

**INTERNATIONAL AS
FURTHER MATHEMATICS**

FM02

(9665/FM02) Unit FPSM1 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(a)(i)	$\begin{bmatrix} 0 & -1 \\ -1 & 0 \end{bmatrix}$	B1	
		1	

Q	Answer	Marks	Comments
1(a)(ii)	$\mathbf{C} = \begin{bmatrix} 0 & -1 \\ -1 & 0 \end{bmatrix} \begin{bmatrix} 3 & q \\ 4-q & 2 \end{bmatrix}$ $= \begin{bmatrix} q-4 & -2 \\ -3 & -q \end{bmatrix}$	M1 M1 A1	<i>their B x A</i> (must be correct order) M1 : obtains a 2 x 2 matrix with at least 2 correct terms for either B x A or A x B for <i>their B</i> A1 : CAO
		3	

Q	Answer	Marks	Comments
1(b)	$3 \times 2 - q(4 - q)$ $6 - 4q + q^2 = [\pm]7$ $q = 2 \pm \sqrt{5}$ $q = 2 + \sqrt{5}$	B1 m1 A1	Correct expression for determinant PI by correct equation later Sets their determinant to ± 7 . Attempts to solve their quadratic PI by correct root of their quadratic CAO
		4	

	Question 1 Total	8	
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Q	Answer	Marks	Comments
2	$hf(3,7) = 0.1 \times 3 \log_2(3^2 + 7) [= 1.2]$ $y_2 [= 7 + 1.2] = 8.2$ $y_3 = 8.2 + 0.1 \times 3 \log_2(3.1^2 + 8.2)$ $[= 9.446384683...]$ 9.446	M1 A1 M1 A1	Correct substitution into RHS of this expression PI in next step Correct substitution using $x_2 = 3.1$ and their y_2 PI by AWRT 9.44 or 9.45 CAO
		4	

	Question 2 Total	4	
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Q	Answer	Marks	Comments
3(a)	$p + B = \frac{\sqrt{A}}{\sqrt{q}}$ $\frac{1}{\sqrt{q}} = \frac{p}{\sqrt{A}} + \frac{B}{\sqrt{A}}$ <p>which is a linear relationship between p and Y</p>	<p>M1</p> <p>A1</p>	<p>Takes square roots and inverts</p> <p>obtains correct relationship and gives conclusion</p> <p>Allow $\frac{1}{\sqrt{q}} = \pm \frac{p}{\sqrt{A}} \pm \frac{B}{\sqrt{A}}$</p>
		2	

Q	Answer	Marks	Comments												
3(b)(i)	<table border="1"> <tr> <td>p</td> <td>-0.7</td> <td>0.2</td> <td>0.8</td> <td>1.5</td> <td>2.0</td> </tr> <tr> <td>Y</td> <td>1.05</td> <td>1.96</td> <td>2.58</td> <td>3.02</td> <td>3.39</td> </tr> </table>	p	-0.7	0.2	0.8	1.5	2.0	Y	1.05	1.96	2.58	3.02	3.39	<p>M1</p> <p>A1</p>	<p>Two values found; allow 1 dp or better</p> <p>All values found correct to 2dp</p>
p	-0.7	0.2	0.8	1.5	2.0										
Y	1.05	1.96	2.58	3.02	3.39										
		2													

Q	Answer	Marks	Comments
3(b)(ii)		<p>B1ft</p> <p>B1</p>	<p>Their points plotted within half a square</p> <p>Straight line of best-fit drawn following general trend of points with at least 4 points plotted</p> <p>Points not on the line should not all be above or all be below the line</p>
		2	

