Question Number	Scheme	Marks
1 (a)	[Mean =] 2.95	B1
	[Variance =] $\frac{2091}{180}-("2.95")^2$	M1
	$= 2.914\ldots$ $(s^2 = 2.930\ldots)$ awrt 2.91 (2.93)	A1
		(3)
(b)	The mean is close to the variance	B1
		(1)
(c)	$W \sim$ Po(3)	
(i)	$\left[P(W \ldots 3) = \right] 1 - P(W \,„\, 2) = 0.5768$ awrt 0.577	M1 A1
(ii)	$\left[P(4 < W < 8) = \right] P(W \,„\, 7) - P(W \,„\, 4)$ or $P(W=5)+P(W=6)+P(W=7)$	M1
	$= 0.1728\ldots$ awrt 0.173	A1
		(4)
(d)	$X \sim$ N(21,21)	B1
	$\left[P(X < 19) = \right] P\left(Z \,„\, \frac{18.5-21}{\sqrt{21}}\right) \left[= -0.5455...\right]$ or $\left[P(X > 23) = \right] P\left(Z \ldots \frac{23.5-21}{\sqrt{21}}\right) \left[= 0.5455...\right]$	M1M1A1
	$= 0.2912$ (calc 0.29268…)*	A1*cso
		(5)
(e)	$Y \sim$ B(13, "0.29")	M1
	$\left[P(Y=5) = \right] {}^{13}C_5 ("0.29")^5 (1-"0.29")^8 = 0.170465$ (calc 0.17317…) awrt 0.17	M1 A1
		(3)

	Notes	Total 16
(a)	**B1**	cao allow exact equivalents
	M1	Ft their mean. Using $\frac{\sum fx^2}{180} - (\text{their mean})^2$ or $\frac{180}{179}\left(\frac{\sum fx^2}{180} - (\text{their mean})^2\right)$ Allow with a square root – may be implied by awrt 1.71
	A1cso	awrt 2.91 (2.93)
(b)	**B1**	cao – Allow equivalent wording. Allow mean = variance. If no values/non compatible values calculated, then B0. Condone the use of 'closed' for 'close'
(c)(i)	**M1**	for $1-P(W \,„\, 2)$ or 1 – 0.4232
	A1	awrt 0.577
(ii)	**M1**	for $P(W \,„\, 7)-P(W \,„\, 4)$ **or** $P(W=5)+P(W=6)+P(W=7)$ **or** 0.9881 – 0.8153 **or** 0.1008 + 0.0504 + 0.0216
	A1	awrt 0.173
(d)	**B1**	for writing or using N(21,21). May be seen in a standardisation expression.
	M1	for standardisation (±) using their mean and sd. Allow 17.5, 18, 18.5, 19, 19.5, 22.5, 23, 23.5, 24, 24.5
	M1	for using 19 ± 0.5 or 23 ± 0.5
	A1	for a fully correct standardisation expression Implied by awrt ±0.546
	A1*	awrt 0.291 or 0.293 from correct working seen
(e)	**M1**	for writing or using B(13, 0.29) ft their 0.29 (Must be 2 sf or better) or for $(p)^5(1-p)^8$ ft their 0.29 (Must be 2 sf or better) . Condone B(0.29, 13)
	M1	for ${}^{13}C_5 (p)^5 (1-p)^8$ oe with $0 < p < 1$ Allow 1287 for ${}^{13}C_5$
	A1	awrt 0.17 (0.17168 from using 0.2912)

