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FM02

(9665/FM02) Unit FPSM1 Pure Mathematics, Statistics and Mechanics

Mark scheme

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256XFM02/MS

Mark schemes are prepared by the Lead Assessment Writer and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation events which all associates participate in and is the scheme which was used by them in this examination. The standardisation process ensures that the mark scheme covers the students' responses to questions and that every associate understands and applies it in the same correct way. As preparation for standardisation each associate analyses a number of students' scripts. Alternative answers not already covered by the mark scheme are discussed and legislated for. If, after the standardisation process, associates encounter unusual answers which have not been raised they are required to refer these to the Lead Examiner.

It must be stressed that a mark scheme is a working document, in many cases further developed and expanded on the basis of students' reactions to a particular paper. Assumptions about future mark schemes on the basis of one year's document should be avoided; whilst the guiding principles of assessment remain constant, details will change, depending on the content of a particular examination paper.

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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)	$1.2\times1.8-(0.4-p)\times(0.4+p)$ $2+p^2$	M1 A1	Correct expression for determinant
		2	

Q	Answer	Marks	Comments
1(b)(i)	Shear parallel to y-axis	B1	
		1	

Q	Answer	Marks	Comments
1(b)(ii)	$\begin{bmatrix}1 & 0\\ k & 1\end{bmatrix}\begin{bmatrix}3\\ 2\end{bmatrix}=\begin{bmatrix}3\\ -4\end{bmatrix}$ $\Rightarrow 3k+2=-4$ $k=-2$	M1 A1	Uses a matrix of the correct form for a shear with x-axis invariant
		2	

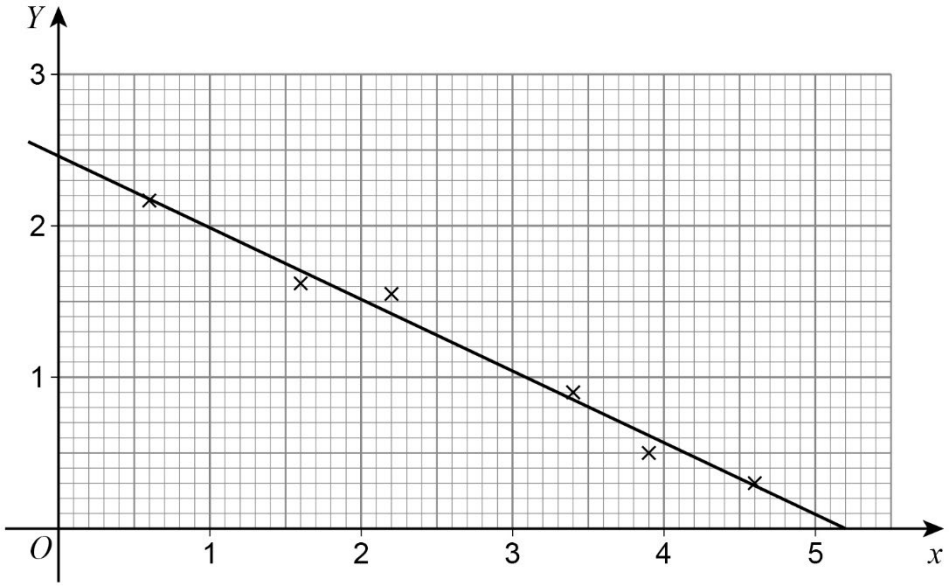
Q	Answer	Marks	Comments
1(c)	$\mathbf{C}=\begin{bmatrix}1.2 & 0.4-p\\ 0.4+p & 1.8\end{bmatrix}\begin{bmatrix}1 & 0\\ -2 & 1\end{bmatrix}$ $=\begin{bmatrix}0.4+2p & 0.4-p\\ p-3.2 & 1.8\end{bmatrix}$	M1 M1 A1	**A** × *their* **B** (must be correct order) obtains a 2 × 2 matrix with at least 2 correct terms for *their* **B** **CAO**
		3	

