Qu	Scheme	Marks		AO
4. (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($R \geqslant 4$) = 1 – P($R \leqslant 3$) = 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($X \leqslant 4$) = 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×"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($R \leqslant 3$) 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($X \leqslant 4$) = awrt 0.02 scores M1A1 No sight of B(75, 0.14) but sight of awrt 0.015 scores M1(⇒)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. $X \leqslant 4$ (mark when prob seen) and $X \geqslant 18$ (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**

Qu	Scheme	Marks	AO
3 (a)	Let N = the number of games Naasir wins $N \sim B(15, \frac{1}{3})$	M1	3.3
(i)	$P(N = 2) = 0.059946\ldots$ **awrt 0.0599**	A1	1.1b
(ii)	$P(N > 5) = 1 - P(N \leqslant 5) = 0.38162\ldots$ **awrt 0.382**	A1	1.1b
		(3)	
(b)	$H_0 : p = \frac{1}{3}$ $H_1 : p > \frac{1}{3}$	B1	2.5
	Let X = the number of games Naasir wins $X \sim B(32, \frac{1}{3})$	M1	3.3
	$P(X \geqslant 16) = 1 - P(X \leqslant 15) = 0.03765$ (< 0.05)	A1	3.4
	[Significant result so reject H_0 (the null model) and conclude:] There is evidence to support Naasir's claim (o.e.)	A1	3.5a
		(4)	
		(7 marks)	

	Notes
(a)	M1 for selecting a binomial model with correct n and p Award for sight of $B(15, \frac{1}{3})$ (o.e. e.g. in words) or implied by 1 correct answer 1st A1 for awrt 0.0599 (from a calculator). Allow 0.05995 2nd A1 for awrt 0.382 (from a calculator)
(b)	B1 for correctly stating both hypotheses in terms of p or π Accept $p = 0.\dot{3}$ or any exact equivalent. $H_1 : p \geqslant \frac{1}{3}$ is B0 M1 for selecting a suitable model to use for the test. Award for sight of $B(32, \frac{1}{3})$ (o.e. e.g. in words) or implied by 0.03765 Can also allow M1 for $P(X \leqslant 15) = 0.962$ or better or $P(X \leqslant 14) = 0.922$ or better 1st A1 for use of the model to calculate an appropriate probability using calc. Sight of $P(X \geqslant 16)$ **and** answer awrt 0.0377
ALT	**CR** May use CR so award 1st A1 for CR of $X \geqslant 16$ must have seen some probabilities though: 1 of $P(X \leqslant 15) = 0.9623$ or $P(X \leqslant 14) = 0.9224$ or 0.9223 2nd A1 for conclusion in context that there is support for Naasir's claim Must mention "Naasir" or "his" and "claim" or "method" (o.e.) or e.g. probability of winning a game is $> \frac{1}{3}$ or has increased Dependent on M1 and 1st A1 but can ignore hypotheses but see below If you see $P(X \geqslant 16) = 0.0376$ followed by a correct contextualised conclusion then please award A0A1
SC	**Use of 0.3 for $\frac{1}{3}$** If used 0.3 instead of $\frac{1}{3}$ in (a) and score M0A0A0 can condone use of 0.3 in (b) 1st A1 ft needs $P(X \geqslant 16) = 0.0138$ or CR of $X \geqslant 15$ and sight of 1 of $P(X \geqslant 15) = 0.0327$ or $P(X \geqslant 14) = 0.0694$

Question	Scheme	Marks	AOs
3(a)	(Discrete) uniform (distribution)	B1	1.2
		(1)	
(b)	B(28, 0.2)	B1	3.3
(i)	$P(X \geq 7) = 1 - P(X \leq 6)$ [= 1 – 0.6784…]	M1	3.4
	awrt **0.322**	A1	1.1b
(ii)	$P(4 \leq X < 8) = P(X \leq 7) - P(X \leq 3)$ [= 0.818… – 0.160…]	M1	3.1b
	awrt **0.658**	A1	1.1b
		(5)	
			(6 marks)

Notes	
(a)	Continuous uniform is B0
(b)	**B1:** for identifying correct model, B(28, 0.2) allow B, bin or binomial may be implied by one correct answer or sight one correct probability i.e. awrt 0.678, awrt 0.818 or awrt 0.160 B(0.2, 28) is B0 unless it is used correctly
(i)	**M1:** Writing or using $1 - P(X \leq 6)$ or $1 - P(X < 7)$ **A1:** awrt 0.322 (correct answer only scores M1A1)
(ii)	**M1:** Writing or using $P(X \leq 7) - P(X \leq 3)$ or $P(X < 8) - P(X < 4)$ or $P(X = 4) + P(X = 5) + P(X = 6) + P(X = 7)$ Condone P(4) as $P(X = 4)$, etc. **A1:** awrt 0.658 (correct answer only scores M1A1)

