
MATHEMATICS

9709/51

Paper 5

October/November 2019

MARK SCHEME

Maximum Mark: 50

Published

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- A** Accuracy mark, awarded for a correct answer or intermediate step correctly obtained. Accuracy marks cannot be given unless the associated method mark is earned (or implied).
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WWW	Without Wrong Working
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Question	Answer	Marks	Guidance
1	Conservation of momentum at $\frac{h}{4}$	B1	
	$\frac{5 \times h}{4} = 3 \times 0.2$	M1	Take moments about <i>A</i>
	$(h =) 0.48 \text{ m}$	A1	
		3	

Question	Answer	Marks	Guidance
2(i)	$-15\sin\theta = 15\sin\theta - 2g$	M1	Use $v = u + at$ vertically
	$(\theta =) 41.8$	A1	
		2	
2(ii)	Vertically: $\frac{v}{15\cos\theta} = \pm \tan 20$	M1	v = vertical velocity
	$v = (\pm) 4.07$	A1	
	$-4.07 = 15\sin 41.8 - gt$	M1	Use $v = u + at$ vertically
	$(t =) 1.41 \text{ s}$	A1	
		4	

Question	Answer	Marks	Guidance
3(i)	$0.25v \frac{dv}{dx} = -kv^2 x^{-2} \rightarrow v \frac{dv}{dx} = -4kv^2 x^{-2}$	B1	AG
		1	
3(ii)	$\int \frac{dv}{v} = -4k \int x^{-2} dx$	M1	Attempt to integrate
	$\ln v = \frac{4k}{x} (+c)$	A1	
	$x = 0.8, v = 3$ hence $c = \ln 3 - 5k$	A1	Finds c
	$\ln v = \frac{4k}{x} + \ln 3 - 5k$	M1	
	$v = 3^{\left(\frac{4k}{x} - 5k\right)}$	A1	
		5	

Question	Answer	Marks	Guidance
4(i)	$x = 30\cos 60t$	B1	Use horizontal motion
	$y = 30\sin 60t - \frac{gt^2}{2}$	B1	Use $s = ut + \frac{gt^2}{2}$ vertically
	$y = \frac{30\sin 60x}{30\cos 60} - \frac{5x^2}{(30\cos 60)^2}$	M1	Attempt to eliminate t
	$y = 1.73x - 0.0222x^2$ or $y = \sqrt{3}x - \frac{x^2}{45}$	A1	
		4	
4(ii)	$x = y$ or $\tan 45 = \frac{y}{x}$	M1	
	$1 = 1.73 - 0.0222x$ or $1 = \sqrt{3} - \frac{x}{45}$	M1	x common to all three terms
	$x = 32.9$	A1	
		3	

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Question	Answer	Marks	Guidance
5(i)	$T = \frac{9 \times (0.8 - 0.6)}{0.6}$	M1	Use $T = \frac{\lambda x}{l}$. Note $OP = \frac{0.4}{\sin 30}$
	$T = 3 \text{ N}$	A1	
	$0.3a = 3 - 0.3g \sin 30$	M1	Use Newton's Second Law along the slope
	$a = 5 \text{ m s}^{-1}$	A1	
		4	
5(ii)	$0.3g \sin 30 = \frac{9e}{0.6}$	M1	Note the maximum speed is at the equilibrium position
	$e = 0.1$	A1	
	$\text{EPE} = \frac{9 \times (0.8 - 0.6)^2}{2 \times 0.6}$ or $\frac{9 \times 0.1^2}{2 \times 0.6}$	B1	
	$\frac{0.3v^2}{2} = \frac{9 \times (0.8 - 0.6)^2}{2 \times 0.6} - \frac{9 \times 0.1^2}{2 \times 0.6} - 0.3g \times 0.1 \sin 30$	M1	Set up a 4 term energy equation
	$v = 0.707 \text{ m s}^{-1}$	A1	
		5	

