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(9660/MA02) Unit PSM1 Pure Mathematics, Statistics and Mechanics

Mark scheme

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Key to mark scheme abbreviations

M	Mark is for method
m	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**	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
sf	Significant figure(s)
dp	Decimal place(s)
ISW	Ignore subsequent working

Q	Answer	Marks	Comments
1	$[\text{Perimeter} =]$ $2r + 4.2r \ [= 124]$	M1	**oe** Correct expression for the perimeter in terms of r **PI** by the correct value of r or the correct final answer.
	$[6.2r = 124 \Rightarrow]$ $[r =] \ 20 \ [\text{cm}]$	A1	Correct value of r **PI** by the correct final answer.
	$[\text{Area} =] \ \frac{1}{2} \times 20^2 \times 4.2$	M1	**oe** Correct substitution into $\frac{1}{2}r^2\theta$ **ft** their r **PI** by the correct final answer.
	$[\text{Area} =] \ 840 \ [\text{cm}^2]$	A1	**CAO**
		4	

	Question 1 Total	**4**	

Q	Answer	Marks	Comments
2(a)	$\left[\begin{array}{l}2\sin x+3\cos x=0\\ \Rightarrow \frac{\sin x}{\cos x}=-\frac{3}{2}\Rightarrow\end{array}\right]$ $\tan x=-\frac{3}{2}$ $[x=]\quad -56.3^\circ, 123.7^\circ$	**M1** **M1** **A1**	**oe** Deduces the correct value of $\tan x$ Must be identified as $\tan x$ **PI** by at least one correct final value rounded to the nearest whole number possibly truncated or better ignoring all other values. **M1:** At least one correct value correctly rounded or both correct values either rounded to the nearest whole number or to 2 or more decimal places. Ignore all other values. **A1: CAO**
		3	

Q	Answer	Marks	Comments
2(b)	$[5\sin y\cos y]\left(\frac{\cos y}{\sin y}+\frac{\sin y}{\cos y}\right)$ $5\sin y\cos y\left(\frac{\cos^2 y+\sin^2 y}{\sin y\cos y}\right)$ or $5\left(\frac{\sin y\cos^2 y}{\sin y}+\frac{\cos y\sin^2 y}{\cos y}\right)$ or $\frac{5\sin y\cos^2 y}{\sin y}+\frac{5\cos y\sin^2 y}{\cos y}$ or $5\cos^2 y+5\sin^2 y$ $5\sin y\cos y\left(\frac{1}{\sin y\cos y}\right)$ and $[a=]5$ or $5\left(\cos^2 y+\sin^2 y\right)$ and $[a=]5$ or 5×1 and $[a=]5$	**M1** **m1** **A1**	**oe** Eliminates $\tan y$ using $\tan y=\frac{\sin y}{\cos y}$ **oe** Writes the bracketed term in a full expression with a common denominator or fully or partially expands the bracketed term. Extra line of working showing clear use of $\cos^2 y+\sin^2 y=1$ before correct value of a given. Must be convincingly shown.
		3	

	Question 2 Total	**6**	

Q	Answer	Marks	Comments
3(a)	$\left[\sin^2\theta+\cos^2\theta=1\Rightarrow\right]$ $\left(\frac{\sqrt{51}}{10}\right)^2+\cos^2\theta=1$ or $\cos\theta=\sqrt{1-\frac{51}{100}}$	M1	**oe** Explicit substitution into $\sin^2\theta+\cos^2\theta=1$
	$\cos\theta=\sqrt{1-\frac{51}{100}}$ or $\cos^2\theta=\frac{49}{100}$ or $\cos\theta=\sqrt{\frac{49}{100}}$ and $\cos\theta=\frac{7}{10}$	A1	**oe AG** Must be convincingly shown.
		2	

Q	Answer	Marks	Comments
3(b)	$(3x+2)^2=(x+9)^2+(5x)^2$ $-2(x+9)(5x)\left(\frac{7}{10}\right)$	M1	**oe** Correct use of the cosine rule with expressions for the lengths and the value of $\cos\theta$ substituted. Allow $\cos\theta$ for $\frac{7}{10}$ **PI** by correct use with at least one bracket expanded.
	$9x^2+12x+4=x^2+18x+81+25x^2$ $-7x^2-63x$ or $9x^2+12x+4=19x^2-45x+81$ and $10x^2-57x+77=0$	M1 A1	**oe** **M1:** All brackets expanded after correct use of the cosine rule. Allow one error **A1:** Brackets correctly expanded and **AG**
		3	