Question	Scheme	Marks	AOs
5(a)	The alternative hypothesis should be $H_1 : p > 0.15$	B1	2.5
	The calculation of the test statistic should be P($X \geq 8$) [= 0.0698]	B1	2.3
		(2)	
(b)	These will affect the conclusion (as the null hypothesis should not be rejected) since P($X \geq 8$) [= 0.0698] is greater than 0.05	B1	2.4
		(1)	
(c)	P($X \leq 8$) = 0.9722… > 0.95 or P($X \geq 9$) = 0.0277… < 0.05	M1	2.1
	CR: {$X \geq 9$}	A1	1.1b
		(2)	
(d)	awrt **0.0278**	B1ft	1.1b
		(1)	
			(6 marks)

Notes	
(a)	**B1:** Identifying that ≥ should be > in the alternative hypothesis **B1:** Identifying that P($X = 8$) should be P($X \geq 8$) Stating P($X = 8$) is incorrect on its own is insufficient Check for errors identified and corrected next to the question
(b)	**B1:** Will affect conclusion **and** correct supporting reason
(c)	**M1:** For use of tables to find probability associated with critical value [P($X \leq 8$) or P($X \geq 9$) with B(30, 0.15) (may be implied by either correct probability awrt 0.97 or awrt 0.03) or by the correct CR] **A1:** [30≥]$X \geq 9$ o.e. e.g. $X > 8$ Allow '9 or more' or 'CR ≥ 9'
(d)	**B1ft:** awrt 0.0278 (allow awrt 2.78%) or correct ft their one-tailed upper CR from B(30, 0.15) to 3s.f.

Question	Scheme	Marks	AOs
5(a)	Let C = the number of successful calls. $C \sim \mathrm{B}\left(9, \frac{1}{6}\right)$	M1	3.3
	$\mathrm{P}(C \geq 3) = 1 - \mathrm{P}(C \leq 2) = 0.1782\ldots$ **awrt 0.178**	A1	1.1b
		(2)	
(b)	Let X = the number of occasions when at least 3 calls are successful. $\mathrm{P}(X = 1) = 5 \times (\text{"0.1782..."}) \times (\text{"0.8217..."})^4$	M1	1.1b
	$= 0.4061\ldots$ **awrt 0.406**	A1	1.1b
		(2)	
(c)	$\mathrm{H}_0 : p = \frac{1}{6}$ $\quad$ $\mathrm{H}_1 : p > \frac{1}{6}$	B1	2.5
	Let R = the number of successful calls $R \sim \mathrm{B}\left(35, \frac{1}{6}\right)$	M1	3.3
	$\mathrm{P}(R \geq 11) = 1 - \mathrm{P}(R \leq 10) = 0.02...$	A1	3.4
	There is sufficient evidence to support that **Rowan** has more successful sales calls than Afrika.	A1	2.2b
		(4)	
			(8 marks)

Notes		
5(a)	**M1:**	For selecting the right model
	A1:	awrt 0.178
(b)	**M1:**	For $5 \times (\text{"their}(a)\text{"}) \times (\text{"1} - \text{their}(a)\text{"})^4$
	A1:	awrt 0.406
(c)	**B1:**	for correctly stating both hypotheses in terms of p or π Accept $p = 0.1\dot{6}$
	M1:	For selecting a suitable model. May be implied by a correct probability or CR
	A1:	Correct probability statement and answer of 0.02 or better (0.02318…) (CR $R \geq 11$ and either $\mathrm{P}(R \leq 9) = 0.9450$ or $\mathrm{P}(R \leq 10) = 0.9768$ or $1 - \mathrm{P}(R \leq 10) = 0.0232$)
	A1:	Dependent on M1A1 but can ignore hypotheses. For conclusion in context supporting **Rowan's** belief / **Rowan** is a better sales person
		Do not accept Rowan can reject H_0

