



Maths Questions By Topic:

**Statistical Hypothesis Testing
Mark Scheme**

A-Level Edexcel

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Qu	Scheme	Mark	AO
1.	$H_0 : p = 0.08 \quad H_1 : p < 0.08$ $[X \sim] B(70, 0.08)$ $0.0739756... \quad \text{awrt } \underline{\mathbf{0.074}}$ $[0.074 < 0.10 \text{ so significant, reject } H_0 \text{ so...}]$ there <u>is</u> evidence to <u>support</u> supplier <u>B's claim</u> (o.e.)	B1 M1 A1 A1 (4) (4 marks)	2.5 2.1 1.1b 2.2b
Notes			
1.	B1 for both hypotheses correct in terms of p or π [Condone 8% for 0.08] M1 for sight or correct use of $B(70, 0.08)$ [Condone $B(0.08, 70)$] May be implied by prob of 0.074 or better 1 st A1 for final answer awrt 0.074 can condone poor notation e.g. $P(X = 2) = \text{awrt } 0.074$ Can allow this mark for CR of $X = 2$ provided $[P(X = 2)] = 0.074$ (or better) is seen [Can allow 0.07 if $X \sim B(70, 0.08)$ and $P(X = 2)$ are both seen] 2 nd A1 (dep on M1A1 but independent of hypotheses) for a correct inference in context Must mention <u>claim</u> or <u>B</u> and idea of <u>support for</u> ... <u>or</u> <u>proportion/probability</u> (of damp bags) and idea of <u>less</u> than 8% or A 2 nd A0 for contradictory statements e.g. "accept H_0 so evidence to support B's claim" 2 nd A0 if you see $0.0739... < 0.08$ so significant/ reject H_0 etc		
MR	0.8 for 0.08 In (a) allow M1 for $B(35, 0.8)$ then A0A0 In (b) allow B1 for Hypotheses and M1 for $B(70, 0.8)$ seen, then A0A0		

Qu 2	Scheme	Marks	AO
(a)	$H_0 : p = 0.14 \quad H_1 : p \neq 0.14$ [X = number of red beads in the sample] $X \sim B(75, 0.14)$ $P(X = 4) = 0.01506\dots$ or if B(75, 0.14) seen awrt 0.02 $\{0.02 < 0.025$ so significant <u>or</u> reject H_0 } There is evidence that the proportion of red beads has changed	B1 M1 A1 A1 (4)	2.5 3.3 3.4 2.2b
(b)	p -value is $2 \times "0.01506\dots" = 0.030123\dots =$ awrt 0.03	B1ft (1)	1.1b
		(5 marks)	
Notes			
(a)	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 <u>or</u> $[P(X > 4) =] 0.9849\dots$ i.e. 0.985 or better 1 st A1 for use of the correct model awrt 0.015 (accept awrt 0.02 following a correct expression) Allow 1 st A1 for awrt 0.985 <u>only if</u> correct comparison with 0.975 is seen. Sight of B(75, 0.14) and $P(X = 4) =$ awrt 0.02 scores M1A1 <u>No sight</u> of B(75, 0.14) <u>but</u> sight of awrt 0.015 scores M1(\Rightarrow)A1 [Condone $P(X = 4) = \dots$] 2 nd A1 (dep on M1A1) for a correct conclusion in context mentioning "proportion", "red" and "changed"		
NB	If there is a statement about H_0 or significance it must be compatible. May see CR i.e. $X = 4$ (mark when prob seen) and $X = 18$ (prob = 0.01406..) Ignore upper limit NB for information $P(X = 4) = 0.0104\dots$ and can only score M1A0A0 if B(75, 0.14) seen		
(b)	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 $0.01506\dots + 0.01406\dots = 0.029\dots$ score B1 no ft		

Question	Scheme		Marks	AOs
3	$H_0 : p = \frac{1}{6} \quad H_1 : p > \frac{1}{6}$		B1	2.5
	Let R = the number of successful calls $R \sim B\left(35, \frac{1}{6}\right)$		M1	3.3
	$P(R \geq 11) = 1 - P(R \leq 10) = 0.02\dots$		A1	3.4
	There is sufficient evidence to support that Rowan has more successful sales calls than Afrika.		A1	2.2b
			(4)	
(4 marks)				
Notes				
3	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 $P(R \leq 9) = 0.9450$ or $P(R \leq 10) = 0.9768$ or $1 - P(R \leq 10) = 0.0232$)		
	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
4(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 <u>0.0278</u>	B1ft	1.1b
		(1)	
(6 marks)			
Notes			
(a)	B1: Identifying that \geq 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: $[30 \geq] X \geq 9$ 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.		

Qu	Scheme	Marks	AO
5	$H_0 : p = \frac{1}{3}$ $H_1 : p > \frac{1}{3}$ Let X = the number of games Naasir wins $X \sim B(32, \frac{1}{3})$ $P(X \geq 16) = 1 - P(X \leq 15) = 0.03765$ (< 0.05) [Significant result so reject H_0 (the null model) and conclude:] There is evidence to support Naasir's claim (o.e.)	B1 M1 A1 A1 (4)	2.5 3.3 3.4 3.5a (4 marks)
Notes			
5	B1 for correctly stating both hypotheses in terms of p or π Accept $p = 0.\dot{3}$ or any exact equivalent. $H_1 : p \geq \frac{1}{3}$ 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 $P(X \leq 15) = 0.962$ or better or $P(X \leq 14) = 0.922$ or better 1 st A1 for use of the model to calculate an appropriate probability using calc. Sight of $P(X \geq 16)$ and answer awrt 0.0377		
ALT	CR May use CR so award 1 st A1 for CR of $X \geq 16$ must have seen some probabilities though: 1 of $P(X \leq 15) = 0.9623$ or $P(X \leq 14) = 0.9224$ or 0.9223 2 nd A1 for conclusion in context that there is support for Naasir's claim Must mention " <u>Naasir</u> " or " <u>his</u> " and " <u>claim</u> " or " <u>method</u> " (o.e.) <u>or</u> e.g. <u>probability</u> of <u>winning</u> a game is $> \frac{1}{3}$ or has <u>increased</u> Dependent on M1 and 1 st A1 but can ignore hypotheses but see below If you see $P(X \geq 16) = 0.0376$ 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) 1 st A1 ft needs $P(X \geq 16) = 0.0138$ or CR of $X \geq 15$ and sight of 1 of $P(X \geq 15) = 0.0327$ or $P(X \geq 14) = 0.0694$ 2 nd A1 as before with 0.3 instead (if appropriate)		

Question	Scheme	Marks	AOs	
6(a)	$H_0: p = 0.25$ $H_1: p > 0.25$ (both correct in terms of p or p)	B1	2.5	
	$Y \sim B(40, 0.25)$	M1	3.3	
	<u>Method 1</u>	<u>Method 2</u>		
	$P(Y \geq 16) = 1 - P(Y \leq 15)$	$P(Y \geq 17) = 0.0116$	M1	1.1b
	$= 1 - 0.9738$	$P(Y \geq 18) = 0.0047$		
	$= 0.0262$	$CR Y \geq 18$	A1	1.1b
	0.0262 > 0.01 16 < 18 or 16 is not in the critical region or 16 is not significant, accept H_0 . There is no significant evidence that the proportion of people who bought organic eggs has increased		A1cso	2.2b
		(5)		
(b)	There is evidence that the proportion of people who bought organic eggs has increased [since $0.05 > 0.0262$ or 16 is in critical region]	B1ft	2.2b	
		(1)		
(6 marks)				
Notes:				
<p>(a) B1: Both hypotheses correct using p or p and 0.25 M1: Realising that the model $B(40, 0.25)$ is to be used. This may be stated or used. M1: Using or writing $1 - P(Y \leq 15)$ or $1 - P(Y < 16)$ a correct CR or $P(Y \geq 17) = 0.0116$ and $P(Y \geq 18) = 0.0047$ A1: awrt 0.0262 or $CR Y \geq 18$ or $Y > 17$ A1cso: A fully correct solution with a correct conclusion in context to include the idea of proportion and increased plus referring to organic</p>				
(b) B1ft: For $0.0262 < 0.05$ [ft their probability in part(b)] or a CR of 16^3 15 (allow $16 > 14$) and a correct contextual conclusion.				

