A-Level

Topic : Discrete , Continuous Hypothesis and Types of Error

May 2013–May 2025

Answers

Question 1

Assume shots independent OR prob of scoring constant	B1		In context
H_0: P(score) = 0.82 H_1: P(score) > 0.82	B1		Both. Allow 'p'
$20 \times 0.82^{19} \times 0.18 + 0.82^{20}$ = 0.102 (3 sf) No evidence that improved	M1 A1 B1f	 5	For use of Bin(20,0.82)and either P(19) and/or P(20) attempted Valid comparison seen (with 0.05 if H_1 $p \neq 0.82$) and correct conclusion ft numerical errors in 0.102 only Normal approx'n: B1 B1 ($\mu = 16.4$ acceptable here) if earned, then: CR = 1.222 (from $\frac{18.5 - 20 \times 0.82}{\sqrt{20 \times 0.82 \times (1-0.82)}}$, need cc) comp $z = 1.282$ No evidence that improved SC 1 Same scheme for proportions
	[Total: 5]		

Question 2

(i)	Assume sd unchanged or 4500	B1		
	H_0: Pop mean = 34600 H_1: Pop mean > 34600	B1		Both. Allow just μ, but not just "mean"
	$\dfrac{35400-34600}{\frac{4500}{\sqrt{90}}}$	M1		Allow without $\sqrt{90}$
	= 1.687/1.686 (1.69)	A1		
	cf 1.645 < 1.686	M1		Valid comparison (or 0.0458/0.0459 <0.05 or 35380 < 35400 or 34600 < 34620)
	Evidence that mean wkly profit has increased	A1 f	6	If H_1: $\neq$, and 1.96 used, max B1B0M1A1M1A1f No contradictions
(ii)	Distr'n of X unknown.	B1*		Allow not Normal
	Yes	B1* dep	2	
(iii)	0.05 or 5 %	B1	1	
(iv)	$\dfrac{a-34600}{\frac{4500}{\sqrt{90}}} = 1.645$	M1		Attempt to find cv must see (+) 1.645 allow without $\sqrt{90}$. If found in (i) award when used
	$a = 35380$	A1		
	$\dfrac{35380-36500}{\frac{4500}{\sqrt{90}}}$ $(= -2.361)$	M1		Standardising with their " CV " must use $\sqrt{90}$
	$1 - \Phi$('2.361')	M1		
	= 0.0091	A1	6	Correct tail
		[Total: 14]		

Question 3

(i)	$\dfrac{73.1-75.2}{\frac{5.7}{\sqrt{n}}} = -1.563$	M1	For standardising (with $\sqrt{n}$)
	$n = \{-1.563\times5.7\div(-2.1)\}^2$	A1	Any correct expression for n or $\sqrt{n}$. May be implied by ans.
	$n = 18$	A1	
	Assume s.d. for the region is 5.7	B1 [4]	
(ii)	H_0: pop mean (or μ) = 75.2 H_0: pop mean (or μ) < 75.2	B1	Both (could be stated in (i))
	1.563 comp 1.555	M1	For comparison of z values / areas / x values
	Evidence that plants shorter	A1 [3]	CWO. No contradictions
		[Total: 7]	

Question 4

(i)	H_0: Pop mean (or λ or μ) is 5.3 H_1: Pop mean (or λ or μ) is less than 5.3	B1	Both
	$P(X \le 1) = e^{-5.3}(1 + 5.3)$ $P(X \le 2) = e^{-5.3}(1 + 5.3 + \frac{5.3^2}{2})$/P(X=2)	M1	Both attempted
	$P(X \le 1) = 0.0314$ or 0.0315 & $P(X \le 2) = 0.102$/ P(X=2)=0.7071	A1	Both correct
	CR is 0 or 1 cases	A1	Dep. M1 and $P(X \le 1) < 0.05 < P(X \le 2)$
	No evidence mean has decreased	B1f [5]	ft their CR
(ii)	Concluding mean has decreased when it hasn't	B1	In context
	'0.0314 or 0.0315'	B1ft[2]	ft their $P(X \le 1)$, dep. < 0.05
(iii)	(Po(18.4)) N(18.4, 18.4)	B1 B1ft	Stated or implied B1 for N(18.4, ..); B1f for var. = 18.4
	$\frac{20.5-18.4}{\sqrt{18.4}}$ (= 0.490)	M1	For standardising with or without cc.Allow without √
	$1 - \Phi$('0.490')	M1	Use of tables and attempt to find area consistent with their working
	= 0.312 (3 s.f.)	A1 [5]	
		[Total: 12]	

Question 5

(i)	Conclude die is biased when it isn't oe	B1	In context
	${}^5C_3\left(\frac{1}{6}\right)^3\left(\frac{5}{6}\right)^2 + 5\left(\frac{1}{6}\right)^4\left(\frac{5}{6}\right) + \left(\frac{1}{6}\right)^5 + 5$	M1	or $1 - \left({}^5C_2\left(\frac{1}{6}\right)^2\left(\frac{5}{6}\right)3 + 5\left(\frac{1}{6}\right)\left(\frac{5}{6}\right)^4 + \left(\frac{5}{6}\right)^5\right)$
	$= \frac{23}{648}$ or 0.0355 (3 sf)	A1 [3]	allow 1 end error
(ii)	State or attempt P(0, 1, 2) with $p = \frac{2}{3}$	M1	Or 1– P(3,4,5)
	${}^5C_2\left(\frac{2}{3}\right)^2\left(\frac{1}{3}\right)^3 + 5\left(\frac{2}{3}\right)\left(\frac{1}{3}\right)^4 + \left(\frac{1}{3}\right)^5$	M1	Attempt at correct expression
	$= \frac{17}{81}$ or 0.210 (3 sf)	A1 [3]	Allow 0.21
(iii)	Est Var(P_s) = $\frac{0.625 \times (1-0.625)}{80}$	M1	
	$(= \frac{3}{1024})$		
	$z = 2.054$ (or 2.055)	B1	
	$0.625 \pm z \times \sqrt{\frac{'3'}{1024}}$	M1	Any z
	= 0.514 to 0.736 (3 sf)	A1 [4]	