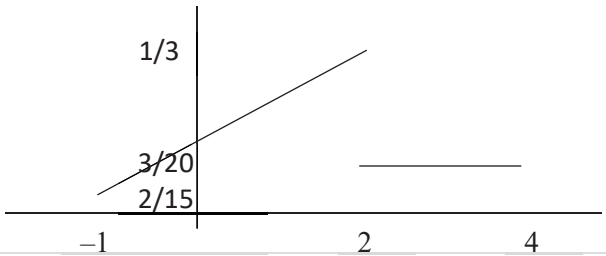
Question Number	Scheme	Marks
2 (a)	$\left[\mathrm{P}(D<108)=\right]\ \mathrm{P}\left(Z<\dfrac{108-112.4}{\sigma}\right)=\ 0.05$	
	$\Rightarrow \dfrac{108-112.4}{\sigma}=-1.6449$	M1 M1
	$\sigma = 2.6749...$ days (calc 2.67501…) awrt 2.67/2.68	A1
		(3)
(b)	$J \sim \mathrm{B}(25,\ 0.05)$	
	$\left[\mathrm{P}(J \ldots 4)=\right]1-\mathrm{P}(J \text{ ,, } 3)=1-0.9659$	M1
	$= 0.0341$ (calc 0.034090…) awrt 0.0341	A1
		(2)
(c)	$T \sim \mathrm{Po}[200\times"0.0341"]=6.82$ (calc 6.8181…)	M1
	$\left[\mathrm{P}(T \ldots 2)=\right]1-\mathrm{P}(X \text{ ,, } 1)=1-\left(\mathrm{e}^{-"6.82"}+\mathrm{e}^{-"6.82"}\times"6.82"\right)$	M1
	$= 0.99146\ldots$ calc (0.99144…) awrt 0.991	dA1
		(3)

	Notes	**Total 8**
(a) (i)	**M1**	for standardisation using 108(Condone 107.5), 112.4 and σ set equal to z where $1.5<\lvert z\rvert<2.5$
	M1	for correct equation awrt –1.6449 (Allow awrt 1.6449 if compatible with their equation)
	A1	awrt 2.67/2.68 **NB** M1 M0 A1 is possible
(b)	**M1**	for $1-\mathrm{P}(J \text{ ,, } 3)$ or 1 – 0.9659
	A1	awrt 0.0341
(c)	**M1**	for writing or using correct Poisson model ft their part (b) May be implied by 0.00853(73)
	M1	for writing or using $1-\left(\mathrm{e}^{-"\lambda"}+\mathrm{e}^{-"\lambda"}\times"\lambda"\right)$ where $1<\lambda<200$ (may be implied by awrt 0.991) Allow $1-\mathrm{P}(X \text{ ,, } 1)$ if Poisson distribution is stated or used
	dA1	dep on both method marks being awarded awrt 0.991 (**NB** Binomial gives awrt 0.992 and if no working shown awrt 0.992 will gain M0M0A0) Allow 0.9915 if both M marks are awarded

Question Number	Scheme	Marks
3 (a)	The vacuum **tubes shatter** independently	B1
	The probability of a vacuum **tube shattering** is constant	B1
		(2)
(b)	$C \sim B(15, 0.35)$ plus $[P(C \leqslant 9) =]0.0142$ or $[P(C \geqslant 10) =]0.0124$ or $[P(C \leqslant 9) =]0.9876$	M1
	Critical regions $[0 \leqslant] C \leqslant 1$ or $10 \leqslant C [\leqslant 15]$	M1
	$[0 \leqslant] C \leqslant 1$ and $10 \leqslant C [\leqslant 15]$ plus $P(C \leqslant 9) = 0.0142$ and $P(C \geqslant 10) = 0.0124$	A1
		(3)
(c)	0.0266	B1ft
		(1)
(d)	[4 is not in the CR therefore] there is no evidence to reject **Rowan's** belief	B1ft
		(1)
(e)	$F \sim B(40, 0.35)$	
	$H_0: p = 0.35$ and $H_1: p < 0.35$	B1
	$P(F \leqslant 8) = 0.0303$ or CR $F \leqslant 8$	M1A1
	Sufficient evidence to reject H_0 or significant or 8 lies in the Critical region	M1
	There is sufficient evidence to support that the **proportion** of type *B* vacuum **tubes** that shatter when exposed to alternating high and low temperatures is less than 35%	A1
		(5)
	Notes	**Total 12**