Question	Scheme	Marks	AOs
7(a)	$H_0 : p = 0.3 \quad H_1 : p \neq 0.3$ (Both correct in terms of p or π)	B1	2.5
		(1)	
(b)	$[Y \sim B(20, 0.3)]$ sight of $P(Y \leq 2) = 0.0355$ or $P(Y \leq 9) = 0.9520$	M1	2.1
	Critical region is $\{Y \leq 2\}$ or (o.e.)	A1	1.1b
	$\{Y \geq 10\}$ (o.e.)	A1	1.1b
		(3)	
(c)	$[0.0355 + (1 - 0.9520)] = 0.0835$ or 8.35%	B1ft	1.1b
		(1)	
(d)	(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)	
(e)	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)	
			(7 marks)

Continued question 7
Notes:
(a) B1: For both hypotheses in terms of p or π and H_1 must be 2-tail
(b) M1: For correct use of tables to find probability associated with critical value A1: For the correct lower limit of the CR. Do not award for $P(Y \leq 2)$ A1: For the correct upper limit
(c) B1: ft on their 0.0355 and $(1 - \text{their } 0.9520)$ provided each probability is less than 0.05
(d) B1: ft for a comment that relates 12 to their CR and makes a consistent comment relating this to the manager's suspicion
(e) B1: For a comment that: gives a suitable reason based on lack of independence or the sample not being random so the binomial model is not valid

Question	Scheme		Marks	AOs
8(a)	H ₀ : $p = 0.1$ H ₁ : $p \neq 0.1$		B1	2.5
			(1)	
(b)	Use of $X \sim B(50, 0.1)$ implied by sight of one of awrt 0.0052 or awrt 0.9755 or awrt 0.0245		M1	3.4
	Critical regions $X = 0$ or $X \geq 10$		A1	1.1b
	$X = 0$ and $X \geq 10$ plus $P(X = 0) = \text{awrt } 0.0052$ and $P(X \geq 10) = \text{awrt } 0.0245$		A1	1.1b
	SC: Both CR correct with no probabilities and no distribution seen scores M0A1A0			
			(3)	
(c)	0.0297		B1ft	1.1b
			(1)	
(d)	15 is <u>in the critical region</u> therefore there is evidence to support the <u>manager's</u> belief		B1ft	2.2b
			(1)	
(6 marks)				
Notes				
(a)	B1	For both hypotheses in terms of p or π . Connected to H ₀ and H ₁ correctly Condone 10% but not 10		
(b)	M1	Using correct distribution to find the probability associated with one tail of the CR If the correct distribution is <u>stated</u> (may be seen in part(a)) allow for one tail of the correct CR or one of (awrt 0.025 or awrt 0.005 or awrt 0.975) seen connected to a correct probability statement		
	A1	Lower CR $X = 0 / X < 1 / X \leq 0$ [condone eg $P(X = 0)$ labelled as CR] Or Upper CR $X \geq 10$ or $X > 9$ [condone $P(X \geq 10)$ oe labelled as CR]		
	A1	Both CR's correct with the relevant probabilities Allow \cup for "and" and $X > 9, X < 1, X \leq 0$ [do not allow $P(X = 0)$ or $P(X \geq 10)$ oe] Allow CR in different form eg $(9, \infty), [10, \infty)$		
(c)	B1ft	awrt 0.0297 or 2.97% or ft for the sum of the probabilities in (b) for "their 2 critical regions" if seen. If none seen it must be awrt 0.0297 SC M0 in (b) for a one tail test Allow B1ft for their one tail CR in (b) eg 0.0338 or 0.0245 or 0.0579		
(d)	B1ft	A correct statement about 15 and "their CR" or sight $P(X \geq 15) = 0.0000738\dots$ and comparison with "their 0.0245" and a compatible correct statement in context. eg There is evidence that there has been a change in the <u>proportion/probability</u> arriving <u>late</u> Condone increase rather than change Do not allow contradicting statements. NB No CR given in (b) then B0		

Question	Scheme	Marks	AOs
9	$H_0 : \rho = 0$ $H_1 : \rho < 0$	B1	2.5
	Critical value – 0.3887 (Allow \pm)	M1	1.1b
	There is evidence that the product moment correlation is less than 0/ <u>there is a negative correlation</u>	A1	2.2b
		(3)	

Notes:

(3 marks)

9	B1	Both hypotheses correct in terms of ρ (allow p)
	M1	For the cv of -0.3887 or any cv such that $0.3 < cv < 0.5$
	A1	Independent of hypotheses. Correct conclusion that implies reject H_0 on basis of seeing -0.3887 or if they give 0.3887 we must see the comparison $0.3887 < 0.897$ and which mentions “pmcc/correlation/relationship” and less than 0/ negative or $\rho < 0$ A contradictory statement scores A0 eg Accept H_0 therefore negative correlation

Qu 10	Scheme	Marks	AO
(a)	$(r =) - 0.54458266\dots$ awrt <u>-0.545</u>	B1	1.1b
(b)	$H_0 : \rho = 0 \quad H_1 : \rho < 0$ [5% 1-tail cv =] (+) 0.4259 (significant result / reject H_0) There <u>is</u> evidence of negative <u>correlation</u> between the <u>number of letters</u> in (or <u>length</u> of) a student's last <u>name</u> and their first <u>name</u>	B1 M1 A1	2.5 1.1a 2.2b
		(1) (3)	
Notes			
(a)	B1 for awrt - 0.545		
(b)	B1 for both hypotheses correct in terms of ρ M1 for a critical value compatible with their H_1 : 1-tail: awrt ± 0.426 (condone ± 0.425) or 2-tail (B0 scored for H_1) : awrt ± 0.497 If hypotheses are in words and can deduce whether one or two-tail then use their words. If no hypotheses or their H_1 is not clearly one or two tail assume one-tail		
NB	A1 for compatible signs between cv and r and a correct conclusion in context mentioning <u>correlation</u> and <u>number of letters</u> or <u>length</u> and <u>name</u> (ft their value from (c)) Do NOT award this A mark if contradictory comments or working seen e.g. "accept H_0 " or comparison of 0.426 with significance level of 0.05 etc The M1A1 can be scored independently of the hypotheses		

Qu 11	Scheme	Marks	AO
11	$H_0 : \mu = 166.5 \quad H_1 : \mu < 166.5$	B1	2.5
	[Let X = height of female from 2 nd country] $\bar{X} \sim N\left(166.5, \left(\frac{7.4}{\sqrt{50}}\right)^2\right)$	M1	3.3
	$P(\bar{X} < 164.6) = 0.03472\dots$	A1	3.4
	[0.0347... < 0.05 so significant <u>or</u> reject H_0] There is evidence to support Mia's belief	dA1	2.2b
		(4)	
Notes			
11	B1 for both correct hypotheses in terms of μ 1 st M1 for selecting the correct model (needn't use $\bar{X} \Rightarrow$ by standardisation or 1 st A1) 1 st A1 for correct use of the correct model i.e. awrt 0.035 (allow 0.04 if $P(\bar{X} < 164.6)$ seen) Condone $P(\bar{X} > 164.6) = 0.9652$ or awrt 0.97 <u>only</u> if comparison with 0.95 is made		
ALT	Use of z value: Need to see $Z = -1.8(15\dots)$ and cv of ± 1.6449 (allow 1.64 or better) for 1 st A1		
ALT	Use of CR or CV for \bar{X}: Need to see " \bar{X} " < 164.7786... or CV = ... (awrt 164.8) for 1 st A1 Condone truncation i.e 164.7 or better		
	2 nd dA1 (dep on M1A1 only) for a correct inference in context. Must mention <u>Mia's belief</u> or <u>mean height of females/women</u> Do NOT award if contradictory statements about hypotheses made e.g. "not sig"		
SC	M0 for $\bar{X} \sim N(164.6, \dots)$ If they achieve $p =$ awrt 0.035 (o.e. with z-value or CV of 166.3) and a correct conclusion in context is given score M0A0A1 [and SC for awrt 0.97 > 0.95 case]		

Qu 12	Scheme	Marks	AO
12	$H_0 : \rho = 0$ $H_1 : \rho \neq 0$ Critical value: $-0.361(0)$ $r < -0.3610$ so significant result and there is evidence of a correlation between Daily Total <u>Sunshine</u> and Daily Maximum Relative <u>Humidity</u>	B1 M1 A1 (3)	2.5 1.1b 2.2b
		(3 marks)	
Notes			
12	B1 for both hypotheses correct in terms of ρ M1 for the correct critical value compatible with their H_1 : allow $\pm 0.361(0)$ If the hypotheses are 1-tail then allow cv of ± 0.3061 e.g. Alternative hypothesis with $r < \pm 0.377$ implies a one-tail test <u>or</u> H_0 and H_1 in words saying “ H_0 : there is no correlation, H_1 : there is correlation” is two-tail If there are no hypotheses (or they are nonsensical) assume 2-tail so M1 for $\pm 0.361(0)$ A1 for a correct conclusion in context based on comparing -0.377 with their cv. Condone incorrect inequality e.g. $-0.3610 < -0.377$ as long as they reject H_0 Do not accept contradictory statements such as “accept H_0 so there is evidence of ...” Can say “support for Stav’s <u>belief</u> ”(o.e.e.g. “claim”) or “evidence of a correlation between <u>sunshine</u> and <u>humidity</u> ” condone “negative correlation” or comments such as “if humidity is high amount of sunshine will be low”		

