Question Number	Scheme	Marks
1 (a)	$X =$ Number of items of litter found in a 2m^2 area of the beach So $X \sim \text{Po}(8)$	
	$\text{P}(X=5)=\dfrac{\text{e}^{-8}\times 8^5}{5!}$ or $\text{P}(X \leqslant 5)-\text{P}(X \leqslant 4)=0.1912-0.0996$	M1
	$=0.09160...$ awrt 0.0916	A1
		(2)
(b)	$Y =$ Number of face masks found in a 5m^2 area of the beach	
	$Y \sim \text{Po}(6)$ or $\text{P}(Y \geqslant 5)=1-\text{P}(Y \leqslant 4)=1-0.2851$	M1
	$=0.7149$ awrt 0.715	A1
		(2)
(c)	$W =$ Number of items of litter that are not face masks found in a 20m^2 area of the beach	
	$W \sim \text{N}(56,56)$	M1
	$\text{P}(W<60)=\text{P}\left(Z<\dfrac{59.5-56}{\sqrt{56}}\right)$	M1 M1
	Tables $\left[=\text{P}(Z<0.47)\right]=0.6808$ calculator $0.68000\ldots$ awrt 0.68	A1
		(4)
	Notes	**Total 8**

(a)	**M1**	for use of $\dfrac{\text{e}^{-8}\lambda^5}{5!}$ or $\text{P}(X \leqslant 5)-\text{P}(X \leqslant 4)$
	A1	awrt 0.0916 (correct answer scores 2 out of 2)
(b)	**M1**	for writing or using Po(6) **or** for a correct probability statement $1-\text{P}(Y \leqslant 4)$ or $\text{P}(Y \geqslant 5)$ e.g. $\text{P}(Y \geqslant 5)=1-\text{P}(Y \leqslant 5)$ is M0
	A1	awrt 0.715 (correct answer scores 2 out of 2)
(c)	**M1**	for writing or using N(56, 56) may be seen in standardisation (may be implied by the standardisation $\dfrac{x-56}{\sqrt{56}}$)
	M1	standardising with 59.5/60/60.5, their mean and their standard deviation
	M1	using a continuity correction 60 + 0.5 [=60.5] or 60 – 0.5 [=59.5]
	A1	awrt 0.68 (NB Use of exact Poisson gives 0.68617…and scores 0 out of 4)

Question Number	Scheme		Marks
2 (a)	$\mathrm{B}\left(25, \frac{1}{5}\right)$		B1
			(1)
(b)(i)	$[M =]4X-(25-X) \quad [=5X-25]$		B1
(ii)	$\mathrm{E}(M)='5'\mathrm{E}(X)-'25'$		M1
	$\mathrm{E}(X)=np=25\times\frac{1}{5}=5$		M1
	$\mathrm{E}(M)=5\times5-25=0$ *		A1*
			(4)
(c)	$M \geq 30 \Rightarrow '5'X-'25' \geq 30 [\Rightarrow X \geq 11]$		M1
	$[\mathrm{P}(X \geq '11')=1-\mathrm{P}(X \leq '10')]=1-'0.9944'$		M1
	$=0.0056$	awrt 0.0056	A1
			(3)
(d)	$Y \sim \mathrm{B}(50, 0.5)$		
	$\mathrm{P}(n<Y \leq 30)=0.9328$		M1
	$\mathrm{P}(Y \leq 30)-\mathrm{P}(Y \leq n)=0.9328$		M1
	$\mathrm{P}(Y \leq n)=0.0077$		M1
	$n=16$		A1
			(4)
	Notes		**Total 12**

