Question	Scheme		Marks	AOs
1(a)(i)	X ~B(15, 0.48)		M1	3.3
	$\mathrm{P}(X=3)=0.019668...$ awrt 0.0197		A1	3.4
(ii)	$\left[\mathrm{P}(X\geqslant 5)=1-\mathrm{P}(X\leqslant 4)\right]=0.92013...$ awrt 0.920		A1	1.1b
			(3)	
(b)	Y is the number of hits	M is the number of misses		
	$Y\sim \mathrm{N}(120, 62.4)$	$M\sim \mathrm{N}(130, 62.4)$	B1	3.3
	$\mathrm{P}(X>110)\approx \mathrm{P}(Y>110.5)$ $\left[=\mathrm{P}\left(Z>\frac{110.5-"120"}{\sqrt{"62.4"}}\right)\right]$	$\mathrm{P}(X>110)\approx \mathrm{P}(M<139.5)$ $\left[=\mathrm{P}\left(Z<\frac{139.5-"130"}{\sqrt{"62.4"}}\right)\right]$	M1	3.4
	= 0.88544…		A1	1.1b
			(3)	
				(6 marks)

Notes:

(a)	**M1**	Writing or using the binomial distribution in (i) or (ii) Allow for sight of B(15, 0.48) or in words: <u>binomial</u> with <u>n = 15</u> and <u>p = 0.48</u> may be implied in (i) or (ii) by one correct answer to 3sf <u>or</u> sight of $\mathrm{P}(X\leqslant 4)$ = 0.07986… i.e. awrt 0.0799. Allow for ${}^{15}C_3\times 0.48^3\times 0.52^{12}$ as this is "correct use" Condone B(0.48, 15)
(i)	**A1**	awrt 0.0197
(ii)	**A1**	awrt 0.920 (Allow 0.92)
(b)	**B1**	Setting up a correct Normal model**.** Allow sight of $\mathrm{N}(120, 62.4)$ or $\mathrm{N}(130, 62.4)$ or $\mathrm{N}\left(120, \frac{312}{5}\right)$ or $\mathrm{N}\left(130, \frac{312}{5}\right)$ or may be awarded if used correctly in standardisation or in words: <u>Normal</u> with <u>mean = 120/130</u> and <u>variance = 62.4</u> or sd = $\sqrt{62.4}$ condone $\mathrm{N}\left(120, \sqrt{62.4}\right)$ or $\mathrm{N}\left(130, \sqrt{62.4}\right)$ or sd = 62.4 Look out for $\sigma=\frac{\sqrt{1560}}{5}$ or $\frac{2\sqrt{390}}{5}$ or awrt 7.90 (condone 7.9) This may be implied by sight of 0.897 or 0.885**4**…
	M1	Sight of the continuity correction with a normal distribution
		110.5 or 111.5 or 109.5 / **139.5** or 140.5 or 138.5
		NB we will also allow **129.5** or 130.5 or 128.5 / NB we will also allow **120.5** or 119.5 or 121.5
		Continuity correction may be seen in standardisation NB No continuity correction(CC) gives awrt 0.897 which is M0 unless CC seen
	A1	awrt 0.8854 or awrt 0.885 dependent on sight of >110.5 or <129.5 or < 139.5 or >120.5 Allow $\leqslant$ or $\geqslant$ instead of < or > NB 0.885548… from B(250, 0.48) scores M0A0

Qu	Scheme	Marks	AOs
2(a)	$\left[\mathrm{P}\left(L<7.902\right)=0.025\Rightarrow\right]\ \dfrac{7.902-8}{x}=-1.96$ oe	M1	3.4
	$\left[x=\right]0.05$*	A1cso*	1.1b
	SC B1(mark as M0A1) for $\dfrac{7.902-8}{0.05}=-1.96\Rightarrow 0.024998$		
		(2)	
(b)	$\mathrm{P}\left(7.94\leqslant L\leqslant 8.09\right)=0.8490\ldots$ **awrt 0.849**	B1	1.1b
		(1)	
(c)	$[\mathrm{P}\left(L<7.94\right)=]\ 0.115069\ldots$(awrt 0.115) **or** $[\mathrm{P}\left(L>8.09\right)=]\ 0.03593\ldots$(awrt 0.036)	B1	1.1b
	$[\mathrm{P}\left(L<7.94\right)=]\ 0.115069\ldots$(awrt 0.115) **&** $[\mathrm{P}\left(L>8.09\right)=]\ 0.03593\ldots$**(**awrt 0.036)	B1	1.1b
	Expected income per 500 rods = $\sum\left(\text{Income}\times\text{probability}\times 500\right)$ $\left(500\times\text{"0.849"}\times 0.5\right)+\left(500\times\text{"0.1150..."}\times 0.05\right)+\left(500\times\text{"0.03593..."}\times 0.4\right)$ **or** Expected profit per rod = $\sum\left(\text{Profit}\times\text{probability}\right)$ $0.30\times\text{"0.849"}+-0.15\times\text{"0.1150..."}+0.20\times\text{"0.03593..."}$ **[**= 0.2446..]	M1	3.4
	Expected profit per 500 rods $500\times\sum\left(\text{Profit}\times\text{probability}\right)$ **or** $\sum\left(\text{Income}\times\text{probability}\times 500\right)-500\times 0.2$ $=500\times\text{"0.2446..."}$ **or** $=\ \text{"222.3"}-500\times 0.2$	M1d	3.1b
	= [£]122.3… **awrt [£]122**	A1	1.1b
		(5)	
(d)	Let $X\sim \mathrm{B}(200,0.015)$	M1	3.3
	$\mathrm{P}(X\leqslant 5)=$ $\quad$ $\mathrm{P}\left(X\geqslant 6\right)=$	M1	1.1b
	0.9176… $\quad$ 0.0824	A1	1.1b
	Manufacturer is unlikely to achieve their aim since $\underline{0.9176<0.95}$ $\quad$ Manufacturer is unlikely to achieve their aim since $\underline{0.0824>0.05}$	A1ft	2.4
		(4)	