Q	Answer	Marks	Comments
3(c)	$\left[10x^2 - 57x + 77 = 0 \Rightarrow\right]$ $(5x - 11)(2x - 7)$ $[= 0]$	M1	**oe PI** by both correct values of x , $\frac{7}{2}$ used to calculate the area, or correct final answer. Correct attempt to solve the quadratic equation Could see use of the quadratic formula but values must be correctly substituted
	$[x =]$ $\frac{7}{2}$ and $[x =]$ $\frac{11}{5}$	A1	**oe** Both correct values. **PI** by , $\frac{7}{2}$ used to calculate the area or by the correct final answer.
	$[\text{Area} =]$ $\frac{1}{2} \times \left(\frac{7}{2} + 9\right) \times \left(5 \times \frac{7}{2}\right) \times \frac{\sqrt{51}}{10}$ or $\frac{1}{2} \times \frac{25}{2} \times \frac{35}{2} \times \frac{\sqrt{51}}{10}$	M1	**oe** Correct use of Area $= \frac{1}{2}ab\sin C$ with values substututed **ft** their largest value of x **PI** by the correct final answer.
	$[\text{Area} =]$ $\frac{175\sqrt{51}}{16}$ $\left[\text{cm}^2\right]$	A1	**ACF ISW**
		4	

	Question 3 total	**9**	

Q	Answer	Marks	Comments
4(a)	$\left[\begin{array}{l} x^2+y^2=18x+4y-68 \\ \Rightarrow x^2-18x+y^2-4y+68=0 \end{array}\right]$ $(x-9)^2 \ldots$ or $(y-2)^2 \ldots$	**M1**	**PI** by the correct centre.
	$(x-9)^2-9^2+(y-2)^2-2^2+68 \ [=0]$ or $(x-9)^2-81+(y-2)^2-4+68 \ [=0]$ or $(x-9)^2+(y-2)^2=17$	**M1**	**oe** Correctly completes both squares simplified or unsimplified. **PI** by the correct centre and radius.
	[Centre] $(9,2)$	**A1**	**CAO**
	[Radius] $\sqrt{17}$	**A1**	**CAO**
		4	

Q	Answer	Marks	Comments
4(b)	$[\text{Gradient} =]\ \dfrac{3-2}{13-9}\ \left[=\dfrac{1}{4}\right]$	**M1**	**oe** Correct method for finding gradient of radius of *C* at *Q*. **PI** by correct value for the gradient of the radius or the gradient of l_2 **ft** their centre.
	$y-3=-4(x-13)$ or $y-3=-4x+52$ or $y=-4x+55$ or $4x+y=55$	**m1**	**oe** Correct equation of l_2 **ACF** **ft** their centre from **part (a)** and their gradient of radius
	$[R]\ (12, 7)$	**A1**	Solves equations of l_1 and l_2 simultaneously to find the correct coordinates *R*
	$\left[\lvert QR\rvert^2 =\right]\ (13-12)^2+(3-7)^2\ [=17]$ or $\left[\lvert QR\rvert =\right]\ \sqrt{(13-12)^2+(3-7)^2}\ \left[=\sqrt{17}\right]$ or $\lvert QR\rvert^2=17$ or $\lvert QR\rvert=\sqrt{17}$	**M1**	**oe** Correct method to calculate $\lvert QR\rvert^2$ or $\lvert QR\rvert$ or 17 or $\sqrt{17}$ clearly identified. **PI** by correct final answer. Must be using the correct coordinates of *R*
	$\sqrt{17-\left(\dfrac{1}{2}\sqrt{34}\right)^2}$	**M1**	**oe** Correct method to find the correct distance to the chord.
	$\dfrac{1}{2}\sqrt{34}$ or $\dfrac{\sqrt{34}}{2}$ or $\sqrt{\dfrac{17}{2}}$	**A1**	**CAO** Correct shortest distance from *R* to the chord
		6	