Question 6

H_0: Pop mean = 17 H_1: Pop mean $\neq$ 17	B1	Both correct. Allow μ, but not just "mean"	
$\dfrac{18.2-17}{\frac{2.4}{\sqrt{5}}}$	M1	Allow incorrect 18.2. Must have $\sqrt{5}$	$17 \pm 1.96\,\dfrac{2.4}{\sqrt{5}}$ M1
= 1.12 (3 sf)	A1		= (14.9, 19.1) A1
'1.12' < 1.96 oe	M1	Comp '1.12' with 1.96 or area '0.132' with 0.025	'14.9'<18.2<'19.1' M1
Claim can be accepted	A1ft	ft their '1.12'	
	[5]	If H_1: $\mu > 17$ and cf 1.645: can score max B0M1A1M1A1ft	

Question 7

(i)	E (X)= 3.5 $(1^2+2^2+3^2+4^2+5^2+6^2) \div 6 -$ "3.5"^{2} $(=\frac{35}{12}$ **AG**)	**B1** **B1**	**2**	21/6 oe, must see correct expression and no incorrect working
(ii)	Attempt P $(X < 3)$ or $1 - P(X \geq 3)$	**M1**		seen or implied
	N $(3.5, \frac{35}{12}/50)$	**M1**		seen or implied
	$\dfrac{3-\text{"3.5"}}{\sqrt{\frac{35}{12}/50}}$ $(= -2.070)$	**M1**		or $\dfrac{2.99-\text{"3.5"}}{\sqrt{\frac{35}{12}/50}}$ $(= -2.111)$
	Φ ("–2.070") = 1 – Φ("2.070") = 0.0192	**M1**		Φ ('–2.111') = 1 – Φ ('2.111') = 0.0174 or 0.0173 Consistent area
	as final answer	**A1**	**5**	As final answer or valid total method Allow with incorrect cc (e.g. 2.5) OR no $\sqrt{}$.Must have ÷50
(iii)	Die is biased (towards lower numbers)	**B1 indep**		Comment implying die is biased
	Mean of 50 throws $\geq$ 3 (Allow > 3) or Equal nos of high and low scores or More high scores	**B1 indep**	**2**	Comment implying results of exp't do not indicate bias (or indicate bias towards higher numbers) Both must be in context

Question 8

(i)	Assume sd unchanged or sd = 10.4	B1		Oe e.g. var unchanged
	H_0: Pop mean speed (or μ) = 62.3 H_1: Pop mean speed (or μ) < 62.3	B1		Both. Not just "Mean . . "
	$\frac{59.9-62.3}{\frac{10.4}{\sqrt{75}}}$	M1		Accept sd/var mixes, but must have $\sqrt{75}$
	= – 1.999 or – 2.00 (allow + or –)	A1		Correct z value (or correct critical value)
	Compare – 2.054 or –2.055	M1		Valid comparison of z`s/areas/critical values
	No evidence that mean speed decreased	A1 ft	6	No contradictions. Do not ft 2-tail test.
(ii)	Pop distribution unknown	B1		
	Yes	B1	2	

Question 9

(i)	P(Type I) = 1 - P($\geq$ 4 assuming p = 0.7)	M1		or P($\leq$ 3 assuming p = 0.7) May be implied
	$1-({}^6C_4 \times 0.7^4 \times 0.3^2 + {}^6C_5 \times 0.7^5 \times 0.3 + 0.7^6)$	M1		${}^6C_3 \times 0.7^3 \times 0.3^3 + {}^6C_2 \times 0.7^2 \times 0.3^4 + {}^6C_1 \times 0.7 \times 0.3^5 + 0.3^6$
	(= 1 – 0.744)			Allow one end error
	= 0.256 (3 s.f.)	A1	[3]	= 0.256 (3 s.f.) SR if zero scored allow B1 for use of B(6, 0.7) in any two or more terms
(ii)	P(Type II) = P($\geqslant$ 4 assuming p = 0.35)	M1		May be implied
	$= {}^6C_4 \times 0.35^4 \times 0.65^2 + {}^6C_5 \times 0.35^5 \times 0.65 + 0.35^6$	M1		Allow one end error
	= 0.117	A1	[3]	SR if zero scored allow B1 for use of B(6, 0.35) in any two or more terms
(iii)	Type 1	B1		
	They will reject Luigi's belief, although it might be true.	B1	[2]	In context

Question 10

(i)	H_0: $p = 0.2$ H_1: $p < 0.2$	B1	(Allow π)
	P(0 or 1 5s in 25 | H_0)	M1	$0.8^{25} + 25 \times 0.8^{24} \times 0.2$ Use of B(25,1/5) and P(0) or P(1) or both – may be implied by "0.0274"
	= 0.0274 (3 s.f.)	A1	
	Comp with 0.025	M1	Valid comparison
	No evidence (at 2.5% level) to support claim	A1√ [5]	No contradictions **SR** Use of Normal N(5,4) leading to $z = 1.75$ or 0.0401 **B1*** H_0 $\mu = 5$ H_1 $\mu < 5$ B1. Comparison $1.75 < 1.96$ or $0.0401 > 0.025$ **B1* dep**
(ii)	Normal	B1	
	$\mu = 200$, $\sigma^2 = 160$ or $\sigma = \sqrt{160}$	B1 [2]	
(iii)	Concluding that the machine produces the right proportion of 5s, although it doesn't.	B1 [1]	Not concluding that the machine produces too few 5s although it does. Must be in context o.e. No contradictions

Question 11

$\bar{x} = 1.65$	B1	
$\text{est}(\sigma^2) = \frac{100}{99}\left(\frac{276.25}{100} - 1.65^2\right)$	B1	
$= 0.040404\ldots = 4/99$		
$(\pm)\frac{1.65 - 1.6}{\sqrt{\frac{"0.040404"}{100}}}$	M1	Without $\frac{100}{99}$: $\frac{1.65 - 1.6}{\sqrt{\frac{"0.04"}{100}}}$ B1 B0 M1
= (±) 2.487/2.488 accept 2.49 Or 0.0065/0.0064 if area comparison done	A1	= 2.50 A1 CV Method M1 must use 1.96 A1 for 1.639 or 1.6106
comp with 1.96	M1	For valid comparison (z/z Signs consistent or area/area cv)
There is evidence that μ is not 1.6	A1√ [6]	Accept Reject H_0 No contradictions

