
MATHEMATICS

9709/41

Paper 4

October/November 2016

MARK SCHEME

Maximum Mark: 50

Published

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1	$[0.4g - T = 0.4a \quad T = 0.6a]$ System equation $0.4g = (0.4 + 0.6)a]$	M1		For applying Newton's 2nd law to either particle or to the system
		M1		For applying Newton's 2nd law to the other particle and attempt to solve for a and T
	$a = 4 \text{ ms}^{-2}$	A1		
	$T = 2.4 \text{ N}$	A1	[4]	
2 (i)	$2 = 5a \rightarrow a = 0.4 \text{ ms}^{-2}$	B1		
	$[0.1g \sin 20 - F = 0.1 \times 0.4]$	M1		For applying Newton's 2nd law to the particle
	$F = 0.302 \text{ N}$ AG	A1	[3]	
(ii)	$[R = 0.1g \cos 20 \quad (= 0.9397)]$	M1		For attempting to find R and using $\mu = F/R$
	$\mu = 0.3020/0.9397 = 0.321$	A1	[2]	
3 (i)	$[0 = 6^2 - 2g \times s]$	M1		For using $v^2 = u^2 + 2as$
	$s = 1.8$	A1		
	Total height = 2.3 m	B1	[3]	
	Alternative for 3(i)			
	$[6^2 = u^2 - 2g \times 0.5]$	M1		For using $v^2 = u^2 + 2as$ to find the initial velocity
	$u^2 = 46$	A1		
	$0^2 = 46 - 2gs \rightarrow s = \text{total height} = 2.3 \text{ m}$	B1	[3]	

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(ii)	$[2.3 = 0 + 0.5gt^2]$	M1	[3]	For using $s = ut + 0.5gt^2$ to find time to reach the ground
	$t = 0.678$	A1		
	Total time = $2 \times 0.678 = 1.36 \text{ s}$	B1		
	Alternative for 3(ii)			
	$[0 = \sqrt{46} - gt]$	M1	[3]	Using $v = u - gt$ to find time taken to the highest point
	$t = \frac{\sqrt{46}}{10} = 0.678$	A1		
	Total time = $2 \times 0.678 = 1.36 \text{ s}$	B1		
4	$2F + F\cos 60 = 15\cos\alpha$ $F\sin 60 = 15\sin\alpha$ $F = 5.67$ and $\alpha = 19.1$	M1 A1 M1 A1 M1 A1	[6]	For resolving forces horizontally For resolving forces vertically For using Pythagoras or for using $\tan \alpha$ to find F and α Allow $F = 15\sqrt{7} / 7$
5	(i) $a = 0.5 \text{ m s}^{-2}$	B1	[1]	
	(ii) [Distance $= 25 + 100 + 5(5 + V) + 30V + 10V]$ $150 + 45V$			

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6	(i)	[Work done = $50 \cos 10^\circ \times 20$] $= 984.8 \text{ J}$	M1 A1	[2]	Using $WD = Fd \cos \theta$
	(ii)	[$984.8 = \frac{1}{2} \times 25v^2 + 30 \times 20$] $v = 5.55 \text{ m s}^{-1}$	M1 A1	[2]	Using WD by $DF =$ $KE \text{ gain} + WD \text{ against Res.}$
	(iii)	Max power = $50 \cos 10^\circ \times 5.55 = 273 \text{ W}$	M1 A1	[2]	For using $\text{Power} = Fv$ Greatest power is at $v_{\max}$
	(iv)	[$50 \cos 10^\circ - 30 - 25g \sin 5^\circ = 25a$] $a = -0.102 \text{ m s}^{-2}$ [$0 = 5.55 - 0.102t$] Time $t = 54.4 \text{ s}$	M1 A1 M1 A1	[4]	For using Newton's 2nd law up the plane For using $v = u + at$
Alternative for 6(iv)					
		$50 \cos 10^\circ \times s + \frac{1}{2} \times 25 \times 5.55^2 =$ $25g \times s \sin 5^\circ + 30 \times s$ $t = 302/5.55 = 54.4 \text{ s}$	M1 A1 M1 A1	[4]	For using WD by $DF + KE \text{ loss} =$ $PE \text{ gain} + WD \text{ against Res.}$ to find distance s up plane $s = 151 \text{ m}$ For using $s = \frac{1}{2}(u + v)t$
7	(i)	[$15 - 6t = 0$] Max acceleration when $t = 2.5 \text{ s}$ Max acceleration = 18.75 m s^{-2}	M1 A1 A1	[3]	For differentiation May be stated from an $a-t$ diagram
	(ii)	[Speed = $7.5t^2 - t^3 (+ c)$] [Distance = $2.5t^3 - 0.25t^4 (+ ct + d)$] $= 2.5 \times 125 - 0.25 \times 625 = 156.25 \text{ m}$	M1 M1 A1	[3]	For using integration to obtain speed For using integration to obtain distance Allow distance = $625/4$