Q	Answer	Marks	Comments
4(b) Alt	$[\text{Gradient} =]\ \frac{3-2}{13-9}\ \left[=\frac{1}{4}\right]$	**M1**	**oe** Correct method for finding gradient of radius of *C* at *Q* **PI** by correct value for the gradient of the radius or the gradient of l_2 **ft** their centre.
	$y-3=-4(x-13)$ or $y-3=-4x+52$ or $y=-4x+55$ or $4x+y=55$	**m1**	**oe** Correct equation of l_2 **ACF** **ft** their centre from **part (a)** and their gradient of radius
	$[R]\ (12, 7)$	**A1**	Solves equations of l_1 and l_2 simultaneously to find the correct coordinates *R*
	$[P]\ (8, 6)$	**B1**	**PI** Solves equations of l_1 and *C* simultaneously to find the correct coordinates *P*
	$[\text{Length of } MR =]$ $\sqrt{\left(12-\frac{21}{2}\right)^2+\left(7-\frac{9}{2}\right)^2}$	**M1**	**oe** Correct method to find the correct distance from *R* to the midpoint $M\left(\frac{21}{2}, \frac{9}{2}\right)$ of *PQ* Must be using the correct coordinates of *R* and *M*
	$\frac{1}{2}\sqrt{34}$ or $\frac{\sqrt{34}}{2}$ or $\sqrt{\frac{17}{2}}$	**A1**	**CAO** Correct shortest distance from *R* to the chord
		6	

	Question 4 Total	**10**	

Q	Answer	Marks	Comments
5	$\left[\frac{9^{5t}}{7^t} = 81 \Rightarrow \frac{9^{5t}}{81} = 7^t \Rightarrow\right]$ $9^{5t-2} = 7^t$ or $3^{10t-4} = 7^t$ or $\log_3 9^{5t} - \log_3 7^t = \log_3 81$ or $\log_9 9^{5t} - \log_9 7^t = \log_9 81$	**M1**	**oe** Uses index rules to form a correct equation with $\frac{9^{5t}}{81}$ written as a single power of 9 or 3 or **oe** Takes logarithms of both sides and uses a logarithm rule.
	$5t - 2 = \log_9 7^t$ or $10t - 4 = \log_3 7^t$	**M1**	**oe** Takes $\log_9$ or $\log_3$ of both sides to correctly eliminate the power of 9 or 3
	$5t - 2 = t\log_9 7$ or $10t - 4 = t\log_3 7$	**M1**	**oe** Uses power rule for logarithms to write as a correct linear equation.
	$t = \frac{4}{10 - \log_3 7}$	**A1**	**CAO** Must be in the correct form
		4	

	Question 5 Total	**4**	

Q	Answer	Marks	Comments
6(a)	$[d =]\ \log_{10}\left(\frac{b^5}{c}\right) - \log_{10}\left(\frac{b^5}{\sqrt{c}}\right)$	**M1**	**oe** Correct expression for the common difference in terms of logarithms.
	$[d =]\ \log_{10}\left(\frac{\frac{b^5}{c}}{\frac{b^5}{\sqrt{c}}}\right)$ or $[d =]\ \log_{10}\left(b^5\right) - \log_{10} c - \log_{10}\left(b^5\right) + \log_{10}\sqrt{c}$	**A1**	Correct expression as a single logarithm or four separate logarithms, for example $\log_{10}\left(\frac{\frac{1}{c}}{\frac{1}{\sqrt{c}}}\right)$ or $\log_{10}\left(\frac{\sqrt{c}}{c}\right)$
	$[d =] -\log_{10} c + \frac{1}{2}\log_{10} c$ or $[d =]\ \log_{10}\left(\frac{1}{\sqrt{c}}\right)$ or $\log_{10} c^{-\frac{1}{2}}$ or $\frac{1}{2}\log_{10}\left(\frac{1}{c}\right)$ and $[d =]\ -\frac{1}{2}\log_{10} c$	**A1**	Must see this extra line of working before **AG** Must be convincingly shown.
		3	

Q	Answer	Marks	Comments
6(b)	$\frac{1}{2}(15)\left(2\log_{10}\left(\frac{b^5}{\sqrt{c}}\right)+(15-1)\left(-\frac{1}{2}\log_{10} c\right)\right)$ or $\frac{15}{2}\left(2\log_{10}\left(\frac{b^5}{\sqrt{c}}\right)-7\log_{10} c\right)$	**M1**	**oe** Correct expression for the sum of the first 15 terms
	$[S_{15}=]\ \frac{15}{2}\left(\log_{10}\left(\frac{b^{10}}{c}\right)-\log_{10} c^7\right)$	**M1**	**oe** Correct application of the power rule for logarithms to both logarithmic terms in a correct expression.
	$[S_{15}=]\ \frac{15}{2}\log_{10}\left(\frac{b^{10}}{c^8}\right)$	**M1**	**oe** Correct application of subtraction rule for logarithms in a correct expression.
	$[S_{15}=]\ \log_{10}\left(\frac{b^{75}}{c^{60}}\right)$	**A1**	**CAO** Must be in the correct form
		4	