Question 12

(i)	2^{nd}	B1			
	More representative of all appointments or Lengths may vary during the day or 1^{st} does not include later appts so not representative	B1	[2]	Any implication that times or conditions vary throughout day, e.g. doctors get tired	
(ii)	0.01 o.e.	B1			
	Concluding that times spent are too long when they are not.	B1	[2]	Concluding that the mean time spent is more than 10 mins when it is not. Must be in context.	
(iii)	H_0: Pop mean appt time (or μ) = 10 H_1: Pop mean appt time (or μ) > 10	B1		Both correct. Allow μ, but not just "mean"	
	$\dfrac{\frac{147}{12}-10}{\frac{3.4}{\sqrt{12}}}$ (±)	M1		Allow incorrect $\frac{147}{12}$ Must have √12 (accept totals method)	$10+2.326\times\frac{3.4}{\sqrt{12}}$ M1 = 12.28 A1
	= (±)2.292 or (0.0109 if area comparison done)	A1			
	"2.292" < 2.326 o.e.	M1		For valid comparison Comp "2.292" with 2.326 Or 0.0109 with 0.01 Or 147/12 with 12.28	$\frac{147}{12}$ < 12.28 M1
	(No evidence to reject H_0.) No reason to believe appts are too long	A1√	[5]	Dep 2.326, ft their "2.292" No contradictions	
(iv)	Normal population	B1	[1]	Must have "population" or equiv	

Question 13

H_0: Pop mean (or μ or λ) = 50 (or 5)			
H_1: Pop mean (or μ or λ) ≠ 50 (or 5)	B1		Not just "mean"
$\dfrac{60.5-50}{\sqrt{50}}$ (±)	M1		For standardising with N(50,50) or N(5,5/√10)
= (±)1.485 OR 0.0687 OR C.V	A1		Allow M1 with wrong or no continuity correction OR no √ (accept c.v method M1, A1 for 61.63 or 48.868)
1.485 < 1.645 or 0.0687 > 0.05 No evidence that mean changed	M1 A1√	[5]	For valid comparison (zs or areas or cv) (S.R For cv comparison 61.63 only award final A1 if cc used) or if H_1: λ > 50, 1.485 < 1.96 M1 No evid mean changed A0 (i.e. if one-tail test, max B0 M1 A1 M1 A0)

Question 14

(i)	H_0: Rate = 0.9 H_1: Rate < 0.9 1 – P(17, 18, 19, 20)	 B1 M1	p = 0.9 p < 0.9 Use of B(20,0.1)
	$1 - ({}^{20}C_{17} \times 0.1^3 \times 0.9^{17} + {}^{20}C_{18} \times 0.1^2 \times 0.9^{18} + 20 \times 0.1 \times 0.9^{19} + 0.9^{20})$ = 0.133 (3 sf)	M1 A1 [4]	Allow 1–P(18,19,20) or 1–P(16,17,18,19,20)
(ii)	Type II H_0 will not be rejected	B1 B1 [2]	 or Stephan will conclude standard not fallen No contradictions
		[Total: 6]	

Question 15

	H_0: $\mu = 250$ H_1: $\mu > 250$	 B1	 Both hypotheses
	$\dfrac{250.06-250}{0.2 \div \sqrt{40}}$	M1 A1	M1 for standardising, must have √40. Accept cv method
	= 1.90 comp with $z = 1.645$ Claim is justified or There is evidence that claim is true	 M1 A1√ [5]	 For valid comparison "1.90" with 1.645 or area comparison or CVs Correct conclusion. No contradictions NB 2-tail test scores B0 M1 A1 M1 (use 1.96) A0
		[Total: 5]	

Question 16

(i)	H_0: population proportion = 0.1 oe H_1: population proportion > 0.1 oe	**B1**		Allow "$p = 0.1$" and "$p > 0.1$"
	$P(X \geqslant 4) = 1 - P(X \leqslant 3) =$ $1 - \left(0.9^{18} + 18 \times 0.9^{17} \times 0.1 + {}^{18}C_2 \times 0.9^{16} \times 0.1^2 + {}^{18}C_3 \times 0.9^{15} \times 0.1^3 \right)$	**M1**		Allow 1 – (one term omitted or extra or wrong)
	= 0.0982 (3 sf)	**A1**		(note CR method 0.0982 and CR ⩾ 5 for A1)
	Comp 0.08	**M1**		Valid comparison (0.9018 < 0.92 also recovered previous A1). Or 4 is not in CR
	No evidence that more reach 1m	**A1√**	**[5]**	Dep M1M1 no contraditions "Accept H_0" provided H_0 defined
(ii)	Not rejected H_0 Type II	**B1√** **B1dep √**	**[2]**	Ft their (i) If (i) "reject H_0" then ft gives Type I error
(iii)	$P(X \geqslant 5)$ $(= 0.0282)$ 0.0282 < 0.08	**M1** **B1√**		Attempt $P(X \geqslant 5)$ e.g. '0.0982' – ${}^{18}C_4 \times 0.9^{14} \times 0.1^4$ oe. Valid comp of their ⩾ 5 (if CR method used, could be awarded in (i))
	P(Type I error) = 0.0282 (3 sf)	**A1**	**[3]**	

Question 17

(i)	"Different" being investigated	**B1**	**[1]**	Oe ("changed", "not equal to")
(ii)	H_0: Pop mean (or μ) in region same as elsewhere			Must be "pop mean", not just "mean" Can be awarded in (i)
	H_1: Pop mean (or μ) in region diff from elsewhere	**B1**		oe
	1.91 < 2.054 (or 2.055) or –1.91 > –2.054	**M1**		or P(z > 1.91) = 0.0281 > 0.02 or 0.0562 > 0.04 or 0.972 < 0.98 Accept 2.05 if nothing better seen.
	No evidence that mean is different	**A1**	**[3]**	inequality sign incorrect M1A0 no contradictions "accept H_0" provided H_0 reasonably well defined