	Question 1 Total	**8**	

Q	Answer	Marks	Comments
2	$hf(2, 5) = 0.05 \times \frac{1}{2^2 - \sqrt{5}}$	**M1**	Correct substitution into RHS of this expression
	$= 0.02834576...$	**A1**	**PI**
	$y_2 = 5 + 0.02834576... = 5.02834576...$	**m1**	5 + their value of $hf(2, 5)$
	$y_3 = 5.02834576 + 0.05 \times \frac{1}{2^{2.05} - \sqrt{5.02834576}}$	**M1**	Correct substitution using their y_2 into second term here
	$[= 5.05468009]$		
	5.055	**A1**	Correct answer given to 3 dp

	Question 2 Total	**5**	

Q	Answer	Marks	Comments
3(a)	$\frac{y}{x} = Ax + B$	M1	Divides through by x
	which is a linear relationship between x and $\frac{y}{x}$	A1	Obtains correct relationship and gives conclusion
		2	

Q	Answer	Marks	Comments
3(b)(i)		B1	Best-fit line drawn
			
		1	

Q	Answer	Marks	Comments
3(b)(ii)	gradient = –0.47 y-intercept = 2.46	M1	Gradient or intercept seen
	$A = -0.47$ $B = 2.46$	A1	**AWFW** $[-0.5, -0.44]$ for A **AWFW** $[2.38, 2.55]$ for B
		2	

Q	Answer	Marks	Comments
3(c)	$1 = -0.47x^2 + 2.46x$	**M1**	Substitutes their values into original relationship
	$x = 4.7898$ or $x = 0.4442$	**M1**	**PI** Solves resulting quadratic
	$x = 4.8$ or $x = 0.44$	**A1ft**	**ft** Their values, each value must be to two significant figures
		3	

	Question 3 Total	**8**	

Q	Answer	Marks	Comments
4(a)(i)	$\mathrm{f}(2) = -3$ and $\mathrm{f}(3) = 3$	**B1**	Evaluates both
	$\lvert\mathrm{f}(2)\rvert = \lvert\mathrm{f}(3)\rvert$ so linear interpolation divides the interval in two [as does interval bisection]	**E1**	Correct conclusion
		2	

Q	Answer	Marks	Comments
4(a)(ii)	$\mathrm{f}\left(\frac{5}{2}\right) = -2.75$ [and $\mathrm{f}(3) = 3$]	**M1**	
	Change of sign, so $\frac{5}{2} < \alpha < 3$	**A1**	Correct conclusion
		2	

Q	Answer	Marks	Comments
4(b)	$x_1 = \frac{5}{2} + \frac{1}{2} \times \frac{2.75}{2.75+3}$	**M1 M1**	**M1** For $x_1 = \frac{5}{2} + \frac{1}{2} \times \frac{\ldots}{\ldots}$ **oe** **M1** For $\frac{2.75}{2.75+3}$ **oe**
	$x_1 = \frac{63}{23}$	**A1**	
	$\left[\mathrm{f}(x_1)\right] = -0.778$	**B1ft**	For evaluating their $\mathrm{f}(x_1)$
	$\mathrm{f}(x_1) < 0$ so $\alpha > \frac{63}{23}$ and $\frac{63}{23} < \alpha < 3$	**E1**	**AG** Must be convincingly shown
		5	

	Question 4 Total	**9**	

Q	Answer	Marks	Comments
5(a)	$\mathbf{M}^2 = \frac{1}{25}\begin{bmatrix} 2k-3 & 4-k \\ 4k+4 & 3-2k \end{bmatrix}\begin{bmatrix} 2k-3 & 4-k \\ 4k+4 & 3-2k \end{bmatrix}$ $= \frac{1}{25}\begin{bmatrix} (2k-3)^2+(4-k)(4k+4) & (4-k)(2k-3)+(3-2k)(4-k) \\ (4k+4)(2k-3)+(3-2k)(4k+4) & (4-k)(4k+4)+(3-2k)^2 \end{bmatrix}$	M1	For $\frac{1}{25}\times$ a 2 × 2 matrix **oe** with at least one correct algebraic entry
	$= \frac{1}{25}\begin{bmatrix} 25 & 0 \\ 0 & 25 \end{bmatrix}$	M1	For one correctly evaluated entry
	$= \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$	A1	**CAO**
		3	