Question	Answer	Marks	Guidance
6(i)	$0.3^2 + r^2 = 0.5^2$ hence $r = 0.4$	B1	Use Pythagoras's theorem
	$8 \times 0.4 = 3.2 \text{ m s}^{-1}$	B1	Use $v = r\omega$
		2	
6(ii)	$A \times \frac{3}{5} - B \times \frac{3}{5} = 0.3g$	B1	Resolve vertically
	$A \times \frac{4}{5} + B \times \frac{4}{5} = 0.3 \times 8^2 \times 0.4$ or $\frac{0.3 \times 3.2^2}{0.4}$	M1A1	Use Newton's Second Law horizontally
		M1	Attempt to solve for B
	$B = 2.3 \text{ N}$	A1	
	$2.3 = \frac{46(0.5 - L)}{L}$	M1	Use $T = \frac{\lambda x}{l}$ and attempt to solve
	$L = 0.476 \text{ m}$ or $\frac{10}{21}$	A1	
		7	

Question	Answer	Marks	Guidance
7(i)	$BG = 0.3 \text{ m}$	B1	G is the CoM vertically above B . M is the mid-point of AB and E is v the point vertically below C on AB extended.
	$ME = 3 \times 0.2 = 0.6$ and $\tan A = \frac{CE}{AE} = \frac{0.9}{0.8}$	M1	Use of similar triangles and trigonometry of a right angled triangle
	$A = 48.4^\circ$	A1	AG
		3	
7(ii)	$AC = \frac{0.9}{\sin 48.4} = 1.20(41\dots)$	B1	Use trigonometry of a right angled triangle
	$18 \times 1.2041 = 0.4W$	M1	Moments about A
	$W = 54.2 \text{ N}$	A1	
		3	
7(iii)	$H = 18\sin A = 18\sin 48.4 (= 13.46)$	B1	Resolve horizontally
	$V = 54.2 - 18\cos 48.4 (= 42.25)$	B1ft	Resolve vertically
	$\mu = \frac{13.46}{42.25}$	M1	Use $F = \mu R$
	$\mu = 0.319$	A1	Accept 0.32
		4	

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1	$\frac{0.3 \times 4^2}{2} = \frac{9e^2}{2 \times 0.6}$	M1	Set up an energy equation. Note the final velocity is zero.
	$e = 0.566$ or $\frac{2\sqrt{2}}{5}$	A1	
	Distance = 1.17 m	A1	
		3	

Question	Answer	Marks	Guidance
2(i)	$V \cos 30 = 40$	M1	Note V is the velocity of projection
	$V = 46.2 \text{ m s}^{-1}$	A1	Allow $\frac{80}{\sqrt{3}}$ or $\frac{80\sqrt{3}}{3}$
	$y = 23.1t - 5t^2$	B1FT	Use $s = ut + \frac{at^2}{2}$ vertically. FT candidates half V but not $V = 40$ used
		3	
2(ii)	$y = \frac{23.1x}{40} - \frac{5x^2}{1600}$	M1	Attempt to eliminate t by substituting $t = \frac{x}{40}$ into answer to part (i)
	$y = 0.577x - \frac{x^2}{320}$ or $y = 0.577x - 0.003125x^2$	A1	
		2	

Question	Answer	Marks	Guidance
3	$0.5 \times 4 = 0.5g - T$	M1	Use Newton's Second Law vertically
	$T = \frac{12e}{0.6}$	M1	Use $T = \frac{\lambda x}{l}$
	$e\left(\frac{3 \times 0.6}{12}\right) = 0.15$	A1	
	$\text{EPE} = \frac{12 \times 0.15^2}{2 \times 0.6}$ and distance fallen = $0.6 - 0.5 + 0.15$	B1ft	
	$\frac{0.5v^2}{2} = \frac{0.5 \times 2^2}{2} + 0.5g(0.6 - 0.5 + 0.15) - \frac{12 \times 0.15^2}{2 \times 0.6}$	M1	Set up a 4 term energy equation
	$v = 2.85 \text{ m s}^{-1}$	A1	
		6	