Question 18

(i)	$\lambda = 4.65$	B1		
	$e^{-4.65} \times \frac{4.65^4}{4!}$	M1		Poisson P(X = 4) with any λ
	= 0.186 (3 sf)	A1	3	
(ii)	$\lambda = 3.875$	B1		
	$= e^{-3.875}\left(1 + 3.875 + \frac{3.875^2}{2!}\right) = 0.257$ (3 sf)	M1 A1	 3	P(X = 0, 1, 2) Attempted, any λ As final answer
(iii)	$\lambda = 1.5$	B1		
	$1 - e^{-1.5}\left(1 + 1.5 + \frac{1.5^2}{2!}\right)$	M1		1 – P(X = 0, 1, 2) Attempted, any λ
	= 0.191 (3 sf)	A1	3	As final answer
(iv)	He will reject H_0.	B1	1	
		Total: 10		

Question 19

(i)	$\frac{4.8}{\sqrt{40}}$		B1		or $\frac{4.8^2}{40}$. Accept $4.8\sqrt{40}$ or $4.8^2 \times 40$ for totals method
	$\frac{50.3 - 49.5}{\frac{4.8}{\sqrt{40}}}$	(= 1.054)	M1		For standardising with their SD Accept ± Accept totals method. No mixed methods
	1 – Φ('1.054')		M1		For use of tables and finding area consistent with their working
	= 0.146 (3 sf)		A1	4	
(ii) (a)	Looking for decrease		B1	1	
(b)	H_0: Pop mean time spent (or μ) = 49.5 H_1: Pop mean time spent (or μ) < 49.5		B1		Not just "mean time spent"
	$\frac{\frac{1920}{40} - 49.5}{\frac{4.8}{\sqrt{40}}}$	(= –1.976)	M1		For standardising. Allow $\div \frac{4.8}{40}$ Accept totals method; CV method. No mixed methods
	'1.976' > 1.555 (or '–1.976' < –1.555)		M1		For valid comparison (area comparison 0.024 < 0.06)
	There is evidence that mean time has decreased.		A1	4	CWO. No contradictions in conclusions
(c)	Population normally distr so No		B1	1	Both needed

Question 20

(i)	Cables broken or not all cables can be accessed oe or Too many cables oe or too time consuming oe	B1 [1]	e.g. previous days' stocks may have gone
(ii)	H_0: Pop mean brk str (or μ) = 5 H_1: Pop mean brk str (or μ) < 5	B1	Not just "mean"
	$(\pm)\dfrac{4.95-5}{\frac{0.15}{\sqrt{60}}}$	M1	Allow 60 instead of √60
	(= ±2.582)	A1	
	comp ±2.326 There is evidence that mean breaking strength is less than it should be Or reject H_0 (H_0 correctly defined)	B1 ft [4]	Ft their –2.582 (No ft 2 tailed test) Correct comparison shown, no errors seen. Accept area comparison 0.0049 with 0.01 [CR method $(x-5)/(0.15/\sqrt{60})$ = –2.326 M1 A1 leading to x = 4.955 compared to 4.95and correct conclusion B1ft OR $((x-4.95)/0.15/\sqrt{60})$ leading to 4.995 M1 A1 compared to 5and correct conclusion B1ft]
(iii)	Population not necessarily normal so yes	B1 B1dep [2]	SR B1 For "it" is not necc normal (no mention of population) AND Yes

Question 21

(i)	H_0: P(correct) = $\dfrac{1}{8}$ H_1: P(correct) > $\dfrac{1}{8}$	B1 [1]	Or H_0 p = 1/8 H_1p > 1/8
(ii)	$1-\left(\left(\frac{1}{8}\right)^{10}+10\left(\frac{1}{8}\right)^{9}\left(\frac{7}{8}\right)+{}^{10}C_2\left(\frac{1}{8}\right)^{8}\left(\frac{7}{8}\right)^{2}\right)$	M1	M1 for attempt at correct expression accept 1 error only, e.g. 1 term extra, omitted or wrong, or omit "1–" or incorrect p/q
		A1	Correct expression
	= 0.120 (3 sf) or 0.119	A1 [3]	Note Use of Poisson in (ii) could score M1 only for expression 1 –P(0,1,2) λ =1.25
(iii)	12%	B1f [1]	ft their (ii) Must be a probability

Question 22

(i)	Conclude flight times affected when in fact they have not been.	B1 B1 2	Or accept pop mean changed from 6.2 although pop mean has not changed from 6.2
(ii)	H_0: Pop mean (or μ) = 6.2 H_0: Pop mean (or μ) ≠ 6.2 $\dfrac{5.98-6.2}{\frac{0.8}{\sqrt{40}}}$ = −1.739 (±) Accept (±)1.74 comp z = 1.96 No evidence that flight times affected	B1 M1 A1 B1√ 4	Allow with 40 instead of √40 Allow SD/Var mix (CV method 5.952 or 6.2279 M1 A1) For valid comparison or $P(z < -1.739) = 0.041 > 0.025$ or 5.98 > 5.952 or 6.2 < 6.228 and correct conclusion
(iii)	H_0 was not rejected oe Type II	B1* B1*dep 2	If in (ii) H_0 was rejected, then: H_0 rejected B1; Type I B1dep
	Total	**8**	

Question 23

(i)	H_0: $\lambda = 0.5$ H_1: $\lambda > 0.5$	 B1 1	or Pop mean = 0.5, not just Mean = 0.5 or Pop mean (per m^2)= 0.1 Accept μ instead of λ
(ii)	$1 - e^{-0.5}(1 + 0.5)$ = 0.0902 (3 sf) comp 0.1 Claim justified or there is evidence to support claim	M1 A1 M1 A1√ 4	$1 - P(X = 0,1)$ attempted, any λ. Allow 1 end error Allow 0.09 Valid comparison NB 0.9098>0.9 recovers M1A1 M1 oe Accept 'Reject H_0' if correctly defined No contradictions.