(a)	**B1**	Correct distribution fully specified. Allow in words e.g. Binomial with n = 25 and p = 0.2 Must be seen in part (a)
		Mark parts (b)(i) and (b)(ii) together
(b)(i)	**B1**	For a correct expression for M Allow unsimplified
(ii)	**M1**	For either $'5'\mathrm{E}(X)-'25'$ or $\mathrm{E}(M)=5\times\left(25\times\frac{1}{5}\right)-25$ or $'4'\mathrm{E}(X)-1('25'-\mathrm{E}(X))$ This must be an **expectation** statement with the expectation stated in symbol or in words. $5\times5 - 25 = 0$ or $4\times5 - 1\times20 = 0$ on its own is M0
	M1	For sight of $25\times\frac{1}{5}$ or stating E(X) = 5
	A1*	Fully correct solution with $\mathrm{E}(M)=0$ stated. This may be stated in words. The answer is given so no incorrect working can be seen
SC		M1M1 [Expected number of marks (per question) =] $4\times\frac{1}{5}-1\times\frac{4}{5}$ A1 therefore E(M)=0
(c)	**M1**	For substitution of their M into a linear inequality in terms of X implied by $X \geq 11$
	M1	For use of correct probability statement from their '11'
	A1	awrt 0.0056 (calc 0.0055549…)
(d)	**M1**	For a correct probability equation (implied by 2nd M1)
	M1	For $\mathrm{P}(Y \leq 30)-\mathrm{P}(Y \leq n)=0.9328$ or $0.9405-\mathrm{P}(Y \leq n)=0.9328$
	M1	For $\mathrm{P}(Y \leq n)=0.0077$
	A1	Cao
SC		$\mathrm{P}(n<Y \leq 30)=0.9328$ $\mathrm{P}(Y \leq 30)-\mathrm{P}(Y \leq n-1)=0.9328$ $\mathrm{P}(Y \leq n-1)=0.0077$ scores M1M0M1A0

Question Number	Scheme	Marks
3 (a)	Po(7)	B1
		(1)
(b)	**Customers** enter the shop occur singly/randomly/independently/**constant** (average) rate	B1, B1
		(2)
(c)	$\mathrm{H}_0 : \lambda = '7' \quad \mathrm{H}_1 : \lambda \neq '7'$	B1ft
		(1)
(d)	$\mathrm{P}(X?\ 1) =$ awrt 0.0073 $\quad$ $\mathrm{P}(X?\ 2) =$ awrt 0.0296	M1
	$\mathrm{P}(X?\ 13) =$ awrt 0.0270 $\quad$ $\mathrm{P}(X?\ 14) =$ awrt 0.0128	M1
	$X?\ 1 \cup X?\ 14$	A1
		(3)
(e)	$0.0073 + 0.0128 = 0.0201$	M1
	So 2.01%	A1ft
		(2)
(f)	12 is not in the critical region	M1
	So, there is insufficient evidence that **rate** of **customers** entering the shop has **changed**	A1
		(2)
	Notes	**Total 11**

(a)	**B1**	Correct distribution fully specified. Po(isson) and $\lambda = 7$
(b)	**B1, B1**	For two of the given assumptions (must have context of customers/people) Context only needs to be stated once. (B1B0 for one assumption in context **or** for two assumptions with no context)
(c)	**B1ft**	Both hypotheses correct. Must be attached to H_0 and H_1 in terms of λ or μ Ft their 7 from part (a) in the hypotheses
(d)	**M1**	Use of Po(7) to find the lower critical value. May be implied by either awrt 0.0073 or awrt 0.0296 seen (must be seen in part (d)) Also implied by $X = 1$ or $X ?\ 1$
	M1	Use of Po(7) to find the upper critical value. May be implied by awrt 0.0270 or awrt 0.0128 or awrt 0.973 or awrt 0.987 seen (must be seen in part (d)) Also implied by $X = 14$ or $X ?\ 14$
	A1	$X ?\ 1, X ?\ 14$ correct CR scores 3 out of 3 but $14 ?\ X ?\ 1$ is M1M1A0 Allow equivalent forms e.g. $X < 2, X > 13$ Must be a CR and not a probability statement $\mathrm{P}(X?\ 1),\ \mathrm{P}(X?\ 14)$ scores M1M1A0
(e)	**M1**	Adding the two probabilities (each must be less than 0.05) for their critical region
	A1ft	awrt 0.0201 or awrt 2.01% ft the sum of their two selected probability tails
(f)	**M1**	For a correct comparison of 12 with their CR (or their implied CR if one is not explicitly stated), 12 is not in the CR condone 12 < '14' Finding $\mathrm{P}(X = 12)$ is M0 Finding $\mathrm{P}(X \ldots 12)$ on its own is M0, they must state 12 is not in the CR
	A1	Correct conclusion in context. Must be a rate, e.g. number in/per 10-minute period (not number on its own). No hypotheses in part (c) then A0 Do not allow comments about the manager's claim on its own, e.g. The manager's claim is not supported. This is not a ft mark.

