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MA04

(9660/MA04) Unit S2 Statistics

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)	$\mathrm{P}(T<4)=1-\mathrm{e}^{-\frac{1}{8}\times 4}$ $=0.3935$	**M1** **A1**	**PI** Attempts to find correct probability using the cdf of the exponential distribution or through integration **AWRT** 0.3935
		2	

Q	Answer	Marks	Comments
1(b)	$\mathrm{P}(3<T<10)=\left(1-\mathrm{e}^{-\frac{1}{8}\times 10}\right)-\left(1-\mathrm{e}^{-\frac{1}{8}\times 3}\right)$ $=0.4008$	**M1** **A1**	**oe** sight of $\left(1-\mathrm{e}^{-\frac{1}{8}\times 10}\right)$ or $\left(1-\mathrm{e}^{-\frac{1}{8}\times 3}\right)$ **PI** by 0.7134… or 0.3127…. **AWRT**
		2	

Q	Answer	Marks	Comments
1(c)	$\mathrm{e}^{-\frac{1}{8}t}=0.2$ $-\frac{1}{8}t=\ln 0.2$ $t=12.9$ [hours]	**M1** **A1**	Sets up a correct equation and attempts to solve for t **AWRT** 12.9
		2	

Q	Answer	Marks	Comments
1(d)	64	**B1**	
		1	

Q	Answer	Marks	Comments
1(e)	$P(T > 12 \mid T > 9) = P(T > 3)$ $P(T > 3) = e^{-\frac{1}{8}\times 3}$ $= 0.687$	M1 A1	CAO
		2	

	Question 1 total	**9**	

Q	Answer	Marks	Comments
2(a)	$\int_2^a \frac{3}{1072}\sqrt{5x+6}dx = 1$	**M1**	Attempt to integrate and set equal to 1
	$\frac{1}{2680}\left[(5x+6)^{\frac{3}{2}}\right]_2^a = 1$	**A1**	Correct integration and limits seen or used
	$(5a+6)^{\frac{3}{2}} - 64 = 2680$ $5a+6 = 196$	**m1**	Attempt to use limits to find a
	$a = 38$	**A1**	**CAO**
		4	

Q	Answer	Marks	Comments
2(b)	0	**B1**	
		1	

	Question 2 total	**5**	

Q	Answer	Marks	Comments
3(a)	0.85^{30}	M1	oe
	$= 0.00763$	A1	CAO
		2	

Q	Answer	Marks	Comments
3(b)	$H_0 : p = 0.15$ $H_1 : p < 0.15$	B1	Both hypotheses $H_0 : p = 0.85$ $H_1 : p > 0.85$
	$X \sim B(30, 0.15)$	M1	**PI** by a binomial probability calculation $Y \sim B(30, 0.85)$
	$P(X \leq 1) = 0.0480$	A1	$P(Y \geq 29) = 0.0480$ or CR is $X \leq 1$
	$0.0480 < 0.05$	A1ft	Compares their probability with 0.05 or states 1 is in the CR
	Reject H_0	B1ft	Correct conclusion on H_0 based on a comparison of their test statistic with 0.05
	Evidence to suggest that the new computer system has decreased the proportion of missed appointments each workday	E1	Must be in context, must not be definite and all the previous 5 marks must have been awarded
		6	

Q	Answer	Marks	Comments
3(c)	Concluding that the proportion of missed appointments has decreased even though it hasn't	B1	
		1	

	Question 3 total	**9**	

Q	Answer	Marks	Comments
4(a)	Any **two** from; That each car arrives independently of another car That cars arrive at a constant average rate Cars arrive singly	**B2**	**B1** for one correct assumption
		2	

Q	Answer	Marks	Comments
4(b)(i)	$\sum fx = 140$ or $\sum fx^2 = 528$	**M1**	Sight of either summary statistic **PI** by at one correct value
	$\overline{x} = 2.8$	**A1**	**oe**
	$s^2 = 2.78$	**A1**	**AWRT** 2.78 Allow $\frac{136}{49}$
		3	

Q	Answer	Marks	Comments
4(b)(ii)	As $\overline{x} \approx s^2$ we can conclude that a Poisson distribution might be a good model for X	**B1**	**ft** their $\overline{x}$ and s^2 with correct comment on suitability
		1	