Question 24

(i)	H_0: pop mean (or μ) = 12.4 H_1: pop mean (or μ) > 12.4 $\dfrac{12.9-12.4}{2.1 \div \sqrt{50}}$ 1.684 comp cv z = 1.96 No evidence that pop mean time has increased	 B1 M1 A1 B1f [4]	 not just "mean" Allow with 50 instead of √50 or $P(z > 1.684) = 0.0461 > 0.025$ Allow accept H_0 if correctly defined. Ft their test statistic. No contradictions
(ii)	Not reject (or accept) that mean time is unchanged (or is 12.4) oe although mean time has increased (or is more than 12.4) oe	B1 B1 [2]	
(iii)	True (or new) mean	B1 [1]	
		[Total: 7]	

Question 25

(i)	H_0: $p = 0.2$ or $\mu = 10$ H_1: $p > 0.2$ or $\mu > 10$	B1 [1]	
(ii)	N(10, 8) seen or implied	B1	or $N\left(0.2, \frac{0.2 \times 0.8}{50}\right)$
	$\frac{125-10}{\sqrt{8}}$ or $\frac{\frac{125}{50}-02}{\sqrt{\frac{0.2\times0.8}{50}}}$	M1	For standardising allow with no or wrong cc
	$= 0.884$	A1	
	comp 1.282	M1f	Allow area comparison with 0.188 or comp 1.645 if H_1 $p \neq 0.2$
	Claim not justified or No evidence to support claim	A1f [5]	Allow accept H_0 provided correctly defined. Follow through their test statistic ;dep 1–tail test No Contradictions SR; Use of B(50,0.2) scores B1 provided at least two probabilities calculated. M1 For finding $P(X \geqslant 13)$ allow one end error. A1 for 0.186
		[Total: 6]	

Question 26

(i)	Ho: $\mu = 2.60$ H_1: $\mu > 2.60$	**B1**		allow pop mean, not just 'mean'
	$\pm \frac{2.64-2.6}{0.2 \div \sqrt{75}}$	**M1**		
	$= \pm 1.732$	**A1**		accept ± 1.73 (3 sf)
	'1.732' > 1.645 Reject Ho. There is evidence that μ has increased	**B1**√	[4]	valid comparison with 1.645 (or 0.0416 < 0.05) and correct conclusion √ their 1.732 no contradictions (or CV method $x_{crit} = 2.638$ M1A1 comp 2.64 > 2.638 and concln B1 √) SR two tail test, using 1.96 (or using 0.025) can score B0M1A1B1ft max 3/4
(ii)	$\frac{x-2.6}{0.2 \div \sqrt{75}} = 1.645$ $(x = 2.638)$	**M1**		
	$\pm \frac{'2.638'-2.68}{0.2 \div \sqrt{75}}$	**M1**		for standardising with their " 2.638 " using 2.68
	$= \pm 1.819$	**A1**		accept 1.82 (3 sf)
	Φ('–1.819') = 1 – Φ('1.819')	**M1**		indep M mark, calculate correct area/prob consistent with their working
	⊨ 0.0345 or 0.0344	**A1**	[5]	

Question 27

(a)	$\lambda = 4.5$	**B1**		
	$e^{-4.5}$ (= 0.011109)	**M1**		alone allow any λ
	$\left(\frac{99}{100}\right)^{450}$ (= 0.010860)	**M1**		
	$\left(\frac{'0.011109' - '0.010860'}{'0.010860} \times 100\right)$			
	= 2.29% (3 sf)	**A1**	[4]	
(b)	H_0: $P(6) = \frac{1}{6}$ or $p = \frac{1}{6}$			
	H_1: $P(6) < \frac{1}{6}$ or $p < \frac{1}{6}$	**B1**		Both needed
	$\left(\frac{5}{6}\right)^{25} + 25\left(\frac{5}{6}\right)^{24} \times \frac{1}{6} + {}^{25}C_2\left(\frac{5}{6}\right)^{23} \times \left(\frac{1}{6}\right)^2$	**M1**		allow one error (extra term / missing term / incorrect term) CR method: attempt at least P(0) and P(0 and 1) (0.010... and 0.06... < 0.1)
	= 0.189 (3 sf)	**A1**		CR is 0,1 and must see 0.189 for A1
	comp 0.1	**M1**		valid comp '0.189' with 0.1 oe valid comparison of 2 with CR
	No reason to believe die biased	**A1**	[5]	correct conclusion, √ their 0.189 no contradictions

Question 28

(i)	Prob could be different later in day or on a different day oe	**B1**	[1]	or any explanation why not random or "Not random" or "Not representative"
(ii)	Looking for decrease (or improvement) H_0: P(not arrive) = 0.2	**B1**		oe Allow "$p = 0.2$"
	H_1: P(not arrive) < 0.2	**B1**	[2]	
(iii)	Concluding that prob has <u>decreased</u> (or publicity has worked) when it hasn't oe	**B1**	[1]	In context
(iv)	$P(X = 0)$ and $P(X = 1)$ attempted	**M1**		B(30, 0.2) Not nec'y added May be implied by calc $P(X \leqslant 2)$ or $P(X \leqslant 3)$
	$P(X \leqslant 2) = 0.8^{30} + 30 \times 0.8^{29} \times 0.2 + {}^{30}C_2 \times 0.8^{28} \times 0.2^2$ (= 0.0442)	**M1**		Attempt $P(X \leqslant 2)$
	$P(X \leqslant 3) = 0.8^{30} + 30 \times 0.8^{29} \times 0.2 + {}^{30}C_2 \times 0.8^{28} \times 0.2^2 + {}^{30}C_3 \times 0.8^{27} \times 0.2^3$ = 0.123	**B1**		Or '0.0442' + ${}^{30}C_3 \times 0.8^{27} \times 0.2^3 = 0.123$
	cr is $X \leqslant 2$	**A1**		
	P(Type I) = 0.0442 (3 sf)	**A1**	[5]	
(v)	3 is outside cr	**M1**		Comparison of 3 with their cr or $P(X \leqslant 3) = 0.123$ which is > 0.05
	No evidence that p has decreased (or that publicity has worked)	**A1** √	[2]	Correct conclusion. No contradictions

Question 29

(i)	H_0: pop mean journey time = 35.2 mins H_1: pop mean journey time < 35.2 mins	B1	Allow "μ". Not "mean journey time"
	$\frac{34.7-35.2}{5.6/\sqrt{25}}$ (= –0.446)	M1	For standardising ($\sqrt{25}$ needed)
	Φ(< "–0.446") = 1 – Φ("0.446") = 0.328 (3 sf)	M1 A1 [4]	For correct area consistent with their working As final answer
(ii)	H_0 *is* rejected but Type II error can only be made if H_0 is *not* rejected	B1 [1]	Allow just "H_0 is rejected." oe

