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INTERNATIONAL A-LEVEL MATHEMATICS MA04

(9660/MA04) Unit S2 Statistics

Mark scheme

June 2023

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2 3 6 X M A 0 4 / M S

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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)

Q	Answer	Marks	Comments
1(a)(i)	standard deviation = $\sqrt{15}$	B1	Allow AWRT 3.9
		1	

Q	Answer	Marks	Comments
1(a)(ii)	$P(W \leq 20) = 0.9170 \quad [> 0.9]$ $P(W \leq 19) = 0.8752 \quad [< 0.9]$ $a = 20$	M1 A1	For one correct probability PI by correct value of a
		2	

Q	Answer	Marks	Comments
1(a)(iii)	$P(W > 24) = 1 - 0.9888 \quad [= 0.0112 > 0.01]$ $P(W > 25) = 1 - 0.9938 \quad [= 0.0062 < 0.01]$ $b = 25$	M1 A1	For one correct probability PI by correct value of b Allow 0.0111 and 0.0061 from calculator
		2	

Q	Answer	Marks	Comments
1(b)	$P(X \leq 4) - P(X \leq 2)$ $[= 0.8153 - 0.4232]$ $= 0.392$	M1 A1	$P(X \leq m) - P(X \leq n)$ with at least one of $m = 4, n = 2$ PI by correct answer AWRT 0.392
		2	

Q	Answer	Marks	Comments
1(c)(i)	As n is large and p is small	B1	oe eg $n > 20$ and $p < 0.25$
		1	

Q	Answer	Marks	Comments
1(c)(ii)	$\lambda = 10$	B1	oe
		1	

Q	Answer	Marks	Comments
1(c)(iii)	$[\lambda = 15 + 3 + 10]$ $\lambda = 28$ $[P(C < 3) =]$ $\frac{e^{-28} \times 28^0}{0!} + \frac{e^{-28} \times 28^1}{1!} + \frac{e^{-28} \times 28^2}{2!}$ $= 421e^{-28}$	B1ft M1 A1	ft their λ from (c)(ii) M1 for at least one correct probability in the sum in the form $ne^{-\lambda}$ ft their 28 CAO NMS 3/3
		3	

	Question 1 Total	12	
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Q	Answer	Marks	Comments
2(a)	$P(X > 50) = P\left(Z > \frac{50-38}{11}\right)$ $[P(Z < 1.09) =] \quad 0.86214 \quad [\text{from tables}]$ $[P(Z > 1.09) =] \quad 1 - 0.86214$ $= 0.138$	M1 M1 A1	For standardising $\frac{50-38}{11}$ PI 0.862[14] seen or used PI Allow 0.13786 [from use of tables] NMS 3/3
		3	

Q	Answer	Marks	Comments
2(b)	$H_0: \mu = 38$ $H_1: \mu < 38$ $\bar{X} \sim N\left(38, \frac{11^2}{30}\right)$ $z = \frac{34-38}{11/\sqrt{30}}$ $z = -1.9917...$ $z_{\text{critical}} = \pm 2.0537$ Do not reject H_0 as $z_{\text{critical}} < z$ or $-2.0537 < -1.99... \text{ or } z < 2.0537$ Insufficient evidence to support the claim that the journey time has reduced from 38 minutes on average [at the 2% level of significance]	B1 B1 M1 A1 B1 A1ft E1	Condone 'mu' or other letters, but not $\bar{x}$ PI by correct standardisation formulae $z = \frac{34-38}{\sigma/\sqrt{30}}$ with their σ PI by correct z AWRT -1.99 or exact value $-\frac{4\sqrt{30}}{11}$ or $P\left(Z < -\frac{4\sqrt{30}}{11}\right) = 0.0232 \text{ to } 0.0233$ or comparison of $P(\bar{X} < 34) = 0.0232 \text{ to } 0.0233$ with 2% Allow 'accept H_0 ' Comment about H_0 and 0.0232 to 0.0233 > 0.02 Correct conclusion based upon ft their z (signs need to be compatible) Correct statement must be in context and must follow from fully correct solution. Condone definite statement.
		7	