(a)	**B1**	for one correct reason which must mention tube(s) and shatter/shattering or 2 correct reasons not in context
	B1	for 2 correct reasons which must mention tube(s) and shatter/shattering at least once
(b)	**M1**	for using the correct distribution to find awrt 0.0142 or awrt 0.0124 or awrt 0.988 Allow B(15, 0.35) is written **and** one of awrt 0.014 or awrt 0.012 or awrt 0.99 is seen
	M1	for lower CR or $C \leqslant 1$ oe e.g. $C < 2$ or upper CR $C \geqslant 10$ oe e.g. $C > 9$ Allow other notation and any letter(s) for CR Do not allow CR written as a probability statement
	A1	for both CR correct with the relevant probabilities (3 sf and must be seen in part (b)). Do not allow CR written as a probability statement
(c)	**B1ft**	for awrt 0.0266 or 2.66% or ft the sum of the probabilities in (b) for "their 2 critical regions" if seen. If no probabilities for their CR given then the answer must be 0.0266
(d)	**B1ft**	for a correct statement consistent with their CR Must mention **Rowan/his/her** or a correct conclusion based on Rowan's belief with the words highlighted in bold e.g. no evidence to suggest that the **proportion/probability/number/amount** (allow **35%** as proportion) of **tubes** that shatter has changed oe
(e)	**B1**	for both hypotheses correct in terms of p or π
	M1	for using or writing $P(F \leqslant 8)$ or awrt 0.0303
	A1	for awrt 0.0303 or correct CR Allow $F \leqslant 8$ or $F < 9$ but not if part of a probability statement
	M1	for a correct conclusion – need not be in context. ft their probability or CR. Ignore hypotheses. do not allow contradicting non contextual comments. May be implied by a correct contextual statement on its own
	A1	for a correct conclusion – must be in context, with words highlighted in bold. ft their probability or CR only. Independent of hypotheses. Do not allow contradicting statements. Allow probability/number/amount/35% for proportion. Allow decreased for less than 35%

Question	Scheme	Marks

Number		
4 (a)		M1 A1
		(2)
(b)	$[\mathrm{P}(G \text{,,} 2) =]1-2\times\frac{3}{20}[=0.7]$ or $\frac{1}{2}\times3\times\left(\frac{2}{15}+\frac{1}{3}\right)$ or $\frac{1}{15}\int_{-1}^{2}(g+3)\,\mathrm{d}g[=0.7]$ or $\frac{1}{30}\times2^2+\frac{1}{5}\times2+\frac{1}{6}[=0.7]$ or $\left[\mathrm{P}\left(G \text{,,} \frac{1}{2}\right)\right]=\frac{1}{2}\times1.5\times\left(\frac{2}{15}+\frac{3.5}{15}\right)[=0.275]$ or $\frac{1}{15}\int_{-1}^{0.5}(g+3)\,\mathrm{d}g[=0.275]$ or $\frac{1}{30}\times0.5^2+\frac{1}{5}\times0.5+\frac{1}{6}[=0.275]$ or $\left[\mathrm{P}\left(\frac{1}{2} \text{,,} G \text{,,} 2\right)=\right]\ \frac{1}{2}\times1.5\times\left(\frac{7}{30}+\frac{1}{3}\right)[=0.425]$ or $\frac{1}{15}\int_{0.5}^{2}(g+3)\,\mathrm{d}g[=0.425]$ or $\frac{1}{30}\times\left(2^2-0.5^2\right)+\frac{1}{5}\times(2-0.5)[=0.425]$	M1
	$[\mathrm{P}(1 \text{,,} 2G \text{,,} 6 \mid G \text{,,} 2) =]\frac{\mathrm{P}\left(\frac{1}{2} \text{,,} G \text{,,} 2\right)}{\mathrm{P}(G \text{,,} 2)}=\frac{0.425}{0.7}$ or $1-\frac{0.275}{0.7}$ oe	M1M1
	$=\frac{17}{28}$ or 0.607… awrt 0.607	A1
		(4)
(c)	$[\mathrm{E}(H^2)=]2.4+12^2[=146.4]$	M1
	$[\mathrm{E}(G)=]\int_{-1}^{2}\frac{1}{15}(g^2+3g)\,\mathrm{d}g+\int_{2}^{4}\frac{3}{20}g\,\mathrm{d}g$	M1
	$[\mathrm{E}(G)=]\left(\frac{1}{15}\left(\frac{1}{3}g^3+\frac{3}{2}g^2\right)\right)_{-1}^{2}+\left(\frac{3}{40}g^2\right)_{2}^{4}$	M1
	$=\frac{1}{15}\left(\frac{8}{3}+\frac{12}{2}+\frac{1}{3}-\frac{3}{2}\right)+\left(\frac{48}{40}-\frac{12}{40}\right)[=1.4]$	dM1
	$[\mathrm{E}(2H^2+3G+3)=]2\times\text{"146.4"}+3\times\text{"1.4"}+3$	M1
	$=300$	A1 (6)
		Total 12