Question 30

H_0: P(hit target) = 0.65 H_1: P(hit target) > 0.65	B1	Allow $p = 0.65$ Allow $p > 0.65$
$^{20}C_2 \times 0.35^2 \times 0.65^{18} + 19 \times 0.35 \times 0.65^{19} + 0.65^{20}$ = 0.0121 (3 sf)	M1 A1	Allow one end error. Allow p/q mix. Allow (1–) for **M** mark **A** mark recovered following valid comparison
Comp 0.01 There is no evidence (at the 1% level) that she has improved	M1 A1√ [5]	For valid comparison She has probably not improved. No contradictions. (SR Use of Normal **M0**, but **M1A1** for valid comparison could be awarded)

Question 31

(i)	H_0: Pop mean = 2.5 (or 7.5) H_0: Pop mean < 2.5 (or 7.5)	B1	or λ = 2.5(Not just "mean") Allow μ or λ < 2.5
	$\lambda = 7.5$ $P(X \leqslant 2) = e^{-7.5}(1+7.5+\frac{7.5^2}{2}) = 0.0203$ $P(X \leqslant 3) = 0.0203 + e^{-7.5} \times \frac{7.5^3}{3!} = 0.0591$	M1 A1	Either P(X⩽2) or P(X⩽3) , allow any λ *Both Correct*
	CR is $X \leqslant 2$	A1	*Clear statement*
	Reject H_0 Evidence that no of sightings fewer	A1√ [5]	*Follow through their CR/their P(X⩽2)*
(ii)	P(Type I) = 0.0203 (3 sf)	B1√ [1]	ft their $P(X \leqslant 2)$
(iii)	H_0 was rejected oe	B1 [1]	or Type II is P(not reject H_0)oe

Question 32

H_o: Pop mean yield = 8.2 H_1: Pop mean yield > 8.2	B1	or μ = 8.2(not just "mean") $\mu > 8.2$
(±) $\frac{8.7-8.2}{1.2/\sqrt{16}}$	M1	Allow without √ sign (Allow cc)
= (±)1.667	A1	
Comp z = 1.645 Or Area comparison 0.0475-0.0478)	M1	Or comp 1 - Φ('1.667') with 0.05 Valid Comparison z-values (same sign) or areas
Reject H_0 Evidence that mean yield has increased	A1√ [5]	No Contradictions No follow through for 2 tail test

Question 33

H_0: λ (or μ) = 42 H_1: λ (or μ) $\neq$ 42	B1	Or pop weekly mean = 2.1 etc. allow 'population mean' not just 'mean'
Po(42) ~ N(42, 42) stated or implied	B1√	ft their '42' (Accept alt method N(2.1,2.1/20)
$\frac{53.5-42}{\sqrt{42}}$	M1	
= 1.77(4) (or 0.038 for area comparison)	A1	allow with wrong or no cc. Accept alt method using N(2.1,2.1/20) with or without cc
comp 1.96	M1	Valid comp z or 1 – ('1.774') with 0.025 seen
No evidence that mean has changed	A1√ [6]	allow comp 1.645 if H_1: λ (or μ) > 42 No contradictions. No ft for H_1: λ (or μ) > 42 Note – accept other valid methods(e.g. cv method)

Question 34

(i)	Conclude less than 90% satisfied when this is not true oe	B11	In context
(ii)	$1-(0.9^{15}+15\times0.9^{14}\times0.1$ $+{}^{15}C_2\times0.9^{13}\times0.1^2+{}^{15}C_3\times0.9^{12}\times0.1^3)$ = 0.0556 (3 sf) or 0.0555	M1 M1 A1 [3]	Attempt (1–)P(X = 15,14,13,12) allow 1 end error Attempt fully correct expression

Question 35

(i)	H_0: μ = 12.5 H_1: $\mu \neq$ 12.5	B1	
	$\frac{13.5-12.5}{4.2\div\sqrt{50}}$	M1	allow 4.2 ÷ 50
	= 1.68(4)	A1	
	'1.684' < 1.96	M1	comp 1.96 allow comp 1.645 if H1: μ > 12.5 or comp 1 – ('1.684') with 0.025
	No evidence that mean time has changed	A1 ft [5]	No contradictions ft their 1.684, but not comp 1.645
(ii)	0.05	B1 [1]	

Question 36

B(200, $\frac{1}{6}$) → N($\frac{100}{3}$, $\frac{250}{9}$)	B1		seen or implied
$\frac{25.5-\frac{100}{3}}{\sqrt{\frac{250}{9}}}$	M1		allow with wrong or no cc
= –1.486	A1		(Accept alternative correct methods)
comp '1.486' with 1.282	M1		or comp ('1.486') with 0.1
Evidence to reject H_0 There is some evidence that $p < \frac{1}{6}$ or, e.g. It is likely that $p < \frac{1}{6}$ oe	A1 ft	[5]	No contradictions

Question 37

(i)	H_0: P(free gift) = 0.3 or $p = 0.3$ H_1: P(free gift) < 0.3 or $p < 0.3$	**B1**	[1]	
(ii)	$P(X \leqslant 2) =$ $0.7^{20} + 20 \times 0.7^{19} \times 0.3 + {}^{20}C_2 \times 0.7^{18} \times 0.3^2$	**M1***		$P(X \leqslant 2)$ attempted
	= 0.03548 or 0.0355	**A1**		
	$P(X \leqslant 3) =$ '0.03548' + ${}^{20}C_3 \times 0.7^{17} \times 0.3^3$ (= 0.107)	**M1***		$P(X \leqslant 3)$ attempted
	One comparison with 0.05 seen	**M1***		or implied by fully correct methods for $P(X \leqslant 2)$ and $P(X \leqslant 3)$
	P(Type I error) = 0.0355 (3 sf)	**DA1** √	[5]	dep on all 3 Ms
(iii)	$P(X \leqslant 3)$ = '0.107' '0.107' > 0.05 **or** cv = 2 and compare 3 >2	**M1**		Compare their $P(X \leqslant 3)$ with 0.05
	No evidence to reject claim oe	**A1** √	[2]	No evidence that 30% is not correct oe ft their 0.107