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(iii)	$v(5) = 7.5 \times 25 - 125 = 62.5 \text{ ms}^{-1}$ $\int_5^k -\frac{625}{t^2} dt = \left[\frac{625}{t} \right]_5^k$ $= \frac{625}{k} - \frac{625}{5} = \frac{625}{k} - 125$ $\frac{625}{k} - 125 = v(k) - v(5) = -62.5$ $k = 10$	B1 M1 A1 M1 A1	 [5]	Allow $v(5) = 125/2$ Integral with correct limits Use of $v(5) = 62.5$ and $v(k) = 0$
	Alternative for 7(iii)			
	$v(5) = 7.5 \times 25 - 125 = 62.5 \text{ ms}^{-1}$ $v(t) = \int -\frac{625}{t^2} dt = \frac{625}{t} + c$ $[c = -62.5]$ $v(t) = \frac{625}{t} - 62.5$ $v(k) = \frac{625}{k} - 62.5 = 0$ $k = 10$	B1 M1 A1 M1 A1	 [5]	Using indefinite integration For using $v(5) = 62.5$ to find c and setting $v(k) = 0$

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1 (i)	$3.5 = 10a \rightarrow a = 0.35 \text{ ms}^{-2}$ $[10\cos 15 - F = 2 \times 0.35]$ $F = 8.96 \text{ N}$	B1 M1 A1	[3]	Allow $a = 3.5/10$ For applying Newton's 2nd law to the particle
Alternative to 1(i)				
	$s = \frac{1}{2} (0 + 3.5) \times 10 = 17.5 \text{ m}$ $[10\cos 15 \times 17.5 = F \times 17.5 + \frac{1}{2} 2 (3.5)^2]$ $F = 8.96 \text{ N}$	B1 M1 A1	[3]	Distanced moved in 10 secs Work done by 10 N force = WD against F + KE gain
(ii)	$[R = 2g - 10\sin 15]$ $[\mu = 8.96 / (2g - 10\sin 15)]$ $\mu = 0.515$	M1 M1 A1	[3]	Resolving forces vertically Using $F = \mu R$
2 (i)	$[v = 4t - 40t^{0.5}]$ $[a = 4 - 20t^{-0.5}]$ $[4 - 20t^{-0.5} = 0]$ $t = 25 \text{ s}$	M1* M1* DM1 A1	[4]	For differentiating s to find v For differentiating v to find a For setting $a = 0$ and attempt to solve to find t
(ii)	Substitute their t into s or v Displacement = -2083.3 m (= -2080 3sf) and Velocity = -100 ms^{-1}	M1 A1	[2]	or Displacement = $-6250/3$

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3	(i)	$[X = 60\cos 25 + 50\cos 15]$ $= 103 \text{ N}$	M1 A1	[2]	For resolving both forces in the direction of river Value of X is 102.7 N
	(ii)	$Y = 60\sin 25 - 50\sin 15 [= 12.4]$ $[R^2 = X^2 + Y^2]$ or $[\alpha = \arctan(Y/X)]$ Magnitude is 103 N (or $\alpha = 6.9^\circ$ with direction specified unambiguously) $\alpha = 6.9^\circ$ with direction specified unambiguously (or Magnitude = 103 N)	B1 M1 A1 B1	[4]	Component perpendicular to the direction of the river For using Pythagoras or for using arctan to find the resultant force or its direction Magnitude is 103.4 N
4	(i)	PE loss = $mg \times 100\sin 20$ $[\frac{1}{2}mv^2 - \frac{1}{2}m \times 5^2 = mg \times 100\sin 20]$ $v = 26.6 \text{ ms}^{-1}$	B1 M1 A1	[3]	Using KE gain = PE loss
		Alternative method for 4(i)			
		$a = g \sin 20 [= 3.42]$ $[v^2 = 5^2 + 2 \times a \times 100]$ $v = 26.6 \text{ ms}^{-1}$	B1 M1 A1	[3]	Using $v^2 = u^2 + 2as$
	(ii)	KE = $\pm(0.5m \times 441 - 0.5m \times 25) [= \pm 208m]$ $[mg \times 100\sin 20 = 8500 + 208m]$ Mass $m = 63.4 \text{ kg}$	B1 M1 A1	[3]	For using PE loss = WD against Friction + KE gain