Qu 13	Scheme	Marks	AO
13	$H_0 : \mu = 10 \quad H_1 : \mu > 10$ $\bar{X} \sim N\left(10, \left(\frac{4}{\sqrt{20}}\right)^2\right); \quad P(\bar{X} > 11.5) = 0.046766\dots$ [Condone 0.9532...] [This is significant (< 5%) so] there is evidence to support the complaint	B1 M1;A1 A1 (4)	2.5 3.3;3.4 2.2b
		(4 marks)	
Notes			
13	B1 for both hypotheses correct in terms of μ . M1 for selection of a correct model (sight or use of correct normal- may not have label \bar{X}) 1 st A1 for use of this model to get probability allow 0.046~0.047 [Condone awrt 0.953]		
ALT	OR test statistic $z = 1.677\dots$ (awrt 1.68) <u>and</u> cv of 1.64 (or better) or CR $\bar{X} > 11.47\dots$		
	2 nd A1 (dep on 1 st A1 or at least $P(\bar{X} > 11.5) < 0.05$ (o.e.))		
SC	for a correct conclusion in context -must mention complaint /claim or time /mins is > 10 (M0 for $X \sim N(11.5, \dots)$ for correct probability and conclusion (score M0A0A1 on open)		

Question	Scheme	Marks	AOs	
14(a)	$H_0 : \rho = 0$ $H_1 : \rho > 0$	B1	2.5	
	Critical value 0.3438	M1	1.1a	
	(0.446 > 0.3438) so there is evidence that the product moment correlation coefficient (pmcc) is greater than 0/there is positive correlation	A1	2.2b	
		(3)		
(b)	The value is close(r) to 1 or there is strong(er) (positive) correlation	B1	2.4	
		(1)		
(c)	$\log_{10} y = -1.82 + 0.89(\log_{10} x)$	$y = ax^n \rightarrow$ $\log_{10} y = \log_{10}(ax^n)$	M1	1.1b
	$y = 10^{-1.82 + 0.89(\log_{10} x)}$	$\log_{10} y = \log_{10} a + \log_{10} x^n$	M1	2.1
	$y = 10^{-1.82} \times 10^{0.89(\log_{10} x)}$ [$= 10^{-1.82} \times 10^{(\log_{10} x)^{0.89}}$]	$\log_{10} y = \log_{10} a + n \log_{10} x$ [$\log_{10} a = -1.82, n = 0.89$]	M1	1.1b
	$y = 0.015x^{0.89}$	$y = 0.015x^{0.89}$	A1A1	1.1b 1.1b
			(5)	
(9 marks)				
Notes				
(a)	B1: for both hypotheses correct in terms of ρ M1: for the critical value: sight of 0.3438 or any cv such that $0.25 < cv < 0.45$ A1: a comment suggesting a significant result/ H_0 is rejected on the basis of <u>seeing</u> +0.3438 and which mentions “pmcc/correlation/relationship” and “greater than 0/positive” (not just $\rho > 0$) or an answer in context e.g. ‘as “income”(o.e.) increases, “CO ₂ /emissions”(o.e.) increases’ A contradictory statement scores A0 e.g. ‘Accept H_0 , therefore positive correlation’			
	(b)	B1: for suitable reason e.g. r is close(r) to 1 or “strong(er)”/“near perfect” “correlation” Do not allow ‘association’		
(c)	<p style="text-align: center;">For both methods, once an M0 is scored, no further marks can be awarded and condone missing base 10 throughout</p> <p>Method 1: (working to the model) M1: Correct substitution for both c and m (may be implied by 2nd M1 mark) M1: Making y the subject to give an equation in the form $y = 10^{a+b(\log_{10} x)}$ (may be implied by 3rd M1 mark) M1: Correct multiplication to give an equation in the form $y = 10^a \times 10^{b(\log_{10} x)}$ (this line implies M1M1M1 provided no previous incorrect working seen)</p> <p>Method 2: (working from the model) M1: Taking the log of both sides (may be implied by 2nd M1 mark) M1: Correct use of addition rule (may be implied by 3rd M1 mark) M1: Correct multiplication of power (this line implies M1M1M1 provided no previous incorrect working seen)</p> <p>A1: $n = 0.89$ or $a = \text{awrt } 0.015$ or $y = ax^{0.89}$ or $y = \text{awrt } 0.015x^n$ (dep on M3) A1: $n = 0.89$ and $a = \text{awrt } 0.015$ / $y = \text{awrt } 0.015x^{0.89}$ (dep on M3) do not award the final A1 if answer is given in an incorrect form e.g. $y = 0.015 + x^{0.89}$</p>			

Question	Scheme	Marks	AOs
15	$H_0 : \mu = 25$ $H_1 : \mu < 25$	B1	2.5
	$[\bar{D} \sim]N\left(25, \frac{0.16^2}{20}\right)$	M1	3.3
	$P(\bar{D} < 24.94) [= P(Z < -1.677\dots)] = 0.046766\dots$	A1	3.4
	$p = 0.047 < 0.05$ <u>or</u> $z = -1.677\dots < -1.6449$ <u>or</u> $24.94 < 24.94115\dots$ <u>or</u> reject H_0 /in the critical region/significant	M1	1.1b
	There is sufficient evidence to support <u>Hannah's belief</u> .	A1	2.2b
		(5)	
(5 marks)			
15	Notes		
	<p>B1: for both hypotheses in terms of μ</p> <p>M1: selecting suitable model must see N(ormal), mean 25, sd = $\frac{0.16}{\sqrt{20}}$ (o.e.) or var = $\frac{4}{3125}$ (o.e.) Condone $N(25, \frac{0.16}{\sqrt{20}})$ if $\frac{0.16}{\sqrt{20}}$ then used as s.d.</p> <p>A1: p value = awrt 0.047 <u>or</u> test statistic awrt -1.68 <u>or</u> CV awrt 24.941 (any of these values imply the M1 provided they do not come from Normal mean = 24.94)</p> <p>M1: a correct comparison (including compatible signs) or correct non-contextual conclusion (f.t. their p value, test statistic or critical value in the comparison) M1 may be implied by a correct contextual statement</p> <p>NB Any contradictory non contextual statements/comparisons score M0A0 e.g. '$p < 0.05$, not significant'</p> <p>A1: correct conclusion in context mentioning <u>Hannah's belief</u> <u>or</u> the mean <u>amount/liquid</u> in each bottle is now <u>less than 25ml (dep on M1A1M1)</u></p>		

Qu 16	Scheme	Marks	AO
(a)	$H_0 : \rho = 0$ $H_1 : \rho < 0$ Critical value: -0.6215 (Allow any cv in range $0.5 < cv < 0.75$) $r < -0.6215$ so significant result and there is evidence of a negative correlation between w and t	B1	2.5
		M1	1.1a
		A1	2.2b
		(3)	
(b)	e.g. As temperature increases people spend more time on the beach and less time shopping (o.e.)	B1	2.4
(c)	Since r is close to -1 , it is consistent with the suggestion	(1)	
		B1	2.4
(d)	t will be the explanatory variable since sales are likely to depend on the temperature	(1)	
		B1	2.4
(e)	Every degree rise in temperature leads to a drop in weekly earnings of £171	(1)	
		B1	3.4
		(7 marks)	
Notes			
(a)	B1 for both hypotheses in terms of ρ M1 for the critical value: sight of ± 0.6215 or any cv such that $0.5 < cv < 0.75$ A1 must reject H_0 on basis of comparing -0.915 with -0.6215 (if $-0.915 < 0.6215$ is seen then A0 but may use $ r $ o.e. which is fine) <u>and</u> mention “negative”, “correlation/relationship” and at least “ w ” and “ t ”		
(b)	B1 for a suitable <u>reason to explain</u> negative correlation using the context given. e.g. “As temperature drops people are more likely to go shopping (than to the beach)” e.g. “As temperature increases people will be outside rather than in shops” A mere description in context of negative correlation is B0 SO e.g. “As temperature increases people don’t want to go shopping/buy clothes” is B0 e.g. “Less clothes needed as temp increases” is B0		
(c)	B1 for a suitable reason e.g. “strong”/”significant”/”near perfect” “correlation”, $ r $ close to 1 <u>and</u> saying it is consistent with the suggestion. Allow “yes” followed by the reason.		
(d)	B1 For identifying t <u>and</u> giving a suitable reason. Need idea that “ w <u>depends</u> on t ” or “ w <u>responds</u> to t ” or “ t <u>affects</u> w ” (o.e.) Allow t (temperature) <u>affects</u> the other variable etc Just saying “ t is the independent variable” or “ t <u>explains</u> change in w ” is B0 N. B. Suggesting causation is B0 e.g. “ t causes w to decrease”		
(e)	B1 for a description that conveys the idea of rate per degree Celsius. Must have 171, condone missing “£” sign.		