Question	Answer	Marks	Guidance
4(i)	Velocity component vertically = $\pm (V \sin 60 - 3g)$	B1	Use $v = u + at$
	$\tan 30 = \frac{30 - V \sin 60}{V \cos 60}$	M1	Use trigonometry of a right angled triangle
	$V = 15\sqrt{3} = 26(.0) \text{ m s}^{-1}$	A1	
		3	

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Question	Answer	Marks	Guidance
4(ii)	$y = 26 \sin 60 \times 3 - \frac{g \times 3^2}{2}$	B1FT	Use $s = ut + \frac{at^2}{2}$ vertically. Their V from part (i)
	$D^2 = (26 \sin 60 \times 3 - g \times 3^2)^2 + (26 \cos 60 \times 3)^2$	M1	Use Pythagoras's Theorem
	$D = 45(.0) \text{ m}$	A1	
		3	

Question	Answer	Marks	Guidance
5(i)	$r = 0.5 \sin 30 (= 0.25 \text{ m})$	B1	
	$T \cos 30 - T \cos 70 = 0.4g$	M1	Resolve vertically
	$T = 7.6335..$	A1	
	$7.6335 \sin 30 + 7.6335 \sin 70 = 0.4 v^2 / 0.25$	M1	Use Newton's Second Law with $a = \frac{v^2}{r}$
	$v = 2.62 \text{ m s}^{-1}$	A1	
		5	

Question	Answer	Marks	Guidance
5(ii)	$A\cos 30 - B\cos 70 = 0.4g$ and $A\sin 30 + B\sin 70 = 0.4 \times 12^2 \times 0.5\sin 30$	M1	Resolves vertically and uses Newton's Second Law with $a = r\omega^2$
		A1	Both correct
		M1	Attempt to solve for A or B
	$A = 8.82 \text{ N}$	A1	
	$B = 10.6 \text{ N}$	A1	
		5	

Question	Answer	Marks	Guidance
6(i)	$0.2v \frac{dv}{dx} = 0.09\sqrt{x} - 0.3$	M1	Use Newton's Second Law horizontally
	$v \frac{dv}{dx} = 0.45\sqrt{x} - 1.5$	A1	AG
		2	
6(ii)	$0 = 0.45x^{\frac{1}{2}} - 1.5$	M1	Equate acceleration to zero
	$x = \frac{100}{9}$	A1	
		2	

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Question	Answer	Marks	Guidance
6(iii)	$\int v \, dv = \int (0.45x^{\frac{1}{2}} - 1.5)dx$	M1	Attempt to integrate
	$\frac{v^2}{2} = \frac{0.45^{\frac{3}{2}}}{\frac{3}{2}} - 1.5x(+c) = 0.3x^{\frac{3}{2}} - 1.5x(+c)$	A1	
	$0.3\left(\frac{100}{9}\right)^{\frac{3}{2}} - 1.5\left(\frac{100}{9}\right) + c = 0$	M1	
	$c = \frac{50}{9}$	A1	
	$x = 0, \frac{v^2}{2} > \frac{50}{9} \text{ so } v > \frac{10}{3}$	A1	
		5	

Question	Answer	Marks	Guidance
7(i)	Rectangle: Area = $1.2 \times 1.8 = 2.16$, $y = \frac{1.8}{2} = 0.9$	B1	
	Triangle(s): Area = $1.2 \times \frac{1.8}{2} = 1.08$, $y = \frac{1.8}{3} = 0.6$	B1	
	$(2.16 + 1.08)Y = 2.16 \times 0.9 + 1.08 \times 0.6$	M1	Take moments about <i>AD</i>
	$Y = 0.8 \text{ m}$	A1	AG
		4	