Question 38

(i)	H_0: Pop mean time (or μ) = 20.5 H_1: Pop mean time (or μ) < 20.5	**B1**		Not just "mean"
	$\frac{20.3-20.5}{1.2\div\sqrt{100}}$	**M1**		Allow without √ sign
	= –1.667 or 0.0478/0.952 if areas compared	**A1**		(accept ±1.667/1.67)
	'1.667' < 1.751 (or '–1.667' > –1.751)	**M1**		Correct comparison of their z_{calc} with 1.751/1.75 oe valid comparison of areas (0.0478 > 0.04)
	No evidence that (pop) mean time has decreased	**A1ft**	[5]	No contradictions (ft their z)
(ii)	$\frac{cv-20.5}{1.2\div\sqrt{100}}$ = –1.751	**M1***		
	cv = 20.29 or 20.3	**A1**		
	$\frac{'20.29'-20.1}{1.2\div\sqrt{100}}$ (= 1.583 or 1.582)	**DM1**		Allow $\frac{20.3-20.1}{1.2\div\sqrt{100}}$ (= 1.667) M1
	1 – Φ('1.583')	**M1**		1 – Φ('1.667') M1
	= 0.0567 – 0.0569 (3 sf)	**A1**	[5]	= 0.0478 (3 sf) A1
(iii)	Concluding (mean) time not decreased when in fact it has.	**B1**	[1]	Must be in context oe

Question 39

(i)	H_0: P(6) = $^1/_6$ H_1: P(6) < $^1/_6$	**B1**	[1]	Allow H_0: $p = {}^1/_6$ H_1: $p < {}^1/_6$
(ii)	$\left(\frac{5}{6}\right)^{15}$	**M1**		
	= 0.065 > 0.05	**A1**	[2]	Correct result and comparison needed for A1 SR if 2 tail test followed allow A1 for 0.065 > 0.025
(iii)	$\left(\frac{5}{6}\right)^{16}$ = 0.054 and $\left(\frac{5}{6}\right)^{17}$ = 0.045	**M1**		both
	Smallest n is 17	**A1**	[2]	No errors seen
	OR $\left(\frac{5}{6}\right)^{n}$ < 0.05 and attempt to solve	**M1**		
	$n\ln\left(\frac{5}{6}\right)$ < ln 0.05 smallest n is 17	**A1**		

Question 40

(i)	H_0: Pop mean time (or μ) = 20.5 H_1: Pop mean time (or μ) < 20.5	B1		Not just "mean"
	$\frac{20.3-20.5}{1.2\div\sqrt{100}}$	M1		Allow without √ sign
	= –1.667 or 0.0478/0.952 if areas compared	A1		(accept ±1.667/1.67)
	'1.667' < 1.751 (or '–1.667' > –1.751) No evidence that (pop) mean time has decreased	M1 A1ft	[5]	Correct comparison of their z_{calc} with 1.751/1.75 oe valid comparison of areas (0.0478 > 0.04) No contradictions (ft their z)
(ii)	$\frac{cv-20.5}{1.2\div\sqrt{100}} = -1.751$	M1*		
	cv = 20.29 or 20.3	A1		
	$\frac{'20.29'-20.1}{1.2\div\sqrt{100}}$ (= 1.583 or 1.582)	DM1		Allow $\frac{20.3-20.1}{1.2\div\sqrt{100}}$ (= 1.667) M1
	1 – Φ('1.583') = 0.0567 – 0.0569 (3 sf)	M1 A1	[5]	1 – Φ('1.667') M1 = 0.0478 (3 sf) A1
(iii)	Concluding (mean) time not decreased when in fact it has.	B1	[1]	Must be in context oe

Question 41

(i)	(λ =) 4.5	B1	
	$e^{-4.5}(1 + 4.5 + \frac{4.5^2}{2!})$	M1	Allow any λ. Allow one end error
	= 0.174	A1	
	Total:	3	
(ii)	Accept reduction in mean no. of missed appts although untrue	B1	or Mean is 0.9 (or 4.5) but < 3 missed appts. In context
	Total:	1	
(iii)	$P(X \geqslant 3)$	M1	Attempted
	$= 1 - e^{-1}(1 + 1 + \frac{1^2}{2!})$	M1	Allow any λ except 4.5 or 0.9, Allow one end error
	= 0.0803 (3 sfs)	A1	

Question 42

(i)	(H_1): $\mu \neq 6.4$	**B1**	
	Total:	**1**	
(ii)	comp 2.43 with a z-value $z = 2.576$ AND	**M1**	oe valid comparison
	No evidence that μ is not 6.4 or do not reject $\mu = 6.4$	**A1**	Allow "Accept $\mu = 6.4$" Must mention μ, not just "H_0" or "H_1"
	Total:	**2**	
iii)	Testing for an increase in μ, or for a decrease in μ, rather than a change	**B1**	Any equiv statement

Question 43

7(i)	H_0: Pop mean no. accidents = 5.64 H_1: Pop mean no. accidents < 5.64	**B1**	or "= 0.47 (per month)" not just "mean", but allow just "λ" or "μ"
	Use of $\lambda = 5.64$	**B1**	used in a Poisson calculation
	$= e^{-5.64}(1 + 5.64 + \frac{5.64^2}{2})$	**M1**	Allow incorrect λ in otherwise correct
	= 0.08(0)	**A1**	
	Comp with 0.05	**M1**	Valid comparison (Poisson only), no contradictions.
	No evidence to believe mean no. of accidents has decreased; accept H_0 (if correctly defined)	**A1FT**	Normal distribution: **M0M0**
	Total:	**6**	
'(ii)	Mean < 0.47 but conclude that this is not so	**B1**	(Mean) no. of accidents **reduced**, but conclude not reduced. Must be in context.
	Total:	**1**	
(iii)	(Need greatest x such that $P(X \leqslant x) < 0.05$) $P(X \leqslant 1) = e^{-5.64}(1 + 5.64) = 0.024$ $P(X \leqslant 2) = 0.08$	**B1**	Both, could be seen in (i)
	Hence rejection region is $X \leqslant 1$	**B1**	Can be implied
	With $\lambda = 12 \times 0.05 = 0.6$, $1 - P(X \leqslant 1) = 1 - e^{-0.6}(1 + 0.6)$	**M1**	λ=0.6 and $1 - P(X \leqslant 1)$
	= 0.122 (3 sf)	**A1**	Normal scores 0