	Question 2 Total	10	
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Q	Answer	Marks	Comments
3(a)	Exponential and $\lambda = \frac{1}{8}$	B1	
		1	

Q	Answer	Marks	Comments
3(b)	$P(T > 7) = 1 - P(T \leq 7)$ $\left[= 1 - \left(1 - e^{-\frac{7}{8}} \right) \right] = 0.4169$	M1 A1	PI Attempts to find correct probability using cdf of exponential or integration of pdf CAO to 4 sf
		2	

Q	Answer	Marks	Comments
3(c)	$\left[1 - e^{-\frac{x}{8}} = 0.95 \Rightarrow \right] \quad x = -8 \ln(0.05)$ $x = 23.9658\dots$ $L = 23970 \text{ [hours]}$	M1 A1	Attempt to find x by simplifying an equation using a cdf of exponential or integration of pdf oe oe
		2	

Q	Answer	Marks	Comments
3(d)	$P(T < 10 T > 7) = P(T < 3)$	M1	Attempt to find t by simplifying an equation using a cdf of exponential or integration of pdf
	$\left[= 1 - e^{-\frac{3}{8}} \right]$		
	$= 0.3127$	A1	AWRT 0.3127
		2	

Q	Answer	Marks	Comments
3(e)	The no memory property of the exponential distribution suggests the component is memoryless [however given the component is already 7 thousand hours old it is 'more likely' to break]	E1	Reference to 'memory' or comment about increasing chance of breakdown
		1	

	Question 3 Total	8	
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Q	Answer	Marks	Comments
4(a)	$\frac{k-0.4}{5-4} = \frac{0.4-0}{4-2}$ $k = 0.6$	M1 A1	Correct equation to find k M1 for $m = 0.2$ oe
		2	

Q	Answer	Marks	Comments
4(b)	$F(x) = \begin{cases} 0 & x < 2 \\ 0.2x - 0.4 & 2 \leq x < 5 \\ 0.1x + 0.1 & 5 \leq x < 9 \\ 1 & x \geq 9 \end{cases}$	B1 M1 A1 A1 B1	B1 for correct values of $F(x)$ for $x < 2$ and $x \geq 9$ M1 for use of a straight line method to find an equation A1 for one correct equation A1 for both correct equations B1 all correct domains
		5	

Q	Answer	Marks	Comments
4(c)	$[F(6) - F(4) =]$ $(0.1 \times 6 + 0.1) - (0.2 \times 4 - 0.4)$ $= 0.3$	M1 A1	Attempt using their $F(6)$ and $F(4)$ oe
		2	

	Question 4 Total	9	
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Q	Answer	Marks	Comments
5(a)	$X \sim B(50, 0.9)$ [p is the probability of a successful repair] $H_0 : p = 0.9$ $H_1 : p > 0.9$ $[1 - P(X \leq 48) =] 1 - 0.9662 \text{ or } 0.0338$ $P(X \geq 49) = 0.0338$ $0.0338 > 0.01$ Do not reject H_0 Insufficient evidence to suggest that Sam's success rate has improved.	M1 B1 M1 A1 M1 A1ft E1	or $Y \sim B(50, 0.1)$ or $H_0 : p = 0.1$ $H_1 : p < 0.1$ Sight of AWRT 0.0338 $P(Y \leq 1) = 0.0338$ Award M1 A1 for: critical region for Y is $\{0\}$ oe , or critical region for X is $\{50\}$ oe oe Comparison of their probability to 0.01 Correct conclusion for their value Cannot be a definite statement. Must follow a fully correct test
		7	

Q	Answer	Marks	Comments
5(b)	Accepting that the success rate [in repairing water damaged phones] for Sam has increased from 90% when it has not	B1	Must be in context
		1	

Q	Answer	Marks	Comments
5(c)	The successful repair of each phone is not likely to be independent as they were damaged in the same flood and so shouldn't be modelled as a Binomial	B1	
		1	

	Question 5 Total	9	
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[illegible]