Qu 17	Scheme	Marks	AO
17	$H_0 : \mu = 18 \quad H_1 : \mu > 18$	B1	2.5
	$\bar{L} \sim N\left(18, \left(\frac{4}{\sqrt{20}}\right)^2\right)$	M1	3.3
	$P(\bar{L} > 19.2) = P(Z > 1.3416\dots) = 0.089856\dots$	A1	3.4
	(0.0899 > 5%) <u>or</u> (19.2 < 19.5) <u>or</u> 1.34 < 1.6449 so not significant	A1	1.1b
	Insufficient evidence to support Alice's claim (or belief)	A1	3.5a
		(5)	
		(5 marks)	
	Notes		
17	B1	for both hypotheses in terms of μ .	
	M1	for selecting a suitable model. Sight of <u>normal</u> , <u>mean</u> 18, <u>sd</u> $\frac{4}{\sqrt{20}}$ (o.e.) or <u>variance</u> = 0.8	
	1 st A1	for using the model correctly. Allow awrt 0.0899 <u>or</u> 0.09 from correct prob. statement	
ALT		CR $(\bar{L}) > 19.471\dots$ (accept awrt 19.5) <u>or</u> CV of 1.6449 (or better: calc 1.6448536..)	
	2 nd A1	for correct non-contextual conclusion. Wrong comparison or contradictions A0 Error giving 2 nd A0 implies 3 rd A0 but just a correct contextual conclusion can score A1A1	
	3 rd A1	dep on M1 and 1 st A1 for a correct contextual conclusion mentioning <u>Alice's claim</u> / <u>belief</u> <u>or</u> there is insufficient evidence that the mean <u>lifetime</u> is more than 18 hours	

Question	Scheme	Marks	AOs
18(a)	Width = $0.4 \times 5 = 2$ (cm)	B1	3.1a
	Area = 12 cm^2 Frequency = 15 so $1 \text{ cm}^2 = \frac{5}{4}$ packet o.e	M1	1.1b
	Frequency of 9 corresponds to area of 7.2 Height = $7.2 \div 2 = 3.6$ (cm)	A1	1.1b
		(3)	
(b)	$[Q_2 =] (248 +) \frac{22}{35} \times 4$ or (use of $(n+1)$) $(248 +) \frac{22.5}{35} \times 4$	M1	1.1a
	= awrt 250.5 (g) or 250.6	A1	1.1b
		(2)	
(c)	Mean = awrt 250.4 (g)	B1	1.1b
	$[\sigma_x =] \sqrt{\frac{5644171.75}{90} - \left(\frac{22535.5}{90}\right)^2} = \sqrt{15.64...}$	M1	1.1b
	= awrt 4.0 (g)	A1	1.1b
	Accept $\left(s_x = \sqrt{\frac{5644171.75 - 90\left(\frac{22535.5}{90}\right)^2}{89}} = 3.977... \right)$	(3)	
(d)	$H_0 : \mu = 250$ $H_1 : \mu > 250$	B1	2.5
	$\bar{X} \sim N\left(250, \frac{4^2}{90}\right)$ and $\bar{X} > 250.4$	M1	3.3
	$P(\bar{X} > 250.4) = 0.171...$	A1	3.4
	$0.171 > 0.05$ or $z = 0.9486... < 1.6449$	A1	1.1b
	There is insufficient evidence that the mean weight of coffee is greater than 250 g, or there is no evidence to support the sellers claim.	A1	2.2b
		(5)	
(13 marks)			

Question 18 Notes:
<p>(a) B1: for correct width M1: for clear attempt to relate the area to frequency. May be implied by their height \times their width = 7.2 A1: for height = 3.6 cm</p>
<p>(b) M1: for $\frac{22}{35} \times 4$ or $\frac{22.5}{35} \times 4$ A1: awrt 250.5 or 250.6</p>
<p>(c) B1: awrt 250.4 M1: for a correct expression for σ or s, can ft their mean A1: awrt 4.0 (allow $s =$ awrt 4.0)</p>
<p>(d) B1: hypotheses stated correctly M1: for selecting a correct model, (stated or implied) A1: for use of the correct model to find $p =$ awrt 0.171 (allow $z =$ awrt 0.948) A1: for a correct calculation, comparison and correct statement A1: for a correct conclusion in context mentioning mean weight and 250</p>

Question	Scheme	Marks	AOs
19	$H_0 : \rho = 0 \quad H_1 : \rho > 0$	B1	2.5
	Critical value 0.5509	M1	1.1a
	Reject H_0		
	There is evidence that pmcc is greater than zero	A1	2.2b
		(3)	
(3 marks)			
Notes:			
<p>B1: for both hypotheses in terms of ρ</p> <p>M1: for selecting a suitable critical value compatible with their H_1</p> <p>A1: for a correct conclusion stated</p>			

Question	Scheme	Marks	AOs
20(a)	e.g. Linear association between w and t	B1	1.2
		(1)	
(b)	$H_0: \rho = 0$ $H_1: \rho > 0$	B1	2.5
	Critical value 0.5822	M1	1.1a
	Reject H_0		
	There is evidence that the product moment correlation coefficient is greater than 0	A1	2.2b
		(3)	
			(4 marks)
Notes:			
(a)			
B1: for a correct statement			
(b)			
B1: for both hypotheses in terms of ρ			
M1: for selecting a suitable 5% critical value compatible with their H_1			
A1: for a correct conclusion stated			

Question	Scheme	Marks	AOs
21	$H_0 : \mu = 50.1$ $H_1 : \mu > 50.1$	B1	2.5
	$\bar{X} \sim N\left(50.1, \frac{0.6^2}{15}\right)$ and $\bar{X} > 50.4$	M1	3.3
	$P(\bar{X} > 50.4) = 0.0264$	A1	3.4
	$p = 0.0264 > 0.01$ <u>or</u> $z = 1.936\dots < 2.3263$ and not significant	A1	1.1b
	There is insufficient evidence that the <u>mean length</u> of strips is <u>greater than 50.1</u>	A1	2.2b
		(5)	
(5 marks)			
Question 21 continued			
Notes:			
<p>B1: hypotheses stated correctly</p> <p>M1: for selecting a correct model (stated or implied)</p> <p>1st A1: for use of the correct model to find $p = \text{awrt } 0.0264$ (allow $z = \text{awrt } 1.94$)</p> <p>2nd A1: for a correct calculation, comparison and correct statement</p> <p>3rd A1: for a correct conclusion in context mentioning “mean length” and 50.1</p>			

Question Number	Scheme	Marks
22(a)	$H_0 : p = 0.35 \quad H_1 : p > 0.35$	B1
	$V \sim B(40, 0.35) \quad P(V \geq 18) = 1 - P(V \leq 17)$ or $P(V \geq 19) = 0.0699$	M1
	$= 1 - 0.8761$ $P(V \geq 20) = 0.0363$	
	$= 0.1239$ CR $V \geq 20$	A1
	Accept H_0 or not Significant or 18 does not lie in the critical region	M1d
	There is insufficient evidence that the proportion/amount/number/percentage of customers who bought organic vegetables has increased.	A1cso (5)
(b)	$E \sim B(50, 0.35)$	M1
	$P(E \leq 10) = 0.0160$ $P(E \geq 25) = 0.0207$	
	$P(E \leq 11) = 0.0342$ $P(E \geq 24) = 0.0396$	
	CR $E \leq 10$ $E \geq 25$	A1A1 (3)
(c)	The manager's claim is supported or there is sufficient evidence that the proportion of customers buying organic eggs is different from those buying organic vegetables .	B1ft (1)
(d)	$0.016 + 0.0207 = 0.0367$ or 3.67% awrt 0.0367 or 3.67%	B1 (1)
(e)	$F \sim N(40, 32)$	M1 A1
	$P(F < n) = P\left(Z < \frac{n - 0.5 - 40}{\sqrt{32}}\right)$	M1M1d
	$\frac{n - 0.5 - 40}{\sqrt{32}} = -1.68$	B1
	$n = 31$	A1cso (6)
	Notes	Total 16
(a)	<p>B1 both hypotheses correct with p or π M1 writing or using $V \sim B(40, 0.35)$ and $1 - P(V \leq 17)$ or $P(V \leq 17) = 0.8761$ or awrt 0.124 OR writing $P(V \geq 19) = 0.0699$ or $P(V \geq 20) = 0.0363$ leading to a CR. Implied by correct CR A1 awrt 0.124 or $V \geq 20$ or $V > 19$ allow any letter M1d dep on previous M being awarded. ft their CR or probability. A correct statement – do not allow contradicting non-contextual comments A1 cso all previous marks must be awarded. A correct statement in context. Need Bold words. NB award M1A1 for a correct contextual statement on its own. If there are no hypotheses or they are the wrong way around, then M0A0</p>	
(b)	<p>M1 writing $E \sim B(50, 0.35)$ or a correct probability or one tail of the CR correct A1 $E \leq 10$ oe A1 $E \geq 25$ oe, allow any letter. Condone missing letter NB If CR written as probabilities and both are correct or CR written as $10 \geq E \geq 25$ oe award M1A1A0. If just give CV 10 and 25 given award M1A0A0</p>	
(c)	<p>B1 A correct statement including the words managers claim or eggs and vegetable(s) (or veg) ft their 2 tail CR. Cannot be awarded if no CR given in (b)</p>	
(e)	<p>M1 writing/using normal approximation with mean = 40 A1 writing/using normal approximation with mean = 40 and var = 32 M1 $\pm \left(\frac{(n \text{ or } n - 0.5 \text{ or } n + 0.5) - \text{their mean}}{\text{their sd}} \right)$ if no mean or sd given they must be correct here. M1 dep on previous method mark being awarded. Using continuity correction $n - 0.5$ B1 ± 1.68 A1 31 cso all previous marks must be awarded. NB 31 with no working gains no marks</p>	