Notes: **(12 marks)**

(a)	**M1**	Using the normal distribution to set up equation. Allow σ for x and awrt ± 1.96
	A1*	cso For a correct expression for x followed by 0.05 or 0.05000… No incorrect working seen
(b)	**B1**	awrt 0.849
(c)	**B1**	awrt 0.115 (Implied by awrt 57.5 for number of rods) **or** awrt 0.036 (Implied by awrt 18 for number of rods)
	B1	awrt 0.115 (Implied by awrt 57.5 for number of rods) **and** awrt 0.036 (Implied by awrt 18 for number of rods)
	M1	Correct method to find the total income of 500 rods. Attempt at all 3 with at least two correct and no extras **or** Correct method to find sum of all three profits with at least two of 30, −15 or 20 correct. May work in pence but need to be consistent. Allow awrt 24.5 or 0.245
	M1d	Dep on previous method for finding profit for 500 rods. May work in pence but need to be consistent. Allow $\text{"0.2446..."}\times 500$ or "their income" for 500 rods -500×0.2 (accept 499 or 501)
	A1	All previous marks must be awarded for awrt 122 awrt 12200p **NB** if uses any integer values for numbers of rods then it is A0 other than for 18 for L > 8.09
(d)	**M1**	Selecting the appropriate model. May be seen or used. Allow B(200,0.985) or Po(3) Condone B(0.015, 200) or B(0.985, 200).
	M1	Writing or using $\mathrm{P}\left(X\leqslant 5\right)$ Do not accept $\mathrm{P}\left(X<6\right)$ unless found $\mathrm{P}\left(X\leqslant 5\right)$ $\quad$ Writing or using $\mathrm{P}\left(X\geqslant 6\right)$ Do not accept $\mathrm{P}\left(X>5\right)$ unless found $\mathrm{P}\left(X\geqslant 6\right)$
	A1	0.92 (Poisson 0.916…) $\quad$ 0.08 or better
	A1ft	Need at least one of the method marks to be awarded. Correct conclusion with the comparison (may be in words). Ft "their p = 0.9176…" as long as p > 0.9 If "their 0.9176…"< 0.95 must … be unlikely… If "their 0.9176…"> 0.95 they must say … be likely... To ft the alternative then p < 0.1

Qu 3	Scheme	Marks	AO
(a)	Comment in context about either **independence** or **random** packing e.g. "prizes must be placed in packets at random/independently of each other" **or** about **constant probability** e.g. "the probability of a packet containing a prize is constant/ the same/fixed"	B1 **(1)**	3.5b
(b)(i)	[P($T = 6$) =] 0.17273… awrt **0.173**	B1	1.1b
(ii)	[P($T < 3$) = P(T ,, 2) =] 0.061587… awrt **0.0616**	B1 **(2)**	1.1b
(c)	[K= no. of boxes with fewer than 3 packets containing a prize]		
	K ~ B(5, "0.0616")	M1	1.1b
	P($K = 2$) = 0.031344… in the range **[0.0313~0.0314]**	A1 **(2)**	1.1b
(d)	$H_0 : p = \frac{1}{7}$ $H_1 : p < \frac{1}{7}$	B1	2.5
	[X = no of packets containing a prize] X~B(110, $\frac{1}{7}$)	M1	3.3
	[P(X ,, 9)] = 0.038292…	A1	3.4
	[Significant result or reject H_0] E.g. there is evidence to support Kamil's claim	A1 **(4)**	2.2b
		(9 marks)	