Q	Answer	Marks	Comments
3(b)(iii)	$\frac{1}{\sqrt{A}} = 0.86$ $\frac{B}{\sqrt{A}} = 1.74$ $A = 1.35$ $B = 2.02$	<p>M1</p> <p>M1</p> <p>A1</p>	$\frac{1}{\sqrt{A}} = \text{AWFW [0.8,1.0]}$ <p>PI</p> $\frac{B}{\sqrt{A}} = \text{AWFW [1.7,1.8]}$ <p>PI</p> <p>Correct A and B for their values of</p> $\frac{1}{\sqrt{A}} = \text{AWFW [0.8,1.0]}$ and $\frac{B}{\sqrt{A}} = \text{AWFW [1.7,1.8]}$ $A = \left(\frac{1}{\text{gradient}} \right)^2 \text{ and}$ $B = \frac{y - \text{intercept}}{\text{gradient}}$ <p>Values of A and B should be given to at least 2 sf</p> <p>A straight line must have been drawn in part (b)(ii)</p>
		3	
	Question 3 Total	9	

Q	Answer	Marks	Comments
4(a)	$f(0) = 2$ and $f(1) = -1$	M1	Correct evaluation of a suitable interval
	Change of sign and f is continuous on the interval so $0 < \alpha < 1$	A1	Must state or show that there is a change of sign and state that the curve is continuous (condone unbroken) and concludes a root is present in the interval
		2	

Q	Answer	Marks	Comments
4(b)	$f'(x) = 3x^{\frac{1}{2}} - 5$	M1	correct derivative PI
	$f'(5.5) = 2.0356\dots$	A1	AWRT 2.04 PI
	$x_2 = 5.5 - \frac{2 \times 5.5^{\frac{3}{2}} - 5 \times 5.5 + 2}{2.0356\dots}$ $= 5.353957935$	M1	Substitutes their values of $f(5.5)$ and $f'(5.5)$ into the N-R formula Their values must be correct or clearly identified PI
	$[x_2 =] 5.354$	A1	CAO
		4	

	Question 4 Total	6	
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Q	Answer	Marks	Comments
5(a)	$[\det \mathbf{M} =] \frac{1}{25} \left((1-4k)(4-k) - (2+2k)^2 \right) = 0$ $[-25k = 0 \text{ or } -5k = 0]$ $k = 0$	<p>M1</p> <p>A1</p>	correct expression for determinant and sets to zero, PI by eg $-25k$ seen. Condone missing $\frac{1}{25}$ or use of $\frac{1}{5}$
		2	

Q	Answer	Marks	Comments
5(b)	$\mathbf{M}^2 = \frac{1}{25} \begin{bmatrix} 1-4k & 2+2k \\ 2+2k & 4-k \end{bmatrix} \begin{bmatrix} 1-4k & 2+2k \\ 2+2k & 4-k \end{bmatrix}$ $= \frac{1}{25} \begin{bmatrix} (1-4k)^2 + (2+2k)^2 & \\ (1-4k)(2+2k) + (4-k)(2+2k) & \\ (1-4k)(2+2k) + (4-k)(2+2k) & \\ (2+2k)^2 + (4-k)^2 & \end{bmatrix}$ $5 + 20k^2 = 25$ $10 - 10k^2 = 0$ $20 + 5k^2 = 25$ $k = \pm 1$	<p>M1</p> <p>M1</p> <p>A1</p>	for ... \times a 2x2 matrix oe with at least one correct algebraic entry PI or finds $\det(\mathbf{M}^2) = k^2$ or $\det(25\mathbf{M}^2) = 625k^2$ for a correct equation to find k^2 If matrix seen, it must be fully correct All equations seen must be fully correct
		3	

Q	Answer	Marks	Comments
5(c)(i)	$\mathbf{M} = \begin{bmatrix} 5 & -2 \\ -2 & 2 \end{bmatrix}, \text{ so}$ $x' = 5x - 2(mx[+c])$ $y' = -2x + 2(mx[+c])$ $-2x + 2(mx[+c]) = m(5x - 2(mx[+c]))[+c]$ $2m^2 - 3m - 2 = 0$ $m = 2, m = -\frac{1}{2}$ $c(1 + 2m) = 0$ $y = 2x$ $y = -\frac{1}{2}x + c, [c \in \mathbb{R}]$	<p>M1</p> <p>m1</p> <p>m1</p> <p>A1</p> <p>A1</p> <p>A1</p>	<p>Substitutes $k = -6$ and attempts to find x' and y'</p> <p>Condone sign errors</p> <p>Condone using x for x' and y for y'</p> <p>May only consider mx or finds one eigenvalue 1 or 6</p> <p>ft their $y' = m(\text{their } x')$ $[+c]$ or finds both eigenvalues 1 and 6</p> <p>Attempt to find m by comparing coefficients of x or setting x coefficients = 0</p> <p>or uses an eigenvalue to find a possible equation</p> <p>correct values of m</p> <p>or uses both eigenvalues to find $y = 2x$ and $y = -\frac{1}{2}x$</p> <p>having formed a correct equation in terms of c and m or compared coefficients</p> <p>with no restrictions on c having formed a correct equation in terms of c and m or compared coefficients</p>
		6	