Question Number	Scheme			Marks
4 (i)(a)	$\frac{b-27}{b-a}=\frac{3}{4}$ or $\frac{27-a}{b-a}=\frac{1}{4}$ and $\frac{(b-a)^2}{12}=300$			M1M1
	$a = 12$ and $b = 72$			A1
				(3)
(b)	$\left[4\mathrm{P}(X<k-10)=\mathrm{P}(X>k+20)\Rightarrow\right]\ 4\left(\frac{k-10-'12'}{'72-12'}\right)=\frac{'72'-(k+20)}{'72-12'}$			M1
	$4(k-22)=52-k\Rightarrow k=28$			A1
				(2)
(ii)	$L \sim \mathrm{U}(21, 42)$	$L \sim \mathrm{U}(0, 42)$	$S \sim \mathrm{U}(5.25, 10.5)$	
	$\frac{L}{4}-\left(\frac{42-L}{4}\right)>2$	$\frac{L}{4}-\left(\frac{42-L}{4}\right)>2$ or $\left(\frac{42-L}{4}\right)-\frac{L}{4}>2$	$S-(10.5-S)>2$	M1
	$L>25$	$L<17$ or $L>25$	$S>6.25$	A1
	$=(42-'25')\times\frac{1}{21}$	$=('17'-0)\times\frac{1}{42}+(42-'25')\times\frac{1}{42}$	$(10.5-'6.25')\times\frac{1}{5.25}$	M1
	$=\frac{17}{21}$ oe			A1
				(4)

	Notes		Total 9
(i)(a)	**M1**	For setting up a correct equation for the probability **or** the variance	
	M1	For setting up a correct equation for the probability **and** the variance	
	A1	For $a = 12$ and $b = 72$ (correct answers score 3 out of 3)	
(b)	**M1**	For an unsimplified equation ft their a and their b	
	A1	Cao	
(ii)	**M1**	For $\frac{L}{4}-\left(\frac{42-L}{4}\right)>2$ or $\left(\frac{42-L}{4}\right)-\frac{L}{4}>2$ or $S-(10.5-S)>2$ may be seen in a probability statement allow any letter for L or S may be implied by $L>25$ or $L<17$ or $S>6.25$	
	A1	$L>25$ or $L<17$ or $S>6.25$ may be seen in a probability statement or implied by 2nd M1	
	M1	For use of $(42-'25')\times\frac{1}{21}$ or $('17'-0)\times\frac{1}{42}+(42-'25')\times\frac{1}{42}$ or $(10.5-'6.25')\times\frac{1}{5.25}$	
	A1	Allow awrt 0.81	

