15^2)$
	(ii) $v = (g \times 2) = 20$ $v = \sqrt{(15^2 + 20^2)}$ $v = 25$	B1 M1 A1 [3]	
3	(i) $F \times 0.4 \sin 20^\circ = 12 \times (0.4 / 2) \cos 20^\circ$ $F = 16.48$ AG	M1 A1 A1 [3]	Moments about O
	(ii) $R = -16.48 + 12 + W$ $-16.48 + 12 + W = 0$ $W = 4.48$	B1 M1 A1 [3]	Equates forces vertically Works with $R = 0$
4	(i) $e = \sqrt{(0.6^2 + 0.32^2)} - 0.4 (= 0.28)$ $0.3g \times 0.32 = 2[\lambda (0.28^2 - 0.2^2)] / (2 \times 0.4)$ $\lambda = 10$	B1 M1, A1 A1 [4]	Extension of half string = 0.28 m PE loss = EE gain
	(ii) $e = \sqrt{(0.6^2 + 0.25^2)} - 0.4$ $0.3g \times 0.25 = 0.3v^2 / 2 +$ $2[10(0.25^2 - 0.2^2)] / (2 \times 0.4)$ $v = 1.12$	B1 M1 A1ft A1 [4]	Extension of half string = 0.25 m PE loss = KE gain + EE gain N.B. 0.25 is extension of half string ft on candidates λ only
5	(i) $T = 6e / 0.3$ $0.2 \times 5^2 (0.3 + e) = 6e / 0.3$ $e = 0.1$	B1 M1, A1 A1 [4]	Newton's Second Law radially
	(ii) $0.2 \omega^2 (0.3 + e) = 6e / 0.3$ $e = 0.06 \omega^2 / (20 - 0.2 \omega^2)$ $20 - 0.2 \omega^2 > 0$ $(0 <) \omega < 10$	M1 A1 M1 A1 [4]	Newton's Second Law radially Other forms acceptable Uses denominator > 0 Disregard lower limit

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6	(i) $0.2a = -0.2g0.5 - 0.4/x^2$ $v dv/dx = -(5 + 2x^{-2})$ AG	M1 A1 [2]	Uses Newton's Second law
7	(ii) $\int v dv = - \int (5 + 2x^{-2}) dx$ $v^2/2 = -5x + 2/x (+c)$ $3^2/2 = -5 \times 0.5 + 2/0.5 + c$ $x = 1$ Travels $(= 1 - 0.5) = 0.5m$ F towards O (0.4) less than maximum friction $(= 1)$	M1 A1 M1 A1 A1 M1, A1 [7]	Separates variables and integrates Hence $c = 3$, or $[v^2/2]_3^0 = [-5x + 2/x]_{0.5}^x$ From $0 = -5x + 2/x = 3$ Compares $0.5 \times 0.2g$ and $0.4/1^2$
7	(i) $OG_{quadrant} = 2\sin(\pi/4) / (3\pi/4)$ $a^2 (a\sqrt{2}/2) = \pi/4 [2\sin(\pi/4) / (3\pi/4)]$ $+ (a^2 - \pi/4)x$ $x = 2\sqrt{2} (3a^3 - 2) / (12a^2 - 3\pi)$	B1 M1 A2 A1 [5]	$8 / (3\sqrt{2}\pi)$ -1 each error, min zero There must be 3 moment terms Other forms acceptable
7	(ii) $x \cos 45^\circ > 1$ $(6a^3 - 4) / (12a^2 - 3\pi) > 1$ $3a^2(2 - a) < 3\pi/2 - 2$ AG True when $a = 1.68$, not when $a = 1.67$ AG	B1 M1 A1 B1 [4]	RHS = 2.712.. compared with LHS = 2.709.. and 2.76.. respectively