	Notes
(a)	B1 **May use idea of independent events:** a suitable reason, **in context**, covering idea of random packing or packets filled independently. Should mention key words/ideas of: prizes in packets **or** packets in boxes **May use idea of constant probability**. Must see key words underlined in scheme. Idea of probability with "independence" or "not affected by other packets" is B0 B0 for: **Idea of only 2 cases**. E.g. Packet contains a prize or not or **Idea of a fixed number of trials**. E.g. Need a fixed number of packets in each box
(b)(i)	B1 for awrt 0.173
(ii)	B1 for awrt 0.0616
(c)	M1 for sight of B(5, "0.0616") or ${}^5C_2\left("0.0616"\right)^2(1-"0.0616")^3$ ft their answer to (b)(ii). A1 for an answer in the range [0.0313 to 0.0314] Use of 0.0616 gives 0.031356..ans only 2/2
(d)	B1 for both hypotheses correct in terms of p or π M1 for selecting an appropriate model, may be implied by 1st A1 or P($X = 9$) = 0.0199(2…) 1st A1 for 0.038 or better or allow 0.04 with sight of P(X ,, 9)
ALT	**Critical Region.** Allow CR of X ,, 9 (or $X < 10$) provided a supporting probability is seen e.g. A1 for correct CR plus P(X,, 10) = 0.0718… (accept 2sf or 1sf if prob statement seen) 2nd A1 (dep on 1st A1 but indep of hyp's) for a suitable conclusion in context that suggests support for (Kamil's) claim **or** states that there is evidence that proportion /probability/chance of packets containing a prize is less than $\frac{1}{7}$ Do not award 2nd A1 for contradictory statements e.g. "not significant" so "supports claim"
Normal	Sight of $N\left(\frac{110}{7}, \frac{660}{49}\right)$ or awrt 13.5 or probability of 0.045(20..) or 0.033(66..) scores M1

Qu 4	Scheme	Marks	AO
(a)	X~B(10, $\frac{1}{6}$) [Allow 0.167 or better for $\frac{1}{6}$]	M1	3.3
(i)	[P(X = 3) =] 0.155045… **awrt <u>0.155</u>**	A1	1.1b
(ii)	[P(X < 3) = P(X ,, 2) =] 0.775226… **awrt <u>0.775</u>**	A1	1.1b
		(3)	
(b)	[Let D = no. of days when X = 3] D~B(60, "0.155")	M1	3.3
	P(D …12) = 1 – P(D ,, 11) [Allow 1 – P(D < 12)]	M1	3.4
	= 1 – 0.78819… **awrt <u>0.212</u>**	A1	1.1b
		(3)	
(c)	[n = 600, p = $\frac{1}{6}$] estimate = **<u>100</u>**	B1	3.4
		(1)	
(d)	[S = total no. of sixes over 60 days.] $S \approx T \sim N\left("100", \sqrt{\frac{5}{6} \times 100}^2\right)$	M1A1	3.3,1.1b
	P(S > 95) ≈ P($[T >]$95.5) <u>or</u> $P\left([Z >]\frac{95.5-"100"}{"9.128..."}\right)$ <u>or</u> P($[Z >]$ – 0.49..)	M1	3.4
	= 0.688976… **awrt <u>0.689</u>**	A1	1.1b
		(4)	
		(11 marks)	

	Notes
	If you see any attempt using an *n*-sided die with *n* not equal to 6 please send to review.
(a)	M1 for sight or use of the correct distribution. <u>Must</u> have B, or Bin or Bpd or Bcd **and** the correct value for n and p, just n = 10, p = $\frac{1}{6}$ is M0
	Implied by one answer correct to 2dp <u>or</u> by sight of $\binom{10}{3}\left(\frac{1}{6}\right)^3\left(\frac{5}{6}\right)^7$ or one of :
	[P(X = 0) =] **0.16**(1…),[P(X = 1) =] **0.32**(3…), [P(X = 2) =] **0.29**(0…), [P(X ,, 3) =] **0.93**(0…)
(i)	1st A1 for awrt 0.155
(ii)	2nd A1 for awrt 0.775
(b)	1st M1 for selecting a correct model. Sight or use of correct binomial, ft their (a)(i)
	May be implied by sight of [P(D ,, 11) =] 0.78… or 0.79 <u>or</u> [P(D ,, 12) =] 0.87…
	2nd M1 for correct interpretation of "at least 12" and writing or using 1 – P(D ,, 11)
	We are <u>not</u> attempting to ft their incorrect 0.155 on our calculators here.
	A1 for awrt 0.212 [Answer only 3/3]
(c)	B1 for 100 but must be seen in part (c) i.e. between (b) and (d)
(d)	1st M1 for attempting normal **with mean = 100** <u>or</u> ft their answer to (c)
	May be implied by the correct mean and a correctly labelled s.d. (σ) or var (σ^2)
	1st A1 for correctly labelled standard deviation allow $\sqrt{\frac{250}{3}} = \sqrt{83.3...}$ = 9.1(28….) <u>or</u>
	correctly labelled variance. Implied by N($\mu, \frac{250}{3}$) <u>or</u> correct answer.
	2nd M1 for attempt at continuity correction i.e. sight of 95 <u>+</u> 0.5
	2nd A1 for awrt 0.689 [Answer only 4/4]
NB	**If they don't state the model for 1st M1 but just give probabilities with probability statements (*Y* is any letter):**
$\sigma = \frac{250}{3} =$	1st M1 implied by: P(Y > 94.5) = 0.52(63…), P(Y > 95) = 0.52(39…), P(Y > 95.5) = 0.52(15..)
No cc	1st M1 1st A1 implied by: P(T > 95) = 0.70(805…)
	1st M1 1st A1 2nd M1 implied by: P(T > 94.5) = 0.72(657…)
	Exact binomial gives 0.68567… and will likely score 0/4