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Question	Answer	Marks	Guidance
7(ii)	$AG\sin 30 = 0.8$	M1	Use Trigonometry of a right angled triangle
	$AG = 1.6 \text{ m}$	A1	
		2	
7(iii)	AD makes an angle of 40° or 20° with the vertical	B1	
	$W \times AG\sin 10 = 7 \times 2.4\cos 40$	M1	Take moments about A
	$W = 46.3 \text{ N}$	A1	
	$W \times AG\sin 10 = 7 \times 2.4\cos 20$	M1	Take moments about A
	$W = 56.8 \text{ N}$	A1	
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	$(\theta =) 41.8$	A1	
		2	
2(ii)	Vertically: $\frac{v}{15\cos\theta} = \pm \tan 20$	M1	v = vertical velocity
	$v = (\pm) 4.07$	A1	
	$-4.07 = 15\sin 41.8 - gt$	M1	Use $v = u + at$ vertically
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	$\ln v = \frac{4k}{x} (+c)$	A1	
	$x = 0.8, v = 3$ hence $c = \ln 3 - 5k$	A1	Finds c
	$\ln v = \frac{4k}{x} + \ln 3 - 5k$	M1	
	$v = 3^{\left(\frac{4k}{x} - 5k\right)}$	A1	
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	$y = \frac{30\sin 60x}{30\cos 60} - \frac{5x^2}{(30\cos 60)^2}$	M1	Attempt to eliminate t
	$y = 1.73x - 0.0222x^2$ or $y = \sqrt{3}x - \frac{x^2}{45}$	A1	
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	$T = 3 \text{ N}$	A1	
	$0.3a = 3 - 0.3g \sin 30$	M1	Use Newton's Second Law along the slope
	$a = 5 \text{ m s}^{-1}$	A1	
		4	
5(ii)	$0.3g \sin 30 = \frac{9e}{0.6}$	M1	Note the maximum speed is at the equilibrium position
	$e = 0.1$	A1	
	$\text{EPE} = \frac{9 \times (0.8 - 0.6)^2}{2 \times 0.6}$ or $\frac{9 \times 0.1^2}{2 \times 0.6}$	B1	
	$\frac{0.3v^2}{2} = \frac{9 \times (0.8 - 0.6)^2}{2 \times 0.6} - \frac{9 \times 0.1^2}{2 \times 0.6} - 0.3g \times 0.1 \sin 30$	M1	Set up a 4 term energy equation
	$v = 0.707 \text{ m s}^{-1}$	A1	
		5	

Question	Answer	Marks	Guidance
6(i)	$0.3^2 + r^2 = 0.5^2$ hence $r = 0.4$	B1	Use Pythagoras's theorem
	$8 \times 0.4 = 3.2 \text{ m s}^{-1}$	B1	Use $v = r\omega$
		2	
6(ii)	$A \times \frac{3}{5} - B \times \frac{3}{5} = 0.3g$	B1	Resolve vertically
	$A \times \frac{4}{5} + B \times \frac{4}{5} = 0.3 \times 8^2 \times 0.4$ or $\frac{0.3 \times 3.2^2}{0.4}$	M1A1	Use Newton's Second Law horizontally
		M1	Attempt to solve for B
	$B = 2.3 \text{ N}$	A1	
	$2.3 = \frac{46(0.5 - L)}{L}$	M1	Use $T = \frac{\lambda x}{l}$ and attempt to solve
	$L = 0.476 \text{ m}$ or $\frac{10}{21}$	A1	
		7	

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Question	Answer	Marks	Guidance
7(i)	$BG = 0.3 \text{ m}$	B1	G is the CoM vertically above B . M is the mid-point of AB and E is v the point vertically below C on AB extended.
	$ME = 3 \times 0.2 = 0.6$ and $\tan A = \frac{CE}{AE} = \frac{0.9}{0.8}$	M1	Use of similar triangles and trigonometry of a right angled triangle
	$A = 48.4^\circ$	A1	AG
		3	
7(ii)	$AC = \frac{0.9}{\sin 48.4} = 1.20(41\dots)$	B1	Use trigonometry of a right angled triangle
	$18 \times 1.2041 = 0.4W$	M1	Moments about A
	$W = 54.2 \text{ N}$	A1	
		3	
7(iii)	$H = 18\sin A = 18\sin 48.4 (= 13.46)$	B1	Resolve horizontally
	$V = 54.2 - 18\cos 48.4 (= 42.25)$	B1ft	Resolve vertically
	$\mu = \frac{13.46}{42.25}$	M1	Use $F = \mu R$
	$\mu = 0.319$	A1	Accept 0.32
		4	