Question Number	Scheme	Marks
5 (a)	$\int_1^x \frac{1}{4}(3-t)\,\mathrm{d}t = \frac{1}{4}\left[3t-\frac{t^2}{2}\right]_1^x$ or $\int \frac{1}{4}(3-x)\,\mathrm{d}x = \frac{1}{4}\left[3x-\frac{x^2}{2}\right]+C$	M1
	$\frac{1}{4}\left[\left(3x-\frac{x^2}{2}\right)-\left(3-\frac{1}{2}\right)\right]$ or $\frac{1}{4}\left[3(1)-\frac{(1)^2}{2}\right]+C=0$ and $C=-\frac{5}{8}$ Leading to $\frac{1}{4}\left(3x-\frac{x^2}{2}\right)-\frac{5}{8}$ [for $1 ? \ x \ ? \ 2$]*	A1*
		(2)
(b)	$\int_2^x \frac{1}{4}\mathrm{d}t+\mathrm{F}(2)$ or $\int \frac{1}{4}\mathrm{d}x$ and using $+\,c$ with $\mathrm{F}(2)=\frac{3}{8}$ or $0.25(x-2)+\mathrm{F}(2)$	M1
	$\int_3^x \frac{1}{4}(t-2)\,\mathrm{d}t+\mathrm{F}(3)$ or $\int \frac{1}{4}(x-2)\,\mathrm{d}x$ and using $+\,c$ with either $\mathrm{F}(3)=\frac{5}{8}$ or $\mathrm{F}(4)=1$	M1
	$\mathrm{F}(x)=\begin{cases} 0 & x<1 \\ \frac{1}{4}\left(3x-\frac{x^2}{2}\right)-\frac{5}{8} & 1 ? \ x \ ? \ 2 \\ \frac{1}{8}(2x-1) & 2<x \ ? \ 3 \\ \frac{1}{4}\left(\frac{x^2}{2}-2x\right)+1 & 3<x \ ? \ 4 \\ 1 & x>4 \end{cases}$	A1 A1 B1
		(5)
(c)	$\mathrm{P}(1.2<X<3.1)=\mathrm{F}(3.1)-\mathrm{F}(1.2)$	
	$'\left(\frac{1}{4}\left(\frac{(3.1)^2}{2}-2(3.1)\right)+1\right)'-\left(\frac{1}{4}\left(3(1.2)-\frac{(1.2)^2}{2}\right)-\frac{5}{8}\right)=\frac{89}{160}$ awrt 0.556	M1 A1
		(2)
	Notes	**Total 9**

(a)	**M1**	For a correct method for $1 ? \ x \ ? \ 2$ Condone poor notation e.g. $\int_1^x \frac{1}{4}(3-x)\,\mathrm{d}x$
	A1*	A fully correct solution with substitution seen or C found leading to $\mathrm{F}(x)=\frac{1}{4}\left(3x-\frac{x^2}{2}\right)-\frac{5}{8}$
(b)	**M1**	For a correct method for $2<x \ ? \ 3$
	M1	For a correct method for $3<x \ ? \ 4$
	A1	Third line correct including inequality. Allow $<$ instead of $\leqslant$
	A1	Fourth line correct including inequality. Allow $<$ instead of $\leqslant$
	B1	First and fifth line correct. Allow "otherwise" for the range on the first or fifth line but not both
(c)	**M1**	For use of $\mathrm{F}(3.1)-\mathrm{F}(1.2)$ from the correct lines of their F(x) allow ft on their 4th line or correct use of f(x) or area e.g. $\frac{1}{2}\times\frac{7}{10}\times0.8+1\times\frac{1}{4}+\frac{1}{2}\times\frac{21}{40}\times0.1$
	A1	For $\frac{89}{160}$ oe or awrt 0.556 NB: Use of F(3.1) with $\frac{1}{8}(2x-1)$ for $2<x \ ? \ 3$ gives 0.555 and scores M0A0