Question Number	Scheme		Marks
	Allow any letter instead of X or c for this question		
23 (a)	$X \sim B(25, 0.2)$	M1 Writing or using B(25,0.2) or B(25,1/5) [allow Po(5)] May be written in full or implied by a correct CR (allow written as a probability statement)	M1
	$[P(X \geq 9) =]0.0468$ $[P(X \leq 1) =]0.0274$	1st A1 both awrt 0.0468 and awrt 0.0274 seen.	A1
	$X = [0 \leq] X \leq 1$	2nd A1 $X \leq 1$ or $X < 2$ or $0 \leq X \leq 1$ or $[0,1]$ or 0,1 or equivalent statements. $X \leq c$ and $c = 1$	A1
	$9 \leq X [\leq 25]$	3rd A1d dependent on seeing a probability from the B(25, 0.2) and $X \geq 9$ or $X > 8$ or $9 \leq X \leq 25$ or 9,10,11,12,13,14,15,16,17,18,19,20,21,22, 23,24,25 or $[9,25]$ or equivalent statements. $X \geq c$ and $c = 9$	A1d
NB These two final 2 A marks must be for statements with “X” only(or list) – not in probability statements SC If a probability from the B(25, 0.2) is seen and they either have both CR correct but written as probability statements or the CR is written as $1 \geq X \geq 9$ they get A1 A0 for final 2 marks (4)			
(b)	$H_0: p = 0.2$ $H_1: p < 0.2$	B1 both hypotheses with p or π and clear which is H_0 and which is H_1	B1
	$P(X \leq 6) = 0.1034$ or CR $X \leq 5$	1st M1 writing or using B(50, 0.2) and writing or using $P(X \leq 6)$ or $P(X \geq 7)$ on its own. May be implied by a correct CR 1st A1 awrt 0.103. Allow CR $X \leq 5$ or $X < 6$. or if not using CR allow awrt 0.897.	M1 A1
	Insufficient evidence to reject H_0 , Accept H_0 , Not significant. 6 does not lie in the Critical region.	2nd M1 dependent on previous M being awarded. A correct statement (do not allow if there are contradicting non-contextual statements). ft their Prob/CR compared with $0.05/6/(0.95$ if using 0.8979). Do not follow through their hypotheses	M1d
	No evidence that increasing the batch size has reduced the percentage of broken pots (oe) or evidence that there is no change in the percentage of broken pots (oe)	2nd A1cso Conclusion must contain the words reduced/ no change/not affect oe number/percentage/proportion/ probability oe, and pots . All previous marks must be awarded for this mark to be awarded. Do not allow the potters claim /belief is wrong/true NB Correct contextual statement on its own scores M1A1	A1cso (5)
			(Total 9)

Question Number	Scheme		Marks
24	$H_0: p = 0.05$ $H_1: p > 0.05$	B1: Both hypotheses correct and labelled H_0 and H_1 , must use p or π Do not allow $p(x)$	B1
	$P(R \geq 4) = 1 - P(R \leq 3)$	M1: Writing or using B(50,0.05) AND writing or using $1 - P(R \leq 3)$ or $P(R \leq 3) = 0.7604$ on its own or one of the following 4 statements leading to a CR. $P(R \geq 7) = 0.0118$ $P(R \leq 6) = 0.9882$ $P(R \geq 8) = 0.0032$ $P(R \leq 7) = 0.9968$ May be implied by correct CR. Allow any letter	M1
	= 0.2396 CR $R \geq 8$	A1: awrt 0.240 or 0.24 or $R \geq 8$ oe Or 0.7604	A1
	Insufficient evidence to reject H_0 , Not Significant. Accept H_0 . 4 does not lie in the Critical region.	M1: dependent on the previous M being awarded. A correct statement – do not allow contradictory non contextual statements. Follow through their Probability/CR and H_1 . If no H_1 seen then M0. Ignore their comparison in all cases Then mentally compare their probability as follows: For prob < 0.5 statement must be correct compared to 0.01 for 1 tail test and 0.005 for 2 tailed test. For prob > 0.5 statement must be correct compared to 0.99 for 1 tail test and 0.995 for 2 tailed test. NB: If there is no non-contextual statement given you may award the M1 for a correct contextual statement	M1d
	No evidence to support Patrick's claim. Or no evidence that people in <i>Reddman</i> have a probability greater than 5% of having red hair	A1: cso fully correct solution and correct contextual statement containing the word Patrick if writing about the claim Or red hair if full context	A1cso (5)
		Total 5	

Question Number	Scheme		Marks	
25	$H_0 : p = 0.25$ $H_1 : p < 0.25$	B1: Both hypotheses correct, labelled H_0 or NH or H_n and H_1 or AH or H_a , must use p or $p(x)$ or π	B1	
	B(15, 0.25)	M1: for using B(15, 0.25)	M1 A1	
	$P(X \leq 1) = 0.0802$	A1: awrt 0.0802 or CR $X \leq 1$ (allow $P(X \geq 2) = 0.9198$)		
	NB: Allow M1 A1 for a correct CR with no incorrect working			
Reject H_0 or Significant or 1 lies in the critical region	M1: A correct statement – do not allow contradictory non contextual statements. Follow through their Probability/CR (for 1 or 2 tail test). If no H_1 given then M0. Ignore their comparison. For a probability < 0.5 , statement must be correct compared to 0.1 for 1 tail test and 0.05 for 2 tailed test or if the probability > 0.5 , statement must be correct compared to 0.9 for 1 tail test and 0.95 for 2 tailed test.	dM1 A1cso		
There is evidence that the radio company's claim is true. Or The new transmitter will reduce the proportion of houses unable to receive radio	A1: cso (all previous marks awarded) and a correct statement containing the word company if writing about the claim or radio if full context.			
			Total 5	

Question	Scheme	Marks
26.	$H_0 : p = 0.2$ $H_1 : p < 0.2$ $[X \sim B(40, 0.2)]$ $P(X \leq 3) = 0.0285$ or CR of $X \leq 3$ $[0.0285 < 0.05]$ significant, reject H_0 There is evidence to support the supplier's claim or The probability of a ball failing the bounce test is less than 0.2	B1 M1A1 M1dep A1cso (5)
Notes		
1^{st} B1 for both H_0 and H_1 must use p or π 1^{st} M1 for writing or using $B(40, 0.2)$, may be implied by correct answer 1^{st} A1 awrt 0.0285 or CR of $X \leq 3$ as their final answer 2^{nd} M1 dependent on the previous method mark being awarded. A correct statement (this may be contextual) comparing “their probability” and 0.05 (or comparing 3 with their critical region). Do not allow conflicting statements. 2^{nd} A1cso This is cso so can only be awarded for a fully correct solution. A correct contextualised conclusion (to include the words underlined in bold)		

Question Number	Scheme	Marks
27(a)	$X \sim B(20, 0.25)$ $P(X \geq 10) = 1 - 0.9861 = 0.0139$ $P(X \leq 1) = 0.0243$ $(0 \leq) X \leq 1 \cup 10 \leq X (\leq 20)$	M1 A1 A1 A1A1 (5)
27(b)	$H_0: p = 0.25$ $H_1: p < 0.25$ $X \sim B(20, 0.25)$ $P(X \leq 3) = 0.2252$ or CR $X \leq 1$ Insufficient evidence to reject H_0 , Accept H_0 , Not significant. 3 does not lie in the Critical region. No evidence that the changes to the process have reduced the percentage of defective articles (oe)	B1 M1A1 M1d A1cso (5) Total 10 marks
Notes		
27(a)	M1 using $B(20, 0.25)$ may be implied by a correct CR (allow written as a probability statement) 1 st A1 awrt 0.0139 2 nd A1 awrt 0.0243 3 rd A1 $X \leq 1$ or $0 \leq X \leq 1$ or $[0, 1]$ or $0, 1$ or equivalent statements 4 th A1 $X \geq 10$ or $10 \leq X \leq 20$ or $10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20$ or $[10, 20]$ or equivalent statements NB These two A marks must be for statements with X (any letter) only – not in probability statements and SC for CR written as $1 \geq X \geq 10$ gets A1 A0	
27(b)	B1 both hypotheses with p 1 st M1 using $B(20, 0.25)$ and finding $P(X \leq 3)$ or $P(X \geq 4)$ may be implied by a correct CR 1 st A1 0.2252 (allow 0.7748) if not using CR or CR $X \leq 1$ or $X < 2$ 2 nd M1 dependent on previous M being awarded. A correct statement (do not allow if there are contradicting non contextual statements) A1cso Conclusion must contain the words changes/new process oe, reduced oe number/percentage oe , and defective articles/defectives . There must be no incorrect working seen.	