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5	$F = \mu mg \cos 30$	B1		
	$[10 + F - mg \sin 30 = 0]$	M1		Resolving up, first case
	$[75 - F - mg \sin 30 = 0]$	M1		Resolving up, second case
	$[85 = 2mg \sin 30]$ or $[10 + \mu mg \cos 30 - mg \sin 30 = 0]$ $75 - \mu mg \cos 30 - mg \sin 30 = 0]$	M1		Either attempt to solve for m or Solve a pair of two 3 term simultaneous equations for either m or μ
	$m = 8.5 \text{ kg}$ or $\mu = 0.442$	A1		
	$\mu = 0.442$ or $m = 8.5 \text{ kg}$	B1	[6]	
6 (i)	$[\text{Power} = 400 \times 25]$	M1		For using $P = Fv$ where $F = \text{resistance} = 400 \text{ N}$
	Power = 10000 W	A1	[2]	Allow 10 kW
(ii)	Tension = 100 N	B1	[1]	Considering the trailer
(iii)	New driving force $= 25000/20 = 1250 \text{ N}$	B1		Driving force = P/v at the instant when $v = 20$
	$[\text{DF} - 300 - T - 3000 g \sin 4 = 3000a]$ or $[T - 100 - 500 g \sin 4 = 500a]$ or $[\text{DF} - 400 - 3500 g \sin 4 = 3500a]$	M1		For using Newton's second law applied either to the van or to the trailer or to the system of van and trailer.
		M1		For using N2 applied to one of the other cases
	$[a = -0.4547 \text{ may be seen}]$	M1		Solving or using substitution to find T
	$T = 221 \text{ N}$	A1	[5]	Allow $T = 1550/7 \text{ N}$

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7	(i)	$v = 3 \times 10 = 30 \text{ ms}^{-1}$ $[s = \frac{1}{2} (30 + 40) \times 30]$ or equivalent complete method Total distance = 1050 m	B1 M1 A1	[3]	Velocity after 10 seconds For determining distance travelled in first 40 seconds
	(ii)	[Distance = 450 m Time taken = $450/15 = 30 \text{ s}$] Total time of motion for car = 70 s [Motorcycle takes 50 s to travel 1500 m $1500 = \frac{1}{2} (30 + 50) \times V$ or $1500 = 30 V + 0.5 \times 20 V$] $V = 37.5 \text{ ms}^{-1}$ [20 s is split between 5 s accelerating and 15 s decelerating] $a = 37.5/5 = 7.5 \text{ ms}^{-2}$	M1 A1 M1 A1 M1 A1	[6]	For finding distance covered in deceleration stage and time taken for this stage May be implied by time for motorcycle = 50 s For setting up an equation for distance travelled by M/C ($v-t$ graph or other) involving V or a and up to one other variable. For finding time taken to accelerate to speed V
	(iii)	Displacement-time graph	B1 B1 B1	[3]	Two of the three graph stages correct with correct curvature All three stages of the graph correct with correct curvature Correct graph, fully labelled $t=10, 40, 70 \text{ s} = 150, 1050, 1500$

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1	(i)	$PE \text{ gain} = 50g \times 3.5 (=1750)$ $[WD = 50g \times 3.5 + 25 \times 3.5]$ Work done = 1837.5 J or 1840 J	B1 M1 A1	[3]	For using $WD = PE \text{ gain} + WD \text{ against resistance}$
	(ii)	$[P = 1837.5/2]$ or $[P/v = 50g + 25 \text{ and } 3.5=2v]$ Power = 919 W	M1 A1	[2]	For using $P = WD/t$ or for using $P = Fv$ and $s = vt$
2		$T_A \cos 50^\circ - T_B \cos 10^\circ = 0$ and $T_A \sin 50^\circ - T_B \sin 10^\circ - 20g = 0$ Tension in PA is 306 N Tension in PB is 200 N	M1 M1 A1 M1 A1	[5]	For resolving horizontally For resolving vertically For solving equations to find T_A and T_B
		Alternative (Lami's Theorem) $[T_A/\sin 80^\circ = T_B/\sin 140^\circ = 20g/\sin 140^\circ]$ $[T_A=20g \sin 80^\circ/\sin 140^\circ]$ Tension in PA is 306 N $[T_B=20g \sin 140^\circ/\sin 140^\circ]$ Tension in PB is 200 N	M1 M1 A1 M1 A1	[5]	For applying Lami's Theorem For solving for T_A For solving for T_B