	Question 6 Total	10	
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Q	Answer	Marks	Comments
7(a)	$\int_0^1 \frac{3x^{\frac{1}{2}} + k}{6} dx = 1$ $\left[\frac{1}{3} x^{\frac{3}{2}} + \frac{1}{6} kx \right]_0^1 = 1$ $\left[\left(\frac{1}{3} + \frac{1}{6} k \right) - (0 + 0) \right] = 1$ $k = 4$	M1 A1	Correct integral set equal to 1 with at least 1 correct integration oe AG Requires at least one intermediate line after integration
		2	

Q	Answer	Marks	Comments
7(b)	$\left[\int x f(x) dx \right] = \int_0^1 \frac{3x^{\frac{3}{2}} + 4x}{6} dx$ $= \left[\frac{1}{5} x^{\frac{5}{2}} + \frac{1}{3} x^2 \right]_0^1$ $\left[\frac{1}{5} + \frac{1}{3} \right] = \frac{8}{15}$	M1 M1 A1	Identifies correct integral Correct integration for their $x f(x) dx$ CAO
		3	

Q	Answer	Marks	Comments
7(c)	$\left[E(X^2) = \int x^2 f(x) dx = \int_0^1 \frac{3x^{\frac{5}{2}} + 4x^2}{6} dx \right]$ $= \left[\frac{1}{7} x^{\frac{7}{2}} + \frac{2}{9} x^3 \right]_0^1$ $E(X^2) = \frac{23}{63}$ $\text{Var}(X) = E(X^2) - E(X)^2$ $= \frac{23}{63} - \left(\frac{8}{15} \right)^2$ $= \frac{127}{1575}$	M1 M1 A1 M1 A1	Identifies correct integral Correct integration PI ft their $E(X^2)$ AG
		5	

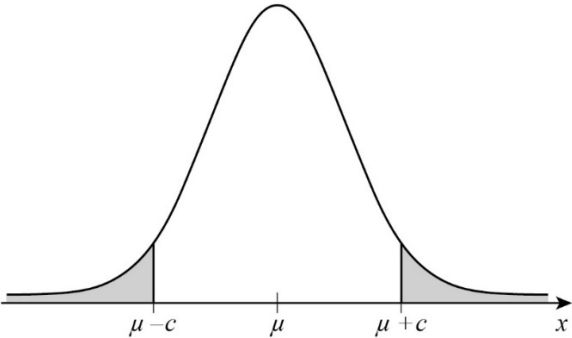
Q	Answer	Marks	Comments
7(d)(i)	$15E(X) - 9E(Y)$ $= 15 \times \frac{8}{15} - 9 \times 2$ $= -10$	M1 A1	
		2	

Q	Answer	Marks	Comments
7(d)(ii)	$225\text{Var}(X) + 81\text{Var}(Y)$ $= 225 \times \frac{127}{1575} + 81 \times \frac{5}{7}$ $= 76$	M1 A1	
		2	

	Question 7 Total	14	
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Q	Answer	Marks	Comments
8(a)(i)	$a = 1.9600\sigma$	B1	Condone AWRT 1.96
		1	

Q	Answer	Marks	Comments
8(a)(ii)	$b = \mu + 0.9945\sigma$	B1	Condone $b = \mu + 0.9944\sigma$
		1	

Q	Answer	Marks	Comments
8(a)(iii)		B1	Must be approximately symmetrical and have labels $\mu - c$ and $\mu + c$
		1	

Q	Answer	Marks	Comments
8(b)	$[P(Z < z) = 0.975 \Rightarrow] z = 1.96$ $1.96 = \frac{205 - m}{\sqrt{0.8m}}$ $(\sqrt{m})^2 + 1.7530[77294]\sqrt{m} - 205 = 0$ $\sqrt{m} = 13.4[6808822...]$ $m = 181.39$	B1 M1 m1 A1 A1	A quadratic equation in m or $\sqrt{m}$ set equal to zero PI by 181.38... or 231.68..., or 13.46... or -15.22... AWFW [13.4, 13.5] PI by $m = 181.39$ This value and no others
		5	

	Question 8 Total	8	
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