Q	Answer	Marks	Comments
5(c)(ii)	$[\det \mathbf{S} =] \det \mathbf{M} = 5 \times 2 - (-2) \times (-2)$ $= 6$	<p>M1</p> <p>A1</p>	<p>attempt at determinant or eigenvalues of \mathbf{M}</p> <p>PI</p>
		2	

	Question 5 Total	13	
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Q	Answer	Marks	Comments
6(a)	$G_X(t) = 0.5 + 0.3t^4 + 0.2t^8$	B1	oe
		1	

Q	Answer	Marks	Comments
6(b)	$G_{X+Y}(t) = (0.5 + 0.3t^4 + 0.2t^8)(1 - k + kt)$	M1	Multiplies their $G_X(t)$ and $G_Y(t)$ oe
	$G_{X+Y}(t) = 0.5(1 - k) + 0.5kt + 0.3(1 - k)t^4 + 0.3kt^5 + 0.2(1 - k)t^8 + 0.2kt^9$	A1	AG Must be convincingly shown.
		2	

Q	Answer	Marks	Comments
6(c)	$G'_{X+Y}(t) = 0.5k + 1.2(1 - k)t^3 + 1.5kt^4 + 1.6(1 - k)t^7 + 1.8kt^8$	M1	Differentiates $G_{X+Y}(t)$ correctly or differentiates their $G_X(t)$ correctly
	$\mu = G'_{X+Y}(1) = 0.5k + 1.2(1 - k) + 1.5k + 1.6(1 - k) + 1.8k$ [$= k + 2.8$]	A1	Finds mean of $X + Y$ in terms of k or finds the mean of $X = 2.8$ oe
	$k + 2.8 = 3.4$	M1	Sets their mean of $X + Y$ in terms of k or their mean of X plus k equal to 3.4 Mean must have been obtained by differentiation
	$k = 0.6$	A1	Must follow correct differentiation oe
		4	

	Question 6 Total	7	
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Q	Answer	Marks	Comments
7(a)	$\frac{1-p}{p^2}$	B1	oe
		1	

Q	Answer	Marks	Comments
7(b)	$2 = \frac{1-p}{p^2} + \frac{1-p}{p^2} - 2 \times \frac{3}{4} \sqrt{\frac{1-p}{p^2}} \sqrt{\frac{1-p}{p^2}}$ $2 = \frac{1-p}{2p^2} \Rightarrow 4p^2 + p - 1 = 0$ $p = 0.3904$	M1 m1 A1	Forms correct equation in terms of p using their $\text{Var}(S)$ Forms correct quadratic equation in terms of p PI CAO If $p = -0.6404$ is seen, it must be rejected
		3	

Q	Answer	Marks	Comments
7(c)	$E(S) = \frac{1}{0.3904} [= E(T)]$ $E(S + T) = \frac{2}{0.3904} = 5.12$	M1 A1ft	Attempt to find $E(S)$ or $E(T)$ using their numerical p AWRT 5.12 ft their p Allow an exact answer
		2	

	Question 7 Total	6	
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Q	Answer	Marks	Comments
8(a)	$\sqrt{\frac{n^2-1}{12}}$	B1	oe
		1	