Question Number	Scheme	Marks
28(a)	A statement concerning a population parameter	B1
(b)	A critical region is the <u>range / set of values / answers</u> or a <u>test statistic</u> or <u>region/area</u> or <u>values</u> (where the test is significant) that would lead to <u>the rejection of H₀ / acceptance of H₁</u>	B1 B1 (3)
(c)	H ₀ : $p = 0.45$ H ₁ : $p < 0.45$ (or $p \neq 0.45$) $X \sim B(20, 0.45)$ $P(X \leq 5) = 0.0553$ CR $X \leq 4$ Accept H ₀ . Not significant. 5 does not lie in the Critical region. There is no evidence that the proportion who voted for <u>Mrs George</u> is not 45% or there is evidence to support <u>Mrs George's</u> claim	M1 A1 M1d A1cso (4)
(d)	B(8, 0.45): $P(0) = 0.0084$ B(7, 0.45): $P(0) = 0.0152$ Hence smallest value of n is 8 Alternative $(0.55)^n < 0.01$ $n \log 0.55 < \log 0.01$ $n > 7.7\dots$ Hence smallest value of n is 8	M1 A1 B1 (3) M1 A1 B1cso
	Notes	Total 10
(a)	It must be a statement including the words population parameter .	
(c)	1 st M1 using B(20, 0.45) and finding $P(X \leq 5)$ or $P(X \geq 6)$ Using the normal approximation to the binomial is M0 A1 0.0553 (allow 0.9447) if not using CR or CR $X \leq 4$ or $X < 5$ 2 nd M1 dependent on previous M being awarded. A correct statement (do not allow if there are contradicting non contextual statements nor award if 2 probabilities are given which would result in different conclusions) A1cso Conclusion must contain the words Mrs George . There must be no incorrect working seen. If there are no hypotheses you cannot award this mark. NB A correct contextual statement on it's own will score M1 A1.	
(d)	M1 Attempt to find $P(0)$ from B(n , 0.45) or $(0.55)^n < 0.01$ or $(0.55)^n = 0.01$ or $(0.55)^n > 0.01$ A1 $P(0) = 0.0084$ and $P(0) = 0.0152$ or getting 7.7 May be implied by correct answer. B1 cso. $n = 8$ should not come from incorrect working. NB An answer of 8 on its own with no working gains M1A1B1	

Question Number	Scheme	Marks
<p>29.(a)</p> <p>(b)</p>	$X \sim B(25, 0.5)$ may be implied by calculations in part a or b $P(X \leq 7) = 0.0216$ $P(X \geq 18) = 0.0216$ $CR X \leq 7; \cup X \geq 18$ $P(\text{rejecting } H_0) = 0.0216 + 0.0216$ $= 0.0432$ awrt 0.0432/0.0433	<p>M1</p> <p>A1, A1 (3)</p> <p>M1</p> <p>A1 (2)</p> <p>Total 5</p>
	Notes	
<p>29(a)</p> <p>(b)</p>	<p>M1 - Using $B(25, 0.5)$ – may be implied by a correct critical region or by calculations in part a or b Note Just seeing either $P(X \leq 7)$ or $P(X \geq 18)$ scores M1 A0 A0. You may need to check their probabilities in the tables for values other than 7 or 18. 1st A1 – also allow $X < 8$ or $[0, 7]$ or $0 \leq X \leq 7$ or $0 \leq X < 8$ oe e.g. $[0, 8)$ or a full list DO NOT allow CRs given as $P(X \leq 7)$ or $7 - 0$ for the A mark. 2nd A1 – also allow $X > 17$ or $[18, 25]$ or $18 \leq X \leq 25$ or $17 < X \leq 25$ oe e.g. $(17, 25]$ or a full list DO NOT allow CRs given as $P(X \geq 18)$ or $18 - 25$ for the A mark. SC $7 \geq X \geq 18$ gains M1 A1 A0.</p> <p>M1 – adding their two critical regions’ probabilities together or may be awarded for awrt 0.0432 If they add their critical regions’ probabilities and then go on and get a different probability as their answer then it is M0A0 e.g. $0.0216 + 0.0216 = 0.0432$ then $0.05 - 0.0432 = 0.0068$ gets M0 A0 e.g. $0.0216 + 0.0216 = 0.0432 < 0.05$ reject H_0 gets M1 A1 e.g. $0.0216 + 0.0216 = 0.0432$ so probability of rejecting H_0 is $1 - 0.0432 = 0.9568$ gets M0 A0</p>	

Question Number	Scheme	Marks
30	$H_0 : p = 0.5$ $H_1 : p > 0.5$ $X \sim B(30, 0.5)$ $P(X \geq 21) = 1 - P(X \leq 20)$ $= 1 - 0.9786$ $= 0.0214$ so significant/reject H_0 /in Critical region Evidence to suggest David's claim is incorrect or The weather forecast produced by the local radio is better than those achieved by tossing/flipping a coin	B1 B1 M1 M1 A1 M1 dep A1 (7)

7

Notes
 1st B1 for $H_0 : p = 0.5$
 2nd B1 for $H_1 : p > 0.5$
 SC If both hypotheses are correct but a different letter to p is used they get B1 B0. If no letter is used they get B0 B0.

1st M1 writing or using $B(30, 0.5)$

One tail

2nd M1 for writing or using $1 - P(X \leq 20)$ or writing $P(X \leq 19) = 0.9506$ or $P(X \geq 20) = 0.0494$. May be implied by correct CR. or probability = 0.0214

A1 for 0.0214 or CR $X \geq 20 / X > 19$. **NB** $P(X \leq 20) = 0.9786$ on its own scores M1A1

3rd M1 dependent on the 2nd M1 being awarded. For a correct statement based on the table below. Do not allow non-contextual conflicting statements eg “significant” and “accept H_0 ”. **Ignore comparisons.**

2nd A1 for a correct contextualised statement. NB A correct contextual statement on its own scores M1A1.

	$0.05 < p < 0.95$	$p < 0.05$ or $p > 0.95$
3 rd M1	not significant/ accept H_0 / Not in CR	significant/ reject H_0 / In CR
2 nd A1	David's claim is correct weather forecast produced by the local radio is no better than those achieved by tossing/flipping a coin	David's claim incorrect weather forecast produced by the local radio is better than those achieved by tossing/flipping a coin

Two tail

1st M1 for writing or using $1 - P(X \leq 20)$ or writing $P(X \leq 20) = 0.9786$ or $P(X \geq 21) = 0.0214$. May be implied by correct CR. or probability = 0.197

A1 for 0.0214 or CR $X \geq 21 / X > 20$. **NB** $P(X \leq 20) = 0.9786$ on its own scores M1A1

3rd M1 dependent on the 2nd M1 being awarded. For a correct statement based on the table below. Do not allow non-contextual conflicting statements eg “significant” and “accept H_0 ”. **Ignore comparisons.**

2nd A1 for a correct contextualised statement. NB A correct contextual statement on its own scores M1A1.

	$0.025 < p < 0.975$	$p < 0.025$ or $p > 0.975$
3 rd M1	not significant/ accept H_0 / Not in CR	significant/ reject H_0 / In CR
2 nd A1	David's claim is correct weather forecast produced by the local radio is no better than those achieved by tossing/flipping a coin	David's claim incorrect weather forecast produced by the local radio is better than those achieved by tossing/flipping a coin