Q	Answer	Marks	Comments
4(c)(i)	$[2.9 + 3.6] = 6.5$	**B1**	
		1	

Q	Answer	Marks	Comments
4(c)(ii)	$\mathrm{P}(T \leq 13) = 0.9929$	**M1**	**oe** such as $\mathrm{P}(T < 14) = 0.9929$
	$\mathrm{P}(T \leq b) = 0.9929 - 0.7692$	**M1**	**oe** $\mathrm{P}(T \leq b) = \mathrm{P}(T \leq 13) - 0.7692$ **ft** their $\mathrm{P}(T \leq 13)$
	$\mathrm{P}(T \leq 4) = 0.2237 \Rightarrow b = 4$	**A1**	**CAO** from fully correct working
		3	

	Question 4 total	**10**	

Q	Answer	Marks	Comments
5(a)	$1-\int_0^{0.5}\frac{1}{2}x^2\ \mathrm{d}x$ $=1-\frac{1}{6}\times 0.5^3$ $=\frac{47}{48}$	**M1** **A1**	**oe** 1 – their attempt at integration **AWRT** 0.979
		2	

Q	Answer	Marks	Comments
5(b)	$\left[\mathrm{E}(X)=\right]\ \int_0^1\frac{1}{2}x^3\mathrm{d}x+\int_1^4\frac{x}{54}(35-8x)\,\mathrm{d}x$ $=\left[\frac{x^4}{8}\right]_0^1+\left[\frac{35x^2}{108}-\frac{4x^3}{81}\right]_1^4$ $=\left(\frac{1}{8}-0\right)+\left(\frac{164}{81}-\frac{89}{324}\right)$ $=\frac{15}{8}$	**M1** **A1** **A1**	Correct integrals and limits **PI** Correct integration with correct limits seen or used **PI** by correct final answer **oe**
		3	

Q	Answer	Marks	Comments
5(c)	$\left[\mathrm{E}\left(X\right)^2 =\right] \int_0^1 \frac{1}{2}x^4 \mathrm{d}x + \int_1^4 \frac{x^2}{54}\left(35-8x\right)\mathrm{d}x$	**M1**	Correct integrals and limits
	$= \left[\frac{x^5}{10}\right]_0^1 + \left[\frac{35x^3}{162} - \frac{x^4}{27}\right]_1^4$		
	$= \left(\frac{1}{10} - 0\right) + \left(\frac{352}{81} - \frac{29}{162}\right)$		
	$= \frac{64}{15}$	**A1**	Correct value for $\mathrm{E}\left(X\right)^2$
	$\left[\mathrm{Var}\left(X\right) = \mathrm{E}\left(X\right)^2 - \left(\mathrm{E}\left(X\right)\right)^2 =\right] \frac{64}{15} - \left(\frac{15}{8}\right)^2$	**M1**	**ft** their $\mathrm{E}\left(X\right)^2$ and their $\mathrm{E}\left(X\right)$ in the correct formula for $\mathrm{Var}\left(X\right)$
	$= \frac{721}{960}$	**A1**	**AG** Must be convincingly shown
		4	

Q	Answer	Marks	Comments
5(d)	$\left[3^2 \times \mathrm{Var}\left(X\right) =\right] 9 \times \frac{721}{960}$	**M1**	**PI** by correct final answer
	$= \frac{2163}{320}$	**A1**	**CAO**
		2	

	Question 5 total	**11**	

Q	Answer	Marks	Comments
6(a)	$c = 6$	B1	
		1	

Q	Answer	Marks	Comments
6(b)	$\frac{\mathrm{d}}{\mathrm{d}t}\left(1-\frac{t}{32}(t-6)^2\right)=\frac{-3t^2}{32}+\frac{3}{4}t-\frac{9}{8}$ $\mathrm{f}(t)=\begin{cases}\frac{-3t^2}{32}+\frac{3}{4}t-\frac{9}{8} & 2\le t\le 6\\ 0 & \text{otherwise}\end{cases}$	M1 A1 A1	**M1**: Attempts to differentiate wrt to t **A1**: Correct expression for $\mathrm{f}(t)$ in terms of t for $2\le t\le 6$ **PI** by $\frac{-3}{32}(t-2)(t-6)$ **oe** Fully correct pdf condone c for 6 Allow $t < 2$, $t > 6$ in place of 'otherwise', which may be written over two lines
		3	

	Question 6 total	**4**	

Q	Answer	Marks	Comments
7(a)	$H_0 : \mu = 2000$ $H_1 : \mu \neq 2000$	**B1**	Both hypotheses
	$\overline{X} \sim N\left(2000, \frac{18^2}{40}\right)$	**M1**	**PI**
	$z = \frac{1995 - 2000}{\sqrt{\frac{18^2}{40}}}$	**M1**	**PI**
	$z = -1.75682...$	**A1**	**AWRT** –1.76
	$z_{critical} = -1.9600...$	**B1**	**AWRT** –1.96 or $P(\overline{X} > 1995)$ = **AWFW** [0.0392, 0.0395]
	Fail to reject H_0 as $-1.96 < -1.76$ or $\lvert z \rvert < \lvert z_{critical} \rvert$	**A1ft**	**oe** Dependent on both **M1** marks and a correct comparison of their values using a z-test, e.g. $z_{critical} < z$, or 0.039511 > 0.025
	Insufficient evidence to suggest the LED lightbulb meantime has changed [at the 5% level of significance]	**E1**	Correct statement must be in context and must not be definite.
		7	