	Notes	
(a)	**M1**	for correct shape $\left(g=\frac{3}{20}\right.$ must be below $\left.\frac{1}{3}\right)$ with the lines not joining at $x = 2$ and none below/touch the x -axis. Ignore any broken/dotted lines drawn
	A1	for fully correct graph with labels on the x axis
(b)	**M1**	For a correct method to find $\mathrm{P}(G,,\ 2)$ or $\mathrm{P}\left(G,,\ \frac{1}{2}\right)$ or $\mathrm{P}\left(\frac{1}{2},,\ G,,\ 2\right)$ May be implied by $0.7 / \frac{7}{10}$ or $0.425 = \frac{17}{40}$ or $0.275 / \frac{11}{40}$
	M1	for $\frac{p}{0.7}$ where $0 < p < 0.7$ or $\frac{0.425}{q}$ where $0.425 < q < 1$ or $1-\frac{0.275}{r}$ where $0.275 < r < 1$ Allow un-simplified probabilities
	M1	For $\frac{\mathrm{P}\left(\frac{1}{2},,\ G,,\ 2\right)}{\mathrm{P}(G,,\ 2)}$ or a correct ratio of probabilities
	A1	$\frac{17}{28}$ oe or awrt 0.607
(c)	**M1**	for a correct method to find $\mathrm{E}\left(H^2\right)$
	M1	for realising $\int x\mathrm{f}(x)\mathrm{d}x$ on both functions and adding together. Ignore limits
	M1	for attempting to integrate ($x^n \rightarrow x^{n+1}$) at least one part of $x\mathrm{f}(x)$
	dM1	dep on previous M1 being awarded. For use of correct limits in one part of $x\mathrm{f}(x)$ If working not shown, then this may be implied by 0.5 or 0.9 or 1.4. If integration is incorrect then working must be shown.
	M1	For using $2\times$"their $\mathrm{E}\left(H^2\right)$"$+3$"their $\mathrm{E}(G)+3$, provided $\mathrm{E}\left(H^2\right)$ and $\mathrm{E}(G)$ have been shown. **NB** You may have to check their answer if no working is shown for $2\times$"their $\mathrm{E}\left(H^2\right)$"$+3$"their $\mathrm{E}(G)+3$
	A1	Cao

Question Number	Scheme	Marks
5(a)	$\dfrac{(a+6)^2}{12}=27$	M1
	$a=\sqrt{27\times12}-6\Rightarrow 12^*$ or $a^2+12a-288=0\Rightarrow a=12^*$	A1*
		(2)
(b)(i)	$\dfrac{12-b}{18}=\dfrac{3}{5}$ or $\dfrac{b+6}{18}=\dfrac{2}{5}$	M1
	$b=1.2$	A1
		(2)
(ii)	$\text{P}(-6<W<\text{"0.6"})=\dfrac{\text{"0.6"}+6}{18}$	M1
	$=\dfrac{11}{30}$ or $0.3666\ldots$	A1ft
		(2)
(c)	Let C be the point where the wood is cut and x is the distance AC	
	$\dfrac{x}{2}$ and $\left(\dfrac{160-x}{2}\right)$ | $L+W=80$ and $LW=975$	M1
	$\dfrac{x}{2}\times\left(\dfrac{160-x}{2}\right)=975\Rightarrow x=30$ or 130 | $L(80-L)=975\Rightarrow L=15$ or 65	M1
	$\text{P}(\text{"30"}<x<\text{"130"})=\dfrac{\text{"130"}-\text{"30"}}{160}\left[=\dfrac{5}{8}\right]$ oe | $\text{P}(\text{"15"}<x<\text{"65"})=\dfrac{\text{"65"}-\text{"15"}}{80}\left[=\dfrac{5}{8}\right]$ oe	dM1
	$=\dfrac{5}{8}$ oe	A1
		(4)