Question Number	Scheme	Marks									
31. (a)	$H_0 : p = 0.15 \quad H_1 : p \neq 0.15$ $X \sim B(30, 0.15)$ $P(X \leq 1) = 0.0480$ or CR: $X = 0$ $(0.0480 > 0.025)$ not a significant result or do not reject H_0 or not in CR there is no evidence of a <u>change</u> in the <u>proportion of customers buying an item from the display</u> .	B1 B1 M1 A1 M1 A1ft (6)									
(b)	$H_0 : p = 0.2 \quad H_1 : p > 0.2$ Let S = the number who buy sandwiches, $S \sim B(120, 0.2)$, $S \approx W \sim N\left(24, \sqrt{19.2}^2\right)$ $P(S \geq 31) = P(W \geq 30.5)$ $= P\left(Z > \frac{30.5 - 24}{\sqrt{19.2}}\right)$ or $\frac{x - 0.5 - 24}{\sqrt{19.2}} = 1.2816$ $[= P(Z > 1.48..)]$ $= 1 - 0.9306$ $= 0.0694$ $x = 30.1$ < 0.10 so a significant result, there is evidence that more customers are purchasing sandwiches or the shopkeepers claim is correct.	B1 M1 A1 M1 M1 M1 A1 B1ft (8)									
Notes:		14									
(a)	<p>1st B1 for H_0 must use p 2nd B1 for H_1 must use p 1st M1 for writing or using $B(30, 0.15)$ – may be implied by correct CR 1st A1 0.0480 or $X = 0$. Allow $X \leq 0$. Ignore upper CR. NB Allow CR $X \leq 1$ if using one tail test. 2nd M1 A correct statement (see table below) Do not allow non-contextual conflicting statements eg “significant” and “accept H_0”. Ignore comparisons 2nd A1 for a correct statement in context. For context we need idea of <u>change/decrease in number of customers buying from display</u> – may use different words. NB A correct contextual statement on its own scores M1A1</p> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th></th> <th>Two tail $0.025 < p < 0.975$ or One tail $0.05 < p < 0.95$</th> <th>Two tail $p < 0.025$ or $p > 0.975$ or One tail $p < 0.05$ or $p > 0.95$</th> </tr> </thead> <tbody> <tr> <td>2nd M1</td> <td>not significant/ accept H_0/ Not in CR or contextual</td> <td>significant/ reject H_0/ In CR or contextual</td> </tr> <tr> <td>2nd A1</td> <td>There is no evidence of a <u>change/decrease</u> in the <u>proportion of customers</u> buying an item from the <u>display</u></td> <td>There is evidence of a <u>change/decrease</u> in the <u>proportion of customers</u> buying an item from the <u>display</u>.</td> </tr> </tbody> </table>			Two tail $0.025 < p < 0.975$ or One tail $0.05 < p < 0.95$	Two tail $p < 0.025$ or $p > 0.975$ or One tail $p < 0.05$ or $p > 0.95$	2 nd M1	not significant/ accept H_0 / Not in CR or contextual	significant/ reject H_0 / In CR or contextual	2 nd A1	There is no evidence of a <u>change/decrease</u> in the <u>proportion of customers</u> buying an item from the <u>display</u>	There is evidence of a <u>change/decrease</u> in the <u>proportion of customers</u> buying an item from the <u>display</u> .
	Two tail $0.025 < p < 0.975$ or One tail $0.05 < p < 0.95$	Two tail $p < 0.025$ or $p > 0.975$ or One tail $p < 0.05$ or $p > 0.95$									
2 nd M1	not significant/ accept H_0 / Not in CR or contextual	significant/ reject H_0 / In CR or contextual									
2 nd A1	There is no evidence of a <u>change/decrease</u> in the <u>proportion of customers</u> buying an item from the <u>display</u>	There is evidence of a <u>change/decrease</u> in the <u>proportion of customers</u> buying an item from the <u>display</u> .									
(b)	<p>1st B1 both hypotheses correct – must use p. 1st M1 for a normal approx 1st A1 for correct mean and sd 2nd M1 for use of continuity correction, either 30.5 or 31.5 or $(x \pm 0.5)$ seen 3rd M1 standardising with their mean and their sd and 30.5, 31 or 31.5 or x or $(x \pm 0.5)$ 4th M1 for 1 - tables value or 1.2816 2nd A1 for awrt 0.069 or $x = 30.1$ 2nd B1ft For a correct conclusion in context using their probability and 0.1 For context we need idea of <u>more customers buying sandwiches</u> – may use different words</p>										

	One tail $0.1 < p < 0.9$ or Two tail $0.05 < p < 0.95$	One tail $p < 0.1$ or $p > 0.9$ or Two tail $p < 0.05$ or $p > 0.95$
2 nd M1	not significant/ accept H_0 / Not in CR or contextual	significant/ reject H_0 / In CR or contextual
2 nd A1	There is no evidence of an increase in the proportion of customers buying sandwiches	There is evidence of a change/increase in the proportion of customers buying sandwiches.
SC using $P(X < 31.5) - P(X < 30.5)$ can get B1M1 A1 M1 M1M0A0B0		

Question Number	Scheme	Marks
32.	$H_0 : p = 0.2 \quad H_1 : p > 0.2$ Under H_0 , $X \sim \text{Bin}(10, 0.2)$ $P(X \geq 4) = 1 - P(X \leq 3) \quad \text{OR} \quad P(X \leq 4) = 0.9672$ $= 1 - 0.8791 \quad P(X \geq 5) = 0.0328$ $= 0.1209 \quad \text{CR } X \geq 5$ $0.1209 > 0.05$. Insufficient evidence to reject H_0 so teacher's claim is supported.	B1 B1 M1 A1 M1A1ft [6]
Notes		
<p>B1 for both H_0 and H_1 correct. Must use p or π (pi)</p> <p>B1 for writing or using $\text{Bin}(10, 0.2)$</p> <p>M1 for finding or writing $1 - P(X \leq 3)$ or $P(X \leq 4) = 0.9672$</p> <p>$P(X \geq 5) = 0.0328$ or a correct critical region</p> <p>A1 awrt 0.121 or $\text{CR } X \geq 5$</p> <p>M1 need $p < 0.5$ and: correct statement using their Probability and 0.05 if one tail test or correct statement using their Probability and 0.025 if two tail test (condone a comparison with 0.05 instead of 0.025 for a two tail test).</p> <p>Do not allow non-contextual conflicting statements eg "significant" and "accept H_0"</p> <p>A1ft correct contextual statement followed through from "their prob".</p> <p>Either a comment on whether the teacher's claim was correct or on whether the student was guessing the answers.</p> <p>NB if a correct contextual statement only is given for their probability then award M1 A1</p> <p>If $p > 0.5$ They may compare with 0.95 (one tail method) or 0.975 (two tail method) Probability is 0.8791.</p>		

Question Number	Scheme	Marks
33 (a)	2 outcomes/faulty or not faulty/success or fail A constant probability Independence Fixed number of trials (fixed n)	B1 B1 (2)
(b)	$X \sim B(50, 0.25)$ $P(X \leq 6) = 0.0194$ $P(X \leq 7) = 0.0453$ $P(X \geq 18) = 0.0551$ $P(X \geq 19) = 0.0287$ CR $X \leq 6$ and $X \geq 19$	M1 A1 A1 (3)
(c)	$0.0194 + 0.0287 = 0.0481$	M1A1 (2)
(d)	8(It) is not in the Critical region or 8(It) is not significant or $0.0916 > 0.025$; There is evidence that the probability of a faulty bolt is 0.25 or the company's claim is correct.	M1; A1ft (2)
(e)	$H_0 : p = 0.25 \quad H_1 : p < 0.25$ $P(X \leq 5) = 0.0070$ or CR $X \leq 5$ $0.007 < 0.01$, 5 is in the critical region, reject H_0 , significant. There is evidence that the probability of faulty bolts has decreased	B1B1 M1A1 M1 A1ft (6) [15]
(a)	Notes	
(b)	B1 B1 one mark for each of any of the four statements. Give first B1 if only one correct statement given. No context needed.	
(c)	M1 for writing or using $B(50, 0.25)$ also may be implied by both CR being correct. Condone use of P in critical region for the method mark. A1 $(X) \leq 6$ o.e. $[0, 6]$ DO NOT accept $P(X \leq 6)$ A1 $(X) \geq 19$ o.e. $[19, 50]$ DO NOT accept $P(X \geq 19)$	
(d)	M1 Adding two probabilities for two tails. Both probabilities must be less than 0.5 A1 awrt 0.0481	
(e)	M1 one of the given statements followed through from their CR. A1 contextual comment followed through from their CR. NB A correct contextual comment alone followed through from their CR will get M1 A1	
	B1 for H_0 must use p or π (π) B1 for H_1 must use p or π (π) M1 for finding or writing $P(X \leq 5)$ or attempting to find a critical region or a correct critical region A1 awrt 0.007/CR $X \leq 5$ M1 correct statement using their Probability and 0.01 if one tail test or a correct statement using their Probability and 0.005 if two tail test. The 0.01 or 0.005 needn't be explicitly seen but implied by correct statement compatible with their H_1 . If no H_1 given M0 A1 correct contextual statement follow through from their prob and H_1 . Need faulty bolts and decreased. NB A correct contextual statement alone followed through from their prob and H_1 get M1 A1	

Question Number	Scheme	Marks
34	<p>(a) The set of values of the test statistic for which the null hypothesis is rejected in a hypothesis test.</p> <p>(b) $X \sim B(30, 0.3)$ $P(X \leq 3) = 0.0093$ $P(X \leq 2) = 0.0021$ $P(X \geq 16) = 1 - 0.9936 = 0.0064$ $P(X \geq 17) = 1 - 0.9979 = 0.0021$ Critical region is $(0 \leq) x \leq 2$ or $16 \leq x (\leq 30)$</p> <p>(c) Actual significance level $0.0021 + 0.0064 = 0.0085$ or 0.85%</p> <p>(d) 15 (it) is not in the critical region not significant No significant evidence of a change in $p = 0.3$ accept H_0, (reject H_1) $P(x \geq 15) = 0.0169$</p>	<p>B1 B1 (2) M1 A1 A1 A1A1 (5) B1 (1) Bft 2, 1, 0 (2) Total [10]</p>
34	<p>Notes</p> <p>(a) 1st B1 for “values/ numbers” 2nd B1 for “reject the null hypothesis” o.e or the test is significant</p> <p>(b) M1 for using $B(30, 0.3)$ 1st A1 $P(x \leq 2) = 0.0021$ 2nd A1 0.0064 3rd A1 for $(X) \leq 2$ or $(X) < 3$ They get A0 if they write $P(X \leq 2/ X < 3)$ 4th A1 $(X) \geq 16$ or $(X) > 15$ They get A0 if they write $P(X \geq 16 X > 15)$ NB these are B1 B1 but mark as A1 A1</p> <p>$16 \leq X \leq 2$ etc is accepted To describe the critical regions they can use any letter or no letter at all. It does not have to be X.</p> <p>(c) B1 correct answer only</p> <p>(d) Follow through 15 and their critical region B1 for any one of the 5 correct statements up to a maximum of B2 – B1 for any incorrect statements</p>	