Q	Answer	Marks	Comments
7(b)	An increase in the standard deviation causes a **decrease** in the magnitude of the z-value of the test statistic.	**E1**	**oe**
	This will have **no** effect to the conclusion of the hypothesis as $\lvert z \rvert < \lvert z_{critical} \rvert$ remains true.	**E1**	**oe** $z_{critical} < z$ Must have been awarded previous **E1** mark
		2	

Q	Answer	Marks	Comments
7(c)	Central limit theorem [applies as the sample size is large enough, the sample mean will be approximately] normally distributed]	E1	Refers to central limit theorem
	The sample size is 40 which is sufficient [to apply the central limit theorem]	E1	Refers to sample size being sufficient
		2	

	Question 7 total	**11**	

Q	Answer	Marks	Comments
8(a)	$H_0 : \lambda = 15$ $H_1 : \lambda \neq 15$	**B1**	
		1	

Q	Answer	Marks	Comments
8(b)	$P(X \leq 8) = 0.0374\ (< 0.05)$ $P(X \leq 9) = 0.0699\ (> 0.05)$	**M1**	Either correct probability statement
	CR $\{X \leq 8\}$	**A1**	Both probabilities and a correct CR for the lower tail
	$P(X \geq 22) = 0.0531\ (> 0.05)$ $P(X \geq 23) = 0.0327\ (< 0.05)$	**M1**	Either correct probability statement or at least one of $P(X \leq 21) = 0.9469\ (< 0.95)$ $P(X \leq 22) = 0.9673\ (> 0.95)$
	CR $\{X \geq 23\}$	**A1**	Both probabilities and a correct CR for the upper tail
		4	

Q	Answer	Marks	Comments
8(c)	As 22 is not in the Critical Region. … there is insufficient evidence to support that the [population] mean number of bacteria in the water has changed (at the 10% level of significance)	**E1ft** **E1ft**	Comparison of 22 to their CR Comment in context which cannot be definite **ft** their CR Must have been awarded previous **E1** mark
		2	

Q	Answer	Marks	Comments
8(d)	Rejecting that there has been a change in the [population] mean number of bacteria in water when there has been a change	**E1**	Must be in context
		1	

	Question 8 total	**8**	

Q	Answer	Marks	Comments
9(a)	$\left[\mathrm{P}\left(\bar{X}_1 > 182\right) = 0.9 \Rightarrow\right]\ z = -1.2816$	**B1**	**Allow** ± 1.28 **PI** by answer correct to 3 sf before rounding
	$-1.2816 > \dfrac{182-185}{\frac{20}{\sqrt{n}}}$	**M1**	For standardising
	$\sqrt{n} > 8.544...$		
	$n > 72.9...$	**m1**	Attempt to solve for n
	$n = 73$	**A1**	**CAO**
		4	

Q	Answer	Marks	Comments
9(b)	Mean of $X_{\mathrm{T}} = 555 + \mu$	**B1**	**PI** if embedded correctly in calculations
	Variance of $X_{\mathrm{T}} = 625 + \sigma^2$	**B1**	**PI** if embedded correctly in calculations
	$1.6449 = \dfrac{750-(555+\mu)}{\sqrt{625+\sigma^2}}$	**M1 A1**	**M1**: Attempt to standardise with **AWRT** z =1.64 **A1**: Fully correct expression
	$-2.0537 = \dfrac{650-(555+\mu)}{\sqrt{625+\sigma^2}}$	**M1 A1**	**M1**: Attempt to standardise with **AWRT** z = –2.05 **A1**: Fully correct expression
	$3.6986\sqrt{625+\sigma^2} = 100$	**m1**	Correctly eliminates one unknown $\dfrac{1.6449}{-2.0537} = \dfrac{195-\mu}{95-\mu}$
	$\sigma = 10.3$ [3 sf]	**A1**	**AWRT** 10.3 (use of 3 sf for 1.64 and –2.05 gives 10.5 (3sf) gets **A0** then **A1** for 151)
	$\mu = 151$ [3 sf]	**A1**	**AWRT** 151
		9	

	Question 9 total	**13**	