	Notes	Total 10
(a)	**M1**	for setting up the correct equation. Do not allow verification
	A1*	for an un-simplified expression for a leading to $a = 12$ or for a correct 3TQ = 0 leading to $a = 12$ Condone any letter for a
(b)(i)	**M1**	for setting up the correct equation
	A1	Cao oe
(ii)	**M1**	for a correct method. Do not ISW
	A1ft	ft their value for b, provided the answer is between 0 and 1
(c)	**M1**	For both expressions seen. Allow any letters e.g. $\dfrac{y}{2}$ for $\left(\dfrac{160-x}{2}\right)$ May be implied by a correct equation for the area
	M1	for a correct equation for area in terms of any letter. Condone an inequality
	dM1	dep on previous method mark awarded. For a fully correct method ft their x values provided add to 160 or 80 Do not ISW
	A1	Cao

Question Number	Scheme	Marks
6(a)	8, 11, 14, 17, 20	M1
	$\left[\mathrm{P}(\text{even})=\right]\frac{1}{5}$ and $\left[\mathrm{P}(\text{odd})=\right]\frac{4}{5}$	M1
	$\left[\mathrm{P}(X=8)=\right]\left(\frac{4}{5}\right)^4$ or $\left[\mathrm{P}(X=20)=\right]\left(\frac{1}{5}\right)^4$	M1
	$\left[\mathrm{P}(X=11)=\right]4\times\left(\frac{1}{5}\right)\left(\frac{4}{5}\right)^3$ or $\left[\mathrm{P}(X=17)=\right]4\times\left(\frac{4}{5}\right)\left(\frac{1}{5}\right)^3$	M1
	$\left[\mathrm{P}(X=14)=\right]{}^4C_2\times\left(\frac{1}{5}\right)^2\left(\frac{4}{5}\right)^2$	M1
	X: 8 | 11 | 14 | 17 | 20 $\mathrm{P}(X=x)$: $\frac{256}{625}$ (0.4096) | $\frac{256}{625}$ (0.4096) | $\frac{96}{625}$ (0.1536) | $\frac{16}{625}$ (0.0256) | $\frac{1}{625}$ (0.0016)	A1
		(6)
(b)	$1-(1-\text{"0.1536"})^n>0.95$ or $(\text{"0.8464"})^n<0.05$	M1
	$n>17.96$ or $n>\frac{\log(0.05)}{\log(\text{"0.8464"})}$ or $n>\log_{\text{"0.8464"}}(0.05)$	M1
	$n=18$	A1
		(3)
	Notes	**Total 9**
(a)	**M1** For at least 2 scores correct and no more than 3 incorrect	
	M1 for writing or using $\frac{4}{5}$ and $\frac{1}{5}$. May be implied by a correct probability	
	M1 for p^4 where $0<p<1$	
	M1 for $4\times(1-p)p^3$ where $0<p<1$	
	M1 for $6\times(1-p)^2p^2$ where $0<p<1$ or probabilities that add to 1 (at least 2 but not more than 5)	
	A1 for all 5 probabilities correct and associated with the correct values. Need not be in a table but probabilities must be attached to the correct total	
(b)	**M1** for using $1-(1-\mathrm{P}(Y=0))^n>0.95$ allow = instead of >/⩾. condone </⩽ or allow for at least 2 trials for n between 10 and 20 ft their P(X = 14)	
	M1 for $n>$ awrt 17.96 or $n>\frac{\log(0.05)}{\log(\text{"0.8464"})}$ ft their 0.8464 or $n>\log_{\text{"0.8464"}}(0.05)$ ft their 0.8464 or for the two trials for n = 17 and 18 Allow = instead of >/⩾. condone </⩽ May be implied by a correct answer ft their 0.8464	
	A1 Cao (Do not allow any inequality for this mark)	