Question Number	Scheme	Marks
35 (a)	$X \sim B(20, 0.3)$ $P(X \leq 9) = 0.9520$ so $P(X \leq 2) = 0.0355$ $P(X \geq 10) = 0.0480$ Therefore the critical region is $\{X \leq 2\} \cup \{X \geq 10\}$	M1 A1 A1 A1A1 (5)
(b)	$0.0355 + 0.0480 = 0.0835$ awrt (0.083 or 0.084)	B1 (1)
(c)	11 is in the critical region there is evidence of a <u>change/ increase</u> in the <u>proportion/number</u> of <u>customers buying single tins</u>	B1ft B1ft (2)
(a)	M1 for B(20,0.3) seen or used 1 st A1 for 0.0355 2 nd A1 for 0.048 3 rd A1 for $(X) \leq 2$ or $(X) < 3$ or $[0,2]$ They get A0 if they write $P(X \leq 2/ X < 3)$ 4 th A1 $(X) \geq 10$ or $(X) > 9$ or $[10,20]$ They get A0 if they write $P(X \geq 10/ X > 9)$ $10 \leq X \leq 2$ etc is accepted To describe the critical regions they can use any letter or no letter at all. It does not have to be X .	
(b)	B1 correct answer only	
(c)	1 st B1 for a correct statement about 11 and their critical region. 2 nd B1 for a correct comment in context consistent with their CR and the value 11 Alternative solution 1 st B0 $P(X \geq 11) = 1 - 0.9829 = 0.0171$ since no comment about the critical region 2 nd B1 a correct contextual statement.	

Question Number	Scheme	Marks
36	<p>(a) $X \sim B(20, 0.3)$</p> <p>$P(X \leq 2) = 0.0355$</p> <p>$P(X \geq 11) = 1 - 0.9829 = 0.0171$</p> <p>Critical region is $(X \leq 2) \cup (X \geq 11)$</p> <p>(b) Significance level = $0.0355 + 0.0171, = 0.0526$ or 5.26%</p> <p>(c) Insufficient evidence to reject H_0 Or sufficient evidence to accept H_0/not significant $x = 3$ (or the value) is not in the critical region or $0.1071 > 0.025$</p> <p>Do not allow inconsistent comments</p>	<p>M1</p> <p>A1 A1 (3)</p> <p>M1 A1 (2)</p> <p>B1 ft</p> <p>B1 ft (2)</p> <p>[7]</p>

Question Number	Scheme	Marks									
37(a)	$X \sim B(15, 0.5)$	B1 B1 (2)									
(b)	$P(X=8) = P(X \leq 8) - P(X \leq 7) \text{ or } \left(\frac{15!}{8!7!} (p)^8 (1-p)^7 \right)$ $= 0.6964 - 0.5$ $= 0.1964$	M1 A1 (2) awrt 0.196									
(c)	$P(X \geq 4) = 1 - P(X \leq 3)$ $= 1 - 0.0176$ $= 0.9824$	M1 A1 (2)									
(d)	$H_0 : p = 0.5$ $H_1 : p > 0.5$ $X \sim B(15, 0.5)$ <table border="0" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 30%; border-right: 1px solid black; padding-right: 10px;"> $P(X \geq 13) = 1 - P(X \leq 12)$ $= 1 - 0.9963$ $= 0.0037$ </td> <td style="width: 40%; padding-left: 10px;"> $[P(X \geq 12) = 1 - 0.9824 = 0.0176] \text{ att } P(X \geq 13)$ $P(X \geq 13) = 1 - 0.9963 = 0.0037$ </td> <td style="width: 30%; padding-left: 10px;"> </td> </tr> <tr> <td style="border-right: 1px solid black; padding-right: 10px;">$0.0037 < 0.01$</td> <td style="padding-left: 10px;">$CR X \geq 13$</td> <td style="padding-left: 10px;">awrt 0.0037/ $CR X \geq 13$</td> </tr> <tr> <td colspan="3" style="padding-top: 10px;">$13 \geq 13$</td> </tr> </table> <p>Reject H_0 or it is significant or a correct statement in context from their values</p> <p>There is sufficient evidence at the 1% significance level that the coin is <u>biased in favour of heads</u></p> <p>Or</p> <p>There is evidence that Sues belief is correct</p>	$P(X \geq 13) = 1 - P(X \leq 12)$ $= 1 - 0.9963$ $= 0.0037$	$[P(X \geq 12) = 1 - 0.9824 = 0.0176] \text{ att } P(X \geq 13)$ $P(X \geq 13) = 1 - 0.9963 = 0.0037$		$0.0037 < 0.01$	$CR X \geq 13$	awrt 0.0037/ $CR X \geq 13$	$13 \geq 13$			B1 B1 M1 A1 M1 A1 (6) [12]
$P(X \geq 13) = 1 - P(X \leq 12)$ $= 1 - 0.9963$ $= 0.0037$	$[P(X \geq 12) = 1 - 0.9824 = 0.0176] \text{ att } P(X \geq 13)$ $P(X \geq 13) = 1 - 0.9963 = 0.0037$										
$0.0037 < 0.01$	$CR X \geq 13$	awrt 0.0037/ $CR X \geq 13$									
$13 \geq 13$											
	<p><u>Notes</u></p> <p>(a) B1 for Binomial B1 for 15 and 0.5 must be in part a This need not be in the form written</p> <p>(b) M1 attempt to find $P(X=8)$ any method. Any value of p A1 awrt 0.196 Answer only full marks</p> <p>(c) M1 for $1 - P(X \leq 3)$. A1 awrt 0.982</p>										

(d) B1 for correct H_0 . must use p or π
B1 for correct H_1 must be one tail must use p or π
M1 attempt to find $P(X \geq 13)$ correctly. E.g. $1 - P(X \leq 12)$
A1 correct probability or CR

To get the next 2 marks the null hypothesis must state or imply that $(p) = 0.5$

M1 for correct statement based on their probability or critical region or a correct contextualised statement that implies that. not just 13 is in the critical region.

A1 This depends on their M1 being awarded for rejecting H_0 . Conclusion in context. Must use the words biased in favour of heads or biased against tails or sues belief is correct .

NB this is a B mark on EPEN.

They may also attempt to find $P(X < 13) = 0.9963$ and compare with 0.99

Question Number	Scheme	Marks
38	<p>$H_0 : p = 0.3; H_1 : p > 0.3$</p> <p>Let X represent the number of tomatoes greater than 4 cm : $X \sim B(40, 0.3)$</p> <p>$P(X \geq 18) = 1 - P(X \leq 17)$ $P(X \geq 18) = 1 - P(X \leq 17) = 0.0320$ $= 0.0320$ $P(X \geq 17) = 1 - P(X \leq 16) = 0.0633$ CR $X \geq 18$</p> <p>$0.0320 < 0.05$ $18 \geq 18$ or 18 in the critical region</p> <p>no evidence to Reject H_0 or it is significant</p> <p>New fertiliser has <u>increased</u> the probability of a <u>tomato</u> being greater than 4 cm Or Dhriti's claim is true</p>	<p>B1 B1</p> <p>B1</p> <p>M1</p> <p>A1</p> <p>M1</p> <p>B1d cao (7)</p>
38	<p>B1 for correct H_0 . must use p or pi</p> <p>B1 for correct H_1 must use p and be one tail.</p> <p>B1 using B(40, 0.3). This may be implied by their calculation</p> <p>M1 attempt to find $1 - P(X \leq 17)$ or get a correct probability. For CR method must attempt to find $P(X \geq 18)$ or give the correct critical region</p> <p>A1 awrt 0.032 or correct CR.</p> <p>M1 correct statement based on their probability , H_1 and 0.05 or a correct contextualised statement that implies that.</p> <p>B1 this is not a follow through .conclusion in context. Must use the words increased, tomato and some reference to size or diameter. This is dependent on them getting the previous M1</p> <p>If they do a two tail test they may get B1 B0 B1 M1 A1 M1 B0 For the second M1 they must have accept H_0 or it is not significant or a correct contextualised statement that implies that.</p>	