	Question 6 Total	**7**	

Q	Answer	Marks	Comments
7(a)	$\left[\binom{14}{5}\times 0.35^5\times(1-0.35)^{14-5}=\right]0.2178$	B1	**AWRT** 0.2178
		1	

Q	Answer	Marks	Comments
7(b)	$\left[\mathrm{P}(X>6)=\right]\ 1-\mathrm{P}(X\leq 6)$ or $\left[\mathrm{P}(X>6)=\right]\ 1-0.8164$	M1	Identifies the correct calculation **PI**
	0.184	A1	**AWRT** 0.184
		2	

Q	Answer	Marks	Comments
7(c)	$\left[\mathrm{P}(2\leq X<8)=\right]\ \mathrm{P}(X\leq 7)-\mathrm{P}(X\leq 1)$ or $\left[\mathrm{P}(2\leq X<8)=\right]\ 0.9247-0.0205$	M1	Identifies the correct calculation **PI**
	0.904	A1	**AWRT** 0.904
		2	

	Question 7 Total	**5**	

Q	Answer	Marks	Comments
8(a)	x | 0 | 100 | 200 P($X = x$) | 0.25 | 0.4125 | 0.3375	M1 A1	Correct calculation of one probability Correct calculation of all probabilities
		2	

Q	Answer	Marks	Comments
8(b)	Mean = $0\times0.25+100\times0.4125+200\times0.3375$ Mean = 108.75	M1 A1	**oe** Correct calculation **ft** their probability distribution **CAO**
		2	

Q	Answer	Marks	Comments
8(c)	[E(Y) =] 27	B1	Correct value of E(Y) **PI** by a final answer of their E(X) minus 27.
	[E($X-Y$) =] 108.75 – 27	M1	Applies E($X-Y$) = E(X) – E(Y) **ft** their E(X) and E(Y)
	[E($X-Y$) =] 81.75	A1ft	**ft** their E(X) and E(Y)
		3	

	Question 8 Total	**7**	

Q	Answer	Marks	Comments
9(a)	$0.6 = k + 2k$	**M1**	Uses $\mathrm{P}(A \cap B) = 0$ and the addition law to form an equation in terms of k **oe PI**
	$[k =]$ 0.2	**A1**	**CAO**
		2	

Q	Answer	Marks	Comments
9(b)	$[\mathrm{P}(A \cap B) =]$ $2k^2$	**B1**	Uses independence law to find $\mathrm{P}(A \cap B)$ in terms of k **PI**
	$0.6 = k + 2k - 2k^2$	**M1**	Uses the addition law to form a correct equation in terms of k **oe** **PI** by both possible roots or the correct final answer.
	$[2k^2 - 3k + 0.6 = 0]$ $[k =]$ 0.238	**A1**	**AWRT** 0.238 If the other root [1.262] is found, it must be rejected
		3	

Q	Answer	Marks	Comments
9(c)	$[\mathrm{P}(A \cap B) =]$ $k + 2k - 0.6$	**B1**	Uses addition law to find $\mathrm{P}(A \cap B)$ in terms of k May be found in earlier parts but must be used in part **(c)** to score **oe** **PI**
	$0.5k = \dfrac{3k - 0.6}{2k}$	**M1**	**oe** Forms a correct equation in terms of k **PI** by both possible roots or the correct final answer.
	$[k^2 - 3k + 0.6 = 0]$ $[k =]$ 0.215	**A1**	Allow 0.2155 or **AWRT** 0.215 If the other root [2.785] is found, it must be rejected
		3	

	Question 9 Total	**8**	

	Answer	Marks	Comments
10(a)	$250 - mg = 0$ or $250 = mg$	**M1**	Allow inequality signs. **PI** by correct final answer.
	$\left[m_{\text{min}} =\right]$ 26	**A1**	**oe AWRT** 26 Allow $\frac{1250}{49}$, 25.510204…
		2	

Q	Answer	Marks	Comments
10(b)(i)	$250 - 25g = 25a$ $a = 0.2$	**B1**	Allow 9.8 for g **AG**
		1	