Question Number	Scheme	Marks
7(a)	$f(x)=[k](a+3bx^2-4x^3)$	M1
	$[k](6bx-12x^2)=0$	M1
	$9b-27=0\Rightarrow b=3$ or $6\times3\times1.5-12\times1.5^2=0\Rightarrow\therefore b=3$ *	A1*
		(3)
(b)	$a+3-1-4=0$ oe $[\Rightarrow a=2]$	B1*
		(1)
(c)	$k(2\times2+3\times2^3-2^4-4)=1 \quad \left[\Rightarrow k=\frac{1}{8}\right]$	M1
	F(x) = 0.5 / F(x) = 4 / F(x) = 0	
	F(1.4) = 0.3988… F(1.5) = 0.5078… / F(1.4) = 3.1904… F(1.5) = 4.0625… / F(1.4) = –0.8(096…) F(1.5) = 0.06(25…)	M1A1
	$0.399<0.5<0.508$ therefore, the median lies between 1.4 and 1.5 / $3.1904<4<4.0625$ therefore, the median lies between 1.4 and 1.5 / $-0.8(096)<0<0.06(25)$ therefore, the median lies between 1.4 and 1.5	A1
	ALTERNATIVE M1A1A1 for F(x) = 0	
	$x_1=2.91...$ $x_2=1.49...$ $x_3=-0.70...$ So x = 1.49… as $1\leqslant x\leqslant 2$	M1 A1
	$1.4<1.49...<1.5$ [therefore, the median lies between 1.4 and 1.5]	dA1
		(4)

	Notes	Total 8
(a)	**M1**	for attempting to differentiate $x^n\rightarrow x^{n-1}$ Condone missing k (May be implied by 2nd M1)
	M1	for correctly differentiating twice and equating to zero. Condone missing k
	A1*	substituting x = 1.5 leading to a correct linear equation in b leading to b = 3
(b)	**B1***	for correctly using F(1) = 0 to form an equation in a (May be seen in part (a)) and substitution of b = 3
(c)	**M1**	for using F(2) = 1 to form a correct equation in terms of k only. May be seen in any part of the question
	M1	For a calculation of F(1.4) **or** F(1.5) correct to 2 sf (If F(x) =0 used then allow 1 sf or better) (Allow F(1.4) = awrt 3.190k **or** F(1.5) = awrt 4.063k)
	A1	For a calculation of F(1.4) **and** F(1.5) correct to 2 sf (If F(x) =0 used then allow 1 sf or better)
	dA1	Dependent on previous A1. For a correct comparison and conclusion. Allow comparisons in words e.g. For F(X) = 0 a comment about a change in sign implies a comparison with 0
		ALTERNATIVE
	M1	For solving the given equation. May be implied by 2.91… or 1.49… or –0.70…
	A1	For x =1.49… identified as being in the range specified by the CDF. May be implied by rejecting the other solutions
	dA1	Dependent on previous A1. For a correct comparison and conclusion

Examples of other acceptable comparisons for 0.5
F(1.4) < 0.5 < F(1.5), Median lies between the range
F(1.4) < F(median) < F(1.5), so median lies between 1.4 and 1.5
F(1.4) < F(Q2) < F(1.5), therefore Q2 lies between 1.4 and 1.5
F(1.4) < F(m) < F(1.5), 1.4 < m < 1.5
F(1.4) < 0.5, F(1.5) > 0.5, so median of X lies between 1.4 and 1.5

Allow equivalent comparisons for 4 and 0