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3	(i)	$[7g - T = 7a \text{ and } T - 3g = 3a]$ or $[7g - 3g = 10a]$ Acceleration is 4 ms^{-2} $[v^2 = 0 + 2 \times 4 \times 0.4] (v^2 = 3.2)$ Speed is 1.79 ms^{-1}	M1 A1 M1 A1	[4]	For applying Newton's second law to P and to Q or for using $m_P g - m_Q g = (m_P + m_Q)a$ For using $v^2 = u^2 + 2as$
	(ii)	$[0 = 3.2 + 2 \times (-g) \times s] (s = 0.16)$ $0.16 + 0.4 = 0.56$ So particle Q does not come to rest before it reaches the pulley Alternative $[v^2 = 3.2 + 2 \times (-g) \times 0.1]$ $v = \sqrt{1.2} (= 1.10)$ So particle Q does not come to rest before it reaches the pulley	M1 A1 M1 A1	[2] [2]	For using $0 = u^2 + 2(-g)s$ For using $v^2 = u^2 + 2(-g)(0.1)$
4	(i)	$s_A = \frac{1}{2}g \times 2.5^2 (= 31.25)$ $[s_B = 20 \times 1.5 - \frac{1}{2}g \times 1.5^2] (= 18.75)$ $\frac{1}{2}g \times 2.5^2 + 20 \times 1.5 - \frac{1}{2}g \times 1.5^2$ Height is 50m AG	B1 M1 A1	[3]	For using $s = ut + \frac{1}{2}at^2$
	(ii)	$50 = 0.5gt_A^2 \quad (t_A = 3.16)$ $t_B = \sqrt{10 - 1} = 2.16$ To top, $0^2 = 20^2 - 2gs_B \quad \rightarrow s_B = 20$ To top, $[0 = 20 - gt_B] \rightarrow t_B = 2$ Downwards, $[s_B = \frac{1}{2}g(0.16)^2] (= 0.13)$ Total distance is 20.1 m	B1 B1 B1 M1 A1	[5]	For using $s = \frac{1}{2}at^2$ For using $v = u + at$ to find time to top for B and $s = \frac{1}{2}at^2$ to find downwards distance for B

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5	(i)	$6t - 0.3t^2 = 0 \rightarrow t = 20$ (or 0) $[s = 6t^2/2 - 0.3t^3/3 (+C)]$ $[s = 6(20)^2/2 - 0.3(20)^3/3]$ Distance OX is 400 m	B1 M1 DM1 A1	[4]	For integrating $v(t)$ to obtain $s(t)$ For evaluating $s(t)$ when $v=0$
	(ii)	$[v = kt - 6t^2 (+C)]$ $[s = kt^2/2 - 6t^3/3]$ $[400 = 0.5k \times 10^2 - 2 \times 10^3]$ $k = 48$	M1* M1* DM1 A1	[4]	For integrating $a(t)$ to obtain $v(t)$ For integrating $v(t)$ to obtain $s(t)$ and for using $s(0) = 0$ For using $t = 10$ and $s = 400$ to form equation in k
6	(i)	Driving force = $160/5$ (= 32 N) $[160/5 - 20 = m \times 0.15]$ Total mass is 80 kg	B1 M1 AG A1	[3]	For using Newton's Second Law
	(ii)	$[300/v - 20 - 80g \sin 2^\circ = 0]$ Speed is 6.26 ms^{-1}	M1 AG A1	[2]	For resolving up hill
	(iii)	Driving force = $300/(0.9 \times 6.26)$ (= 53.2 N) $300/(0.9 \times 6.26) - 20 - 80g \sin 2^\circ = 80a$ Acceleration is 0.0666 ms^{-2}	B1 M1 A1 A1	[4]	For using Newton's Second Law

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7	(i) $R = 50g \cos 10^\circ$ and $F = 50g \sin 10^\circ$ $\mu \geq 0.176$	B1 B1	[2]	$\mu \geq F \div R$ Allow $\mu \geq \tan 10^\circ$
	(ii) PE loss = $50g \times d \sin 10^\circ$ WD against friction = $0.19 \times 50g \cos 10^\circ \times d$ $50 \times 5 + 50g \times 10 \sin 10^\circ - 0.19 \times 50g \cos 10^\circ \times 10 = 0.5 \times 50v^2$ Speed is 2.70 ms^{-1}	B1 B1 M1 A1 A1	[5]	$d = 5$ or $d = 10$ $d = 5$ or $d = 10$ For using WD by 50 N force + PE loss – WD against friction = KE gain SC for candidates using Newton's Second law: max 2/5 B1 $v = 2.94 \text{ ms}^{-1}$ after 5 m B1 Speed is 2.70 ms^{-1}
	(iii) $50g \sin 20^\circ - 0.19 \times 50g \cos 20^\circ = 50a$ Acceleration is 1.63 ms^{-2}	M1 A1	[2]	For using Newton's Second Law