Q	Answer	Marks	Comments
5(b)	$\frac{1}{5}\begin{bmatrix} 2k-3 & 4-k \\ 4k+4 & 3-2k \end{bmatrix}\begin{bmatrix} x \\ 2x \end{bmatrix}$	M1	Applies **M** to a general point on the line $y = 2x$
	$= \frac{1}{5}\begin{bmatrix} (2k-3)x+(4-k)\times 2x \\ (4k+4)x+(3-2k)\times 2x \end{bmatrix}$ $= \frac{1}{5}\begin{bmatrix} 5x \\ 10x \end{bmatrix}$ $= \begin{bmatrix} x \\ 2x \end{bmatrix}$	A1	Obtains $\begin{bmatrix} x \\ 2x \end{bmatrix}$ **oe**
	So any point of the form $(x, 2x)$ is invariant, so $y = 2x$ is a line of invariant points	A1	**CAO**
		3	

Q	Answer	Marks	Comments
5(c)(i)	$k = 0$ gives $\mathbf{M} = \begin{bmatrix} -0.6 & 0.8 \\ 0.8 & 0.6 \end{bmatrix}$	**M1**	Substitutes $k = 0$
	Reflection	**A1**	
	…with $\cos 2\theta = -0.6$ so $\tan\theta = 2$		
	[with mirror line] $y = 2x$	**A1**	
		3	

Q	Answer	Marks	Comments
5(c)(ii)	$a = -\frac{1}{2}$	**B1**	
		1	

	Question 5 Total	**10**	

Q	Answer	Marks	Comments
6(a)	[Discrete] uniform [distribution]	**B1**	
		1	

Q	Answer	Marks	Comments
6(b)	$\frac{5}{11}$	**B1**	**oe**
		1	

Q	Answer	Marks	Comments
6(c)	$\mathrm{E}(X)=\frac{n+1}{2}$ $\mathrm{E}(X)=\frac{11+1}{2}=6$	**B1**	**PI**
	$\mathrm{Var}(X)=\frac{n^2-1}{12}$ $\mathrm{Var}(X)=\frac{11^2-1}{12}=10$	**B1**	**PI**
	$6a+b=13$ $10a^2=90$	**M1**	One correct equation
	$a=3$	**A1**	
	$b=-5$	**A1**	
		5	

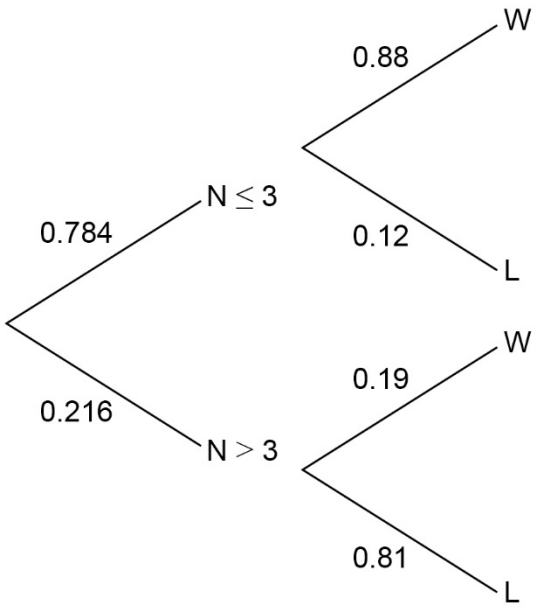
	Question 6 Total	**7**	

Q	Answer	Marks	Comments
7(a)	$1-0.318-0.512=0.17$	**B1**	**AG** Must be convincingly shown
		1	

Q	Answer	Marks	Comments
7(b)	$G'_Y(t)=0.512+0.17bt^{b-1}$	**M1**	Differentiates $G_Y(t)$ **oe**
	$1.872=0.512+0.17b$	**m1**	Forms correct equation to find b
	$b=8$	**A1**	
		3	