Question	Scheme	Marks	AOs
5(a)	$P(X \geqslant 16) = 1 - P(X \leqslant 15)$	M1	1.1b
	$= 1 - 0.949077\ldots$ = awrt **<u>0.0509</u>**	A1	1.1b
		(2)	
(b)	$H_0 : p = 0.3$ $H_1 : p \neq 0.3$ (Both correct in terms of p or π)	B1	2.5
		(1)	
(c)	$[Y \sim B(20, 0.3)]$ sight of $P(Y \leqslant 2) = 0.0355$ or $P(Y \leqslant 9) = 0.9520$	M1	2.1
	Critical region is $\{Y \leqslant \mathbf{2}\}$ or (o.e.)	A1	1.1b
	$\{Y \geqslant \mathbf{10}\}$ (o.e.)	A1	1.1b
		(3)	
(d)	$[0.0355 + (1 - 0.9520)] = 0.0835$ **or** **<u>8.35%</u>**	B1ft	1.1b
		(1)	
(e)	(Assuming that the 20 customers represent a random sample then) 12 is in the CR so the manager's suspicion is supported	B1ft	3.2a
		(1)	
(f)	e.g. (e) requires the 20 customers to be a random sample or independent and the members of the scout group may invalidate this so binomial distribution would not be valid (and conclusion in (e) is probably not valid)	B1	3.5a
		(1)	
			(9 marks)

Question Number	Scheme	Marks
2(a)	Only 2 outcomes **Heads** and **Tails oe**	
	Constant probability of **spinning** a **Head/Tail oe**	
	Coin is **spun** a fixed number of times **oe**	
	Each **spin** of the **coin** is independent **oe**	B1 B1
		(2)
(b)	$T \sim B(6, 0.5)$	
	$P(T \le 5) - P(T \le 4) = 0.9844 - 0.8906$ or $6\left(\frac{1}{2}\right)^5\left(\frac{1}{2}\right)$ **oe**	M1
	$= 0.09375$ or $\frac{3}{32}$ oe awrt 0.0938	A1
		(2)
(c)	$P(T = 4,5,6) = 1 - P(T \le 3)$	M1
	$= 1 - 0.6563$	
	$= 0.3437$ or $\frac{11}{32}$ awrt 0.344	A1
		(2)
(d)	$P(H = 3,4,5,6) = 1 - P(H \le 2)$	B1M1d
	$= 1 - 0.8306$	
	$= 0.1694$ or $\frac{347}{2048}$ awrt 0.169	A1
		(3)
	Notes	**Total 9**

(a) B1 A correct statement – does not need to be in context
B1 A second correct statement in context include coin or heads or tails(do not allow H and T) or spins/flip oe.

(b) M1 [writing or using B(6, 0.5) **and** writing or using $P(T \le 5) - P(T \le 4)$] **or** [$6\left(\frac{1}{2}\right)^6$ **oe**]

(c) M1 for realising they need find $P(T = 4, 5 \text{ or } 6)$ eg $1 - P(T \le 3)$ or $P(T \ge 4)$

(d)

B1	writing/using B(6, 0.25) **and** $P(H \ge 3)$ **oe**	writing/using B(6, 0.75) **and** $P(T \le 3)$
M1d	dep on B1 for $1 - P(H \le 2)$	dep on B1 $(0.25)^6 + 6(0.75)(0.25)^5 + 15(0.75)^2(0.25)^4 + 20(0.75)^3(0.25)^3$
A1	awrt 0.169	awrt 0.169

NB Only accept correct use of H and T in the probability statement unless their variable is correctly defined

NB awrt 0.169 with no incorrect working gains B1M1A1

Question Number	Scheme	Marks
3. (a)	$P(X \leqslant 7) = 0.8883$ or $P(X \leqslant 8) = 0.9644$ or $P(X \geqslant 8) = 0.1117$ or $P(X \geqslant 9) = 0.0356$	**M1**
	Critical Region is $X \geqslant 9$ (o.e.)	**A1**
		(2)
(b)	(1 – 0.9644=) 0.0356 [NB Calculator gives: 0.03557486...]	**B1cao**
		(1)
(c)	Reject H_0/Significant or value of p is > 0.45	**B1ft**
		(1)
(d)(i)	Conclusion would not change as H_0 would still be rejected	**B1**
(ii)	Conclusion would change as H_0 would not be rejected	**B1**
		(2)
		[6]

Notes

(a)
M1 for one of these 4 probabilities - may be implied by a correct critical region
A1 for $X \geqslant 9$ (allow $X > 8$) (o.e.) e.g. [9, 12], {9, 10, 11, 12} etc Ans. only 2/2
NB Must be $X \geqslant 9$ for A1, do not award for just seeing $P(X \geqslant 9)$

(b)
B1 for 0.0356 or better

(c)
B1f ft their critical region in (a) Must say "reject" **and** "H_0" No contradictory statements
Just saying "9 is not in the critical region" is not enough
Allow a restart i.e. calculating $P(X \geqslant 9) = 0.0356 < 0.05$ so significant