Q	Answer	Marks	Comments
10(b)(ii)	$\left[v = 0 + 0.2 \times 3 =\right] 0.6$	**B1**	Achieves velocity as 0.6 **PI** by 0.6 embedded in equation for motion under gravity or in later working.
	$\left[s =\right]\ 0 + \frac{1}{2} \times 0.2 \times 3^2\ \ \left[= 0.9\right]$	**M1**	**oe PI** by 0.9 seen.
	$(0)^2 = (0.6)^2 + 2 \times (-9.8) \times x$ $x = [0.018367\ldots]$ or $(0)^2 = (0.6)^2 + 2 \times (-9.8) \times (d - 0.9)$	**M1**	**oe** Sets up an equation(s) to find additional height. Allow sign errors $\left[x = \frac{9}{490}\right]\left[d = \frac{45}{49}\right]$ **ft** their 0.9 if total height used **PI**
	$\left[d = 0.9 + 0.018[3\ldots] =\right]\ \ 0.92$	**A1**	**CAO AWRT** 0.92 $\left[d = \frac{45}{49}\right]$ Their additional height (0.02 or better) must be correctly obtained
		4	

	Question 10 Total	**7**	

Q	Answer	Marks	Comments
11(a)	$\left[0.06 = 0.05u\right]$ $\left[u =\right]\ 1.2$	**B1**	1.2 or $\frac{6}{5}$ seen but be convinced it is the velocity. **PI** in later working.
	$0^2 = (1.2)^2 + 2\times(a)\times 0.8$	**M1**	**oe** Follow their values/expressions e.g. a may be in terms of μ and g Allow use of other constant acceleration formulae as long as time is eliminated at some point. Condone sign errors.
	$\left[a =\right]\ -0.9$	**A1**	Correct acceleration. Allow 0.9 **PI** in later working.
	$\left[0\right] - 0.05g\mu = 0.05\times(-0.9)$	**M1**	**oe** Allow without 0.05 on both sides and with values substituted **PI** **ft** their a Allow one sign error.
	$\left[\mu = \frac{0.9}{9.8} =\right]\ 0.092$	**A1**	**AWRT** 0.092 $\mu = \frac{9}{98}$
		5	

Q	Answer	Marks	Comments
11(b)	Air resistance [not included].	**E1**	Do not allow reasons based on any values given in the question. Allow 'other resistive forces [not included]'.
		1	

	Question 11 Total	**6**	

Q	Answer	Marks	Comments
12(a)	$\left[v = t^3 - kt^2\right]$ $\left[\frac{dv}{dt} =\right]\ 3t^2 - 2kt$ $[0.25 = 3k^2 - 2k \times k$ $k^2 = 0.25]$ $\left[k =\right]\ 0.5$	**M1** **A1**	Correct derivative. **CAO** Must be positive
		2	

Q	Answer	Marks	Comments
12(b)	$\left[v = t^3 - kt^2\right]\ \left[\int v\ \mathrm{d}t =\right]\ \frac{t^4}{4} - \frac{kt^3}{3}$	**M1**	Correct expression for displacement – allow $+C$
	$\left[\begin{array}{l}\frac{t^4}{4} - \frac{kt^3}{3} = 0 \\ 3t^4 - 4(0.5)t^3 = 0 \Rightarrow t = \\ 3t - 2 = 0\end{array}\right]\ \frac{2}{3}$	**A1**	Uses their expression for displacement and value for k to find the value t when the particle returns to O PI by $T = \frac{4}{3}k$
	$\left[0 = t^2(t-k)\right]\ \ \left[t =\right]\ \ k$ or 0.5	**M1**	Uses $v = 0$ to find the time for the furthest distance from A
	$\frac{(0.5)^4}{4} - \frac{k(0.5)^3}{3}\ \ \left[= -\frac{1}{192}\right]$	**M1**	Correct method for finding the displacement at $t = k$, Ignore signs for this mark. **PI** by $-\frac{1}{192}$ or $\frac{1}{96}$ or $\frac{1}{6}k^4$ or $\frac{k^4}{12}$ **ft** their k provided that it is seen in working
	$\left[\text{Av.Speed} = 2 \times \frac{\left(\frac{1}{192}\right)}{\left(\frac{2}{3}\right)} =\right]\ \frac{1}{64}$ $[= 0.015625]$	**A1**	Final answer must be positive Allow exact values, 2.s.f or better
		5	
	Question 12 Total	**7**	