Question Number	Scheme	Marks
6 (a)	Box A: $P(1)=\frac{1}{4}$ $P(2)=\frac{3}{4}$ Box B: $P(2)=\frac{1}{5}$ $P(5)=\frac{4}{5}$	B1
	Totals (T) 5, 6, 8, 9, 11, 12	B1
	(1, 2, 2) (1, 2, 5) [(1, 5, 2)] (1, 5, 5) (2, 2, 2) (2, 2, 5) [(2, 5, 2)] (2, 5, 5)	B1
	$[P(T=5)=]\frac{1}{4}\times\frac{1}{5}\times\frac{1}{5}\left[=\frac{1}{100}\right]$ $[P(T=6)=]\frac{3}{4}\times\frac{1}{5}\times\frac{1}{5}=\left[\frac{3}{100}\right]$	
	$[P(T=8)=]2\times\frac{1}{4}\times\frac{1}{5}\times\frac{4}{5}=\left[\frac{8}{100}\right]$ $[P(T=9)=]2\times\frac{3}{4}\times\frac{1}{5}\times\frac{4}{5}=\left[\frac{24}{100}\right]$	M1 M1
	$[P(T=11)=]\frac{1}{4}\times\frac{4}{5}\times\frac{4}{5}=\left[\frac{16}{100}\right]$ $[P(T=12)=]\frac{3}{4}\times\frac{4}{5}\times\frac{4}{5}=\left[\frac{48}{100}\right]$	M1
	See table below	A1
		(7)
(b)	$m=2$ $m=5$	B1
	$\left[P(M=2)=\right]'\frac{1}{100}'+'\frac{8}{100}'+'\frac{3}{100}'+'\frac{24}{100}'=\left[\frac{36}{100}\right]$	M1
	$\left[P(M=5)=\right]'\frac{16}{100}'+'\frac{48}{100}'=\left[\frac{64}{100}\right]$ or $P(M=5)=1-'P(M=2)'$	M1
	See table below	A1
		(4)
	Notes	**Total 11**

Table for 6(a) A1:

t	5	6	8	9	11	12
$P(T=t)$	$\frac{1}{100}$	$\frac{3}{100}$	$\frac{8}{100}\left[=\frac{2}{25}\right]$	$\frac{24}{100}\left[=\frac{6}{25}\right]$	$\frac{16}{100}\left[=\frac{4}{25}\right]$	$\frac{48}{100}\left[=\frac{12}{25}\right]$

Table for 6(b) A1:

m	2	5
$P(M=m)$	$\frac{36}{100}$	$\frac{64}{100}$

(a)	**B1**	All 4 correct probabilities – may be seen in an equation
	B1	All 6 totals correct with no extras (ignore units if stated) (condone 8 or 9 listed twice)
	B1	All 6 basic combinations correct, either seen or used (implied by the 3rd M1 mark) Condone any permutation of the 6 basic combinations for this mark
	M1	Correct method for **one** probability (ft their probabilities)
	M1	Correct method for **five** probabilities (ft their probabilities)
	M1	Correct method for all **six** probabilities (ft their probabilities)
	A1	cao Need not be in a table but probabilities must be attached to the correct total
(b)	**B1**	For both values of m (no extras) If $m = 1$ is stated it must be stated that its probability is 0
	M1	Ft part (a) For a correct method to find $P(M = \text{'2'})$ For this mark there must only be 2 probability calculations
	M1	Ft part (a) For a correct method to find $P(M = \text{'5'})$ For this mark there must only be 2 probability calculations
	A1	cao Need not be in a table but probabilities must be attached to the correct total