If they score B0 in (c) then score B0B0 in (d)

(d)	In (c) they reject H_0	In (c) they accept H_0
(i)	B1 for "No", "no change", "significant" etc	B0 whatever they say
(ii)	B1 for "Yes" , "do not reject H_0" etc	B1 for "no change" or "do not reject H_0" etc

CR
(i) NB new CR is $X \geqslant 9$ but can treat any incorrect mention of CR as ISW
(ii) NB new CR is $X \geqslant 10$ but can treat any incorrect mention of CR as ISW

Question Number	Scheme	Marks
5. (a)(i)	$H_0 : p = 0.35 \quad H_1 : p \neq 0.35$	**B1**
(ii)	B(15,0.35)	**M1**
	CR $X \leq 1 \cup X \geq 10$ (Allow any letter)	**A1A1**
		(4)
(b)	8 is not in CR	**M1**
	There is evidence that the Company's <u>claim</u> is true	**A1ft**
		(2)
(c)	0.0142 + 0.0124 = 0.0266	**B1**
		(1)
		[7]

	Notes
(a) (i)	B1 both hypotheses correct. Must mention p (or π). Words only is B0
(ii)	M1 Writing B(15,0.35) May be implied by e.g. P($X \leq 1$) =0.0142 or P($X \leq 9$) = 0.9876
	1st A1 $X \leq 1$ (accept $X < 2$) Allow $0 \leq X \leq 1$ but P($X \leq 1$) is A0
	2nd A1 $X \geq 10$ (accept $X > 9$) Allow $10 \leq X \leq 15$ but P($X \geq 10$) is A0
	Either correct answer will imply M1
(b)	M1 for a reason that matches their CR. "Interpret" their CR of P($X \geq 10$) as $X \geq 10$ etc
	Allow calculation of P($X \geq 8$) = 1 – 0.8868 = 0.1132 and "not sig" comment
	Do not allow contradictory remarks e.g. 8 is not in CR so significant (this gets M0)
	A1ft for a conclusion correct for their CR in context
	Must mention "claim" <u>or</u> "peas" and "germinating"
	NB A correct contextual claim on its own scores M1A1
(c)	B1 for 0.0266 or awrt 0.0266 (calc gives 0.02662196...)

Question Number	Scheme	Marks
2(a)	**List** of all the **customers** (who eat in the restaurant)	B1 (1)
(b)	**Customer(s)** (who ate in the restaurant)	B1 (1)
(c)	Advantage: more/total accuracy, unbiased	B1
	Disadvantage: time consuming to obtain data and analyse it, expensive, difficult to ensure entire population is included	B1 (2)
(d)	Let X = the number of customers who would like more choice on the menu.	
	H_0: $p = 0.3$ H_1: $p > 0.3$	B1
	X~B(50,0.3)	M1
	$P(X \geqslant 20) = 1 - P(X \leqslant 19)$ or CR $P(X \leqslant 20) = 0.9522$ $= 1 - 0.9152$ $P(X \geqslant 21) = 0.0478$ $= 0.0848$ $X \geqslant 21$	M1 A1
	Do not reject H_0/ not significant/20 is not in critical region	M1
	The percentage of customers who would like more choice on the menu is not more than Bill believes. or There is no evidence to reject Bill's belief.	A1cso
		(6)
		Total (10)

Notes

(a) B1 Need the idea of list/register/database and 'customer(s)'
Do not allow customer's opinions.
'All' may be implied. Do not allow a partial list e.g. 'A list of 50 customers'

(b) B1 customer(s)

(c) If not labelled, assume the response refers to a census.
1st B1 is for the advantage and 2nd B1 is for the disadvantage.

(d) B1 need both hypotheses with p
M1 using B(50,0.3)
M1 for $1 - P(X \leqslant 19)$ or
$P(X \leqslant 20) = 0.9522$ or $P(X \geqslant 21) = 0.0478$ leading to a **critical region** $X > k$ or $X \geqslant k$
A1 awrt 0.0848 or critical region $X \geqslant 21$ or $X > 20$
M1 a correct conclusion for their probability. May be implied by a correct contextual conclusion.
A1 a correct contextual conclusion for their hypotheses and a fully correct solution with no errors seen. Must mention 'customers' and 'choice' or 'Bill' and 'belief'.

NB P(X=20) can score B1M1M0A0M0A0
NB normal approximation gives 0.082(457…) and loses all A marks