Qu	Scheme	Marks		AO
1. (a)	[R = no. of red beads in Aliya's bracelet] $R \sim B(18, 0.14)$	B1 **(1)**		3.3
(b)(i)	P(R = 1) = 0.19403… awrt **0.194**	B1		1.1b
(ii)	P(R …4) = 1 – P(R „ 3) = 1 – [0.76184…]	M1		3.4
	= 0.2381588… awrt **0.238**	A1 **(3)**		1.1b
(c)	Requires p = 0.14 to be constant so need a large number of beads in the sack to ensure that removing 18 beads does not appreciably affect this probability, then it could be suitable.	B1 **(1)**		3.5b
(d)	$H_0 : p = 0.14$ $H_1 : p \neq 0.14$	B1		2.5
	[X = number of red beads in the sample] $X \sim B(75, 0.14)$	M1		3.3
	P(X „ 4) = 0.01506… or if B(75, 0.14) seen awrt 0.02	A1		3.4
	{0.02 < 0.025 so significant or reject H_0 } There is evidence that the proportion of red beads has changed	A1 **(4)**		2.2b
(e)	p-value is $2 \times$"0.01506..." = 0.030123... = awrt 0.03	B1ft **(1)**		1.1b
		(10 marks)		

	Notes
(a)	B1 for B(18, 0.14) accept in words e.g. binomial with n = 18 and p = 0.14
(b)(i)	B1 for awrt 0.194
(ii)	M1 for interpreting "at least 4" Need 1 – P(R „ 3) and 1 – p [$0 < p < 1$] P(R = 3) = 0.233.. OK A1 for awrt 0.238
(c)	B1 for mention of large number of beads and need for p = 0.14 to be constant for it to be suitable. Do NOT accept e.g. "events are independent"
(d)	B1 for both hypotheses correct with use of p or π M1 for selecting a suitable model: sight or correct use of B(75, 0.14) May be implied by sight of 0.015 or better or [P($X > 4$) =] 0.9849… i.e. 0.985 or better 1st A1 for use of the correct model awrt 0.015 (accept awrt 0.02 following a correct expression) Allow 1st A1 for awrt 0.985 only if correct comparison with 0.975 is seen. Sight of B(75, 0.14) and P(X „ 4) = awrt 0.02 scores M1A1 No sight of B(75, 0.14) but sight of awrt 0.015 scores M1($\Rightarrow$)A1[Condone P(X = 4) =..] 2nd A1 (**dep on M1A1)** for a correct conclusion in context mentioning "proportion", "red" and "changed" If there is a statement about H_0 or significance it must be compatible.
NB	May see CR i.e. X „ 4 (mark when prob seen) and X …18 (prob = 0.01406..) Ignore upper limit NB for information P(X = 4) = 0.0104… and can only score M1A0A0 if B(75, 0.14) seen
(e)	B1ft for awrt 0.03 Allow ft of their probability in (d) provided at least 3sf used NB an answer of 0.02 in (d) leading to 0.04 in (e) is B0
SC	Use of CR will give significance level of 0.01506…+ 0.01406… = 0.029… score B1 **no ft**

Que.	Scheme	Marks	AOs
2(a)	[H_1 :] $p \neq 0.25$	B1	2.5
		(1)	
(b)	X~B(50, 0.25)	B1	3.3
	[P(X ,, 6) =]0.0194 or [P(X ,, 18) =]0.9713 or [P(X ..19) =]0.0287 or X ,, 6 or X ..19	M1	3.4
	[P(X ,, 6) =]awrt 0.0194 and [P(X ..19) =]awrt 0.0287	A1	1.1b
	CR: X ,, 6 or X ..19	A1	1.1b
		(4)	
(c)	[0.0194 + 0.0287 =] awrt 0.048	B1ft	1.1b
		(1)	
(d)	(Do not reject H_0,) there is insufficient evidence to suggest that the **proportion** of those with the **allergy** differs from 25%/**Rylan's belief** not supported	B1	2.2b
		(1)	
			(7 marks)

Notes	
(a)	**B1:** correct alternative hypothesis may be stated in terms of p or π Ignore null hypothesis if stated
	Mark part (b) and part (c) together
(b)	**B1:** setting up a Binomial model with n = 50 and p = 0.25 (allow if seen previously) May be implied by M mark **M1:** use of Binomial (50, 0.25) to find a tail probability or a CR tail May be implied by a relevant probability e.g. P(X ,, 7) = 0.0453 , P(X ,, 19) = 0.986 , P(X ..20) = 0.0139 For this mark allow 2sf or better. Watch out for P(X = 6) = 0.0123, P(X = 7) = 0.02586, P(X = 18) = 0.0262 which on their own score M0 as these are not tail probabilities. **A1:** both correct probabilities **seen** (condone awrt 0.0193 and awrt 0.0288) **A1:** correct CR oe e.g. $X < 7$, $X > 18$ Condone X ,, 6 and X ..19
(c)	**B1ft:** awrt 0.048 or ft their two-tailed CR from B(50, p) to 2sf accuracy Each tail probability must be < 0.05
(d)	**B1:** correct inference in context. Do not allow contradictory non-contextual statement e.g. 'Reject H_0' or '10 is in CR' Allow 'proportion' or 'probability' or 'percent(age)/%' but not 'number'. 'Rylan's hypothesis is not supported' is B1, but 'Rylan's hypothesis test is not supported' is B0.

Question	Scheme		Marks	AOs
3(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
4(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 5	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