Q	Answer	Marks	Comments
7(c)	$G''_Y(t)=9.52t^6$	**M1**	Differentiates their $G'_Y(t)$ **oe**
	$\text{Var}(Y)=9.52+1.872-1.872^2$	**m1**	Applies correct variance formula
	$\text{Var}(Y)=7.887616$	**A1ft**	**AWRT** 7.89 **ft** Their $0.17b(b-1)-1.632384$
		3	

	Question 7 Total	**7**	

Q	Answer	Marks	Comments
8(a)	$1-(1-0.4)^3$ or $(1-0.4)^3$	M1	Correct calculation of P(ball in hole ≤ 3) or P(ball in hole > 3) **PI** By sight of 0.784 or 0.216
		M1	Correct structure **oe** Allow any sensible notation
		A1	Fully correct **oe**
		3	

Q	Answer	Marks	Comments
8(b)	$\dfrac{0.784\times0.88}{0.784\times0.88+0.216\times0.19}$	M1	Correct numerator (0.68992) **ft** Their 0.784
		M1	Correct denominator (0.73528) **ft** Their 0.784 and 0.216 provided that they sum to 1
	$=0.944$	A1	**AWRT** 0.944
		3	

	Question 8 Total	**6**	

Q	Answer	Marks	Comments
9(a)	MLT^{-2}	B1	Correct dimensions
		1	

Q	Answer	Marks	Comments
9(b)	MLT^{-1}	B1	Correct dimensions
		1	

Q	Answer	Marks	Comments
9(c)	[Rate of change of momentum] $= \frac{MLT^{-1}}{T}$ $= MLT^{-2}$ $=$ [Force] So statement is dimensionally consistent	M1 A1	Dimensions of rate of change of momentum Concludes argument
		2	

	Question 9 Total	**4**	

Q	Answer	Marks	Comments
10(a)	$3\times5+7\times(-2)=3v_A+7v_B$	**M1**	Equation for conservation of momentum
	$1=3v_A+7v_B$	**A1**	Correct equation
	$v_A-v_B=-0.1\big(5-(-2)\big)$	**M1**	Equation using coefficient of restitution
	$=-0.7$	**A1**	Correct equation
	$v_A=-0.39$ Speed of A $=$ 0.39 $\left[\text{m s}^{-1}\right]$	**A1**	Correct equation
		5	

Q	Answer	Marks	Comments
10(b)	$I=3\times\big(-0.39\big)-3\times5$ $=-16.17$	**M1**	Uses impulse formula
	Magnitude $=16.2$ $\left[\text{Ns}\right]$	**A1**	Correct magnitude
		2	

Q	Answer	Marks	Comments
10(c)	$16.17=F\times0.05$	**M1**	Uses $I=Ft$
	$F=323$ $\left[\text{N}\right]$	**A1**	Correct value Allow 324 N
		2	

	Question 10 Total	**9**	

Q	Answer	Marks	Comments
11(a)	$\mathbf{v}_{PQ} = \begin{bmatrix} V\sin\theta - 3\cos 10^\circ \\ V\cos\theta + 3\sin 10^\circ \end{bmatrix}$	M1 A1	Finds relative velocity, with at least one correct component Correct relative velocity
		2	

Q	Answer	Marks	Comments
11(b)	$360\begin{bmatrix} V\sin\theta - 3\cos 10^\circ \\ V\cos\theta + 3\sin 10^\circ \end{bmatrix} = \begin{bmatrix} 0 \\ 1200 \end{bmatrix}$	M1	Forms expressions for $V\sin\theta$ and $V\cos\theta$
	$V\sin\theta = 3\cos 10^\circ$ $V\cos\theta = \frac{1200}{360} - 3\sin 10^\circ$	A1	Both correct
	$V = \sqrt{\left(3\cos 10^\circ\right)^2 + \left(\frac{1200}{360} - 3\sin 10^\circ\right)^2} = 4.1$	M1 A1	**M1**: Eliminates θ **A1**: Correct V
	$\tan\theta = \frac{3\cos 10^\circ}{\frac{1200}{360} - 3\sin 10^\circ}$		
	$\theta = 46$	A1	Correct θ
		5	

	Question 11 Total	**7**	