Question Number	Scheme	Marks
7 (a)	$\frac{1}{2}\times 8\times 4a=1\Rightarrow a=\frac{1}{16}$ * or $\int_{[0]}^{[4]} ax\ \mathrm{d}x=0.5\Rightarrow \left[\frac{ax^2}{2}\right]_0^4=0.5\Rightarrow a=\frac{1}{16}$ *	B1*
		(1)
(b) (i)	(By symmetry) $b=-\frac{1}{16}$	B1
(ii)	At (8, 0) $0=-\frac{1}{16}\times 8+c\Rightarrow c=\frac{1}{2}$ or at (4, 0.25) $0.25=-\frac{1}{16}\times 4+c\Rightarrow c=\frac{1}{2}$	M1 A1
		(3)
(c)	$\mathrm{E}(X)=4$	B1
	$\mathrm{E}(X^2)=\int_0^4 x^2\left(\frac{1}{16}x\right)\mathrm{d}x+\int_4^8 x^2\left(-'\frac{1}{16}'x+'\frac{1}{2}'\right)\mathrm{d}x$	M1
	$=\frac{1}{64}\left[x^4\right]_0^4+\left['-\frac{1}{64}x^4+\frac{1}{6}x^3'\right]_4^8$	A1ft
	$=4+\left[\left(-64+\frac{256}{3}\right)-\left(-4+\frac{32}{3}\right)\right]\left[=\frac{56}{3}\right]$	dM1A1
	$\mathrm{Var}(X)=\frac{56}{3}-4^2=\frac{8}{3}$ *	A1*
		(6)
(d)	$\frac{1}{2}\times Q_1\times\frac{1}{16}\times Q_1=\frac{1}{4}$ or $\int_0^{Q_1}\frac{1}{16}x\ \mathrm{d}x=0.25\to\frac{Q_1^2}{32}=0.25$	M1
	$Q_1=\sqrt{8}=2.828...$ or $Q_3=8-\sqrt{8}=5.171...$ awrt 2.83 or awrt 5.17	A1
	$Q_1=\sqrt{8}=2.828...$ and $Q_3=8-\sqrt{8}=5.171...$ awrt 2.83 and awrt 5.17	A1
		(3)
(e)	50% lies between Q_1 and Q_3	
	Statistician's claim: $\mathrm{P}\left('4'-\sqrt{\frac{8}{3}}<X<'4'+\sqrt{\frac{8}{3}}\right)=\mathrm{P}(2.37<X<5.63)$	M1
	as this is outside Q_1 and Q_3, >0.5/ statistician's claim is correct* or $\mathrm{P}(2.37<X<5.63)=0.6498...>0.5$ / statistician's claim is correct*	A1*
		(2)
	Notes	**Total 15**

(a)	**B1***	Allow any correct equivalent method. E.g. $\frac{1}{2}\times 4\times 4a=\frac{1}{2}\Rightarrow a=\frac{1}{16}$, integration, use of gradients, etc. Answer is given so a complete correct method with no incorrect working must be seen
(b)	**B1**	Cao
	M1	Use of equation of line to find c e.g. $y-0=-\frac{1}{16}(x-8)$ or use of integration or any valid method
	A1	Cao correct answer scores M1A1

(c)	**B1**	For $\mathrm{E}(X)=4$ This may be seen at any point in the solution
	M1	For use of $\int x^2 \mathrm{f}(x)\,\mathrm{d}x \quad x^n \to x^{n+1}$ for both parts of pdf (ignore limits) ft their values of *b* and *c*
	A1ft	For correct integration of **either** of the 2 parts, ft their values of *b* and *c*
	depM1	For use of correct limits in **either** part (dep on previous M1) may be implied by sight of 4 or $\frac{44}{3}$ but **not** implied by $\frac{56}{3}$ allow ft on their values of *b* and *c* which you may need to check
	A1	For complete correct substitution $4+\left[\left(-64+\frac{256}{3}\right)-\left(-4+\frac{32}{3}\right)\right]$ or $\frac{56}{3}$ allow $=4+\frac{44}{3}$
	A1*	Answer is given so need to see use of $\mathrm{Var}(X)=\mathrm{E}(X^2)-\mathrm{E}(X)^2=\frac{8}{3}$ with values substituted
(d)	**M1**	For correct method for either Q_1 or Q_3 e.g. $\frac{1}{2}\times Q_1\times\frac{1}{16}\times Q_1=\frac{1}{4}$, $\int_0^{Q_1}\frac{1}{16}x\,\mathrm{d}x=0.25\to\frac{Q_1^2}{32}=0.25$
	A1	For either awrt 2.83 allow $\sqrt{8}$ oe or awrt 5.17 allow $8-\sqrt{8}$ oe
	A1	For either awrt 2.83 allow $\sqrt{8}$ oe and awrt 5.17 allow $8-\sqrt{8}$ oe
(e)	**M1**	For use of $\mathrm{P}(\mu-\sigma<X<\mu+\sigma)$ ft their μ implied by awrt 2.37 and awrt 5.63
	A1*	Must state that this > 0.5 as it is outside Q_1 and Q_3 Allow '2.83' > '2.37' and '5.16' < '5.63' **or** a correct probability calculated awrt 0.65 Answer is given so no incorrect working can be seen. If their values are not consistent with the statistician's claim, then A0 here.