Q	Answer	Marks	Comments
8(b)	$\frac{\frac{0.6}{n}}{\frac{0.6}{n} + \frac{0.4}{n+2}}$ $= \frac{0.6(n+2)}{0.6(n+2) + 0.4n} = \frac{0.6n+1.2}{n+1.2}$	M1 M1 A1	Correct unsimplified numerator seen anywhere Correct unsimplified denominator seen anywhere AG Must be convincingly shown. An intermediate line must be seen
		3	

Q	Answer	Marks	Comments
8(c)	$\frac{0.6n+1.2}{n+1.2} = \frac{13}{21}$ $12.6n + 25.2 = 13n + 15.6$ $0.4n = 9.6$ $n = 24$ <p>[Discrete] uniform [distribution] with $n = 24$</p>	M1 A1 A1ft	Forms correct equation oe Finds correct value of n ft their n provided it is a positive integer Allow U(24) or U(1,24)
		3	

	Question 8 Total	7	
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Q	Answer	Marks	Comments
9	$\alpha = 1$	B1	Correct value for one of α, β or γ
	$\gamma = 2$	B1	Correct value for two of α, β or γ
	$\beta + \gamma = 1$ $\beta = -1$	B1	Correct values for α, β and γ
		3	

	Question 9 Total	3	
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Q	Answer	Marks	Comments
10(a)	$I = \int_0^{0.2} 270t(1-5t) dt$ $I = 1.8 \text{ [N s]}$	M1	Forms correct integral. Condone missing or incorrect limits and missing dt
		A1	Correct value oe If units seen they must be correct
		2	

Q	Answer	Marks	Comments
10(b)	$1.8 = 0.3v - 0.3 \times (-4)$ $v = \frac{1.8 - 1.2}{0.3} = 2 \text{ [m s}^{-1}\text{]}$	M1 A1	M1: Uses change in momentum equals their non-zero impulse. Condone sign errors A1: Correct equation
		A1	Correct speed Must be positive If units seen they must be correct
		3	

	Question 10 Total	5	
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Q	Answer	Marks	Comments
11	Resultant velocity must be perpendicular to the bank. $2.5^2 = v^2 + 1.5^2$ $v = 2$ $t = \frac{130}{2} = 65 \text{ seconds}$	M1 A1 A1	Forms a correct equation to find the resultant velocity or calculates $2.5 \times \frac{4}{5}$ Correct resultant velocity Ignore any units given PI Correct time and units
		3	
	Question 11 Total	3	

Q	Answer	Marks	Comments
12(a)	$3m + 4 \times 1 = mv_A + 4v_B$	M1	Obtains $\pm 3m \pm 4 \times 1 = \pm mv_A \pm 4v_B$
	$3m + 4 = mv_A + 4v_B$		
	$v_B - v_A = -e(1-3)$	M1	Obtains $\pm v_B \pm v_A = \pm e(1 \pm 3)$
	$v_B = v_A + 2e$		
$3m + 4 = mv_A + 4(v_A + 2e)$	A1	Two correct equations	
$3m + 4 - 8e = v_A(m + 4)$			
$v_A = \frac{3m + 4 - 8e}{m + 4}$			
		4	

Q	Answer	Marks	Comments
12(b)(i)	$\frac{3m + 4 - 8e}{m + 4} < 0$	M1	Forms inequality their part (a) < 0 May just set the numerator < 0
	$3m + 4 - 8e < 0$		
	Use $e = 1$	A1	AG must be convincingly shown using $e = 1$ Before $m < \frac{4}{3}$ is seen, must see either an intermediate line with $e = 1$ substituted in or $m < \frac{8e - 4}{3}$ and $e = 1$ stated
	$3m - 4 < 0$		
$m < \frac{4}{3}$			
		2	

Q	Answer	Marks	Comments
12(b)(ii)	$3 \times \frac{1}{2} + 4 - 8e < 0$	M1	Substitutes for mass in their inequality from part (b)(i) or their part (a) < 0 PI
	$\frac{11}{2} < 8e$		
	$\frac{11}{16} < e$	A1	Obtains $\frac{11}{16}$ from correct inequality oe eg 0.6875
	$\frac{11}{16} < e \leq 1$		
		3	

	Question 12 Total	9	
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