Question 44

(i)	$0.75^{20} + 20 \times 0.75^{19} \times 0.25 + {}^{20}C_2 \times 0.75^{18} \times 0.25^2$	**M1**	No end errors
	= 0.0913	**A1**	As final answer
	Total:	**2**	
(ii)	H_0: Pop proportion=0.25 H_1: Pop proportion<0.25	**B1**	Allow p or π, not "proportion" (Accept anywhere in the question)
	$0.75^{25} + 25 \times 0.75^{24} \times 0.25$	**M1**	Must be B(25,0.25) No end errors
	= 0.00702	**A1**	
	comp 0.01	**M1**	Valid comparison
	There is evidence that the claim is not justified	**A1 FT**	OE. No contradictions

Question 45

5(i)	mean = 6.6	**B1**	**B1** for 6.6 (could be scored in iii)
	$P(X \leqslant 1) = e^{-6.6}(1 + 6.6) = 0.0103$	**M1**	Allow incorrect λ in both probs
	$P(X \leqslant 2) = e^{-6.6}(1 + 6.6 + \frac{6.6^2}{2}) = 0.0400$	**M1A1**	**A1** for both values
	CR is $X \leqslant 1$	**DA1**	Dep on at least one **M**
	P(Type I error) = $P(X \leqslant 1) = 0.0103$	**B1FT**	FT their $P(X \leqslant 1)$
	Total:	**6**	
(ii)	Wrongly concluding that (mean) no of (sports) injuries has decreased	**B1**	Must be in context
5(iii)	H_0: $\lambda = 6.6$ H_1: $\lambda < 6.6$	**B1**	Can be scored in (i). Allow μ or λ / 1.1 or 6.6 or $P(X \leqslant 2) = 0.0400 > 0.02$
	2 not in CR	**M1**	
	No evidence mean no. of injuries has decreased	**A1FT**	
	Total:	**3**	
5(iv)	N(39.6, 39.6)	**B1**	May be implied
	$\frac{29.5 - 39.6}{\sqrt{39.6}}$ (= −1.605)	**M1**	Allow with wrong or no cc
	Φ("−1.605") = 1 − Φ("1.605")	**M1**	For area consistent with their mean
	= 0.0543 (3 sfs)	**A1**	

Question 46

Assume sd still = 3.8	**B1**	or sd unchanged
H_0: $\mu = 64.0$ H_1: $\mu < 64.0$	**B1**	
$\frac{63.3-64.0}{\frac{3.8}{\sqrt{100}}}$	**M1**	Standardising with their values (no sd / var mixes) Must have $\sqrt{100}$
= −1.842	**A1**	
comp "1.842" with z-value "1.842" < 1.96	**M1**	comp +ve with +ve or −ve with −ve or comp Φ ("1.842") with 0.975 0.9672 < 0.975 OE
No evidence that heights are shorter	**A1FT**	OE FT their z_{calc}

Question 47

3(i)	$\overline{x} = 27/150$ (= 0.18)	**B1**	
	$s = \sqrt{\frac{150}{149}} \times \sqrt{\frac{5.01}{150} - 0.18^2}$ or variance (= 0.031729) (var = 3/2980 = 0.0010067)	**M1**	or var = $1/149(5.01 - 27.0^2/150)$
	H_0: Pop mean = 0.185 H_1: Pop mean < 0.185	**B1**	allow just 'μ'
	$\frac{0.18 - 0.185}{\frac{\text{'0.031729'}}{\sqrt{150}}}$	**M1**	standardising, need $\sqrt{150}$
	= (–) 1.930 (3 sfs) or 1.93	**A1**	
	Comp with z = (–) 2.326	**M1**	consistent signs or using probs 0.0268 > 0.01 or 0.9732 < 0.99 or using x_{crit} 0.18 > 0.17897
	There is no evidence (at 1% level) that concentration with drug is less than without drug	**A1 FT**	conclusion FT no contradictions
(ii)	$\frac{cv - 0.185}{\frac{\text{'0.031729'}}{\sqrt{150}}}$ (= – 2.326)	**M1**	must use 0.185 and $\sqrt{150}$
	= 0.17897 or 0.179	**A1**	acceptance region (for H_0) is > 0.179
	$\frac{\text{"0.17897"} - 0.175}{\frac{\text{'0.031729'}}{\sqrt{150}}}$ (=1.534)	**M1**	must use 0.175 and $\sqrt{150}$
	1 – ϕ("1.534")	**M1**	indep mark
	= 0.0625 (3 sf)	**A1**	Accept 0.0610 to 0.0628

Question 48

(i)	H_0: mean no. sales = 3.5	**B1**	or " ... = 0.7 (per day)"
	H_1: mean no. sales > 3.5	**M1**	allow 'λ' or 'μ' but not just 'mean'
	$P(X \geqslant 5) = 1 - e^{-3.5}(1 + 3.5 + \frac{3.5^2}{2!} + \frac{3.5^3}{3!} + \frac{3.5^4}{4!})$	**M1**	
	= 0.275	**A1**	allow 0.274
	Comp with 0.10	**M1**	valid comparison using Poisson
	No evidence (at 10%) to believe that sales per day have increased	**A1 FT**	correct conclusion FT no contradictions
(ii)	$\lambda = 3.9$	**B1**	
	$e^{-3.9} \times \frac{3.9^2}{2!}$	**M1**	any λ ($\neq$ 0.7 or 0.6), single term
	= 0.154 (3 sf)	**A1**	

Question 50

3(i)	$\overline{m} = \frac{98.2}{100} = 0.982$	B1	Accept either
	$s = \sqrt{\frac{100}{99}} \times \sqrt{\frac{104.52}{100} - 0.982^2}$ $(= 0.28582)$ or var = 0.08169	M1	
	H_0: Pop mean mass = 1.01 H_1: Pop mean mass < 1.01	B1	not just 'mean', but allow just 'μ'
	$\pm\frac{0.982 - 1.01}{\frac{0.28582}{\sqrt{100}}}$	M1	$\pm\frac{0.982 - 1.01}{\frac{0.284387}{\sqrt{100}}}$ M1
	$= -0.980$ (3 sf) accept $\pm$	A1	$= -0.985$ (3 sfs) accept $\pm$ A1
	Comp with $z = -1.645$ (or areas $0.1635 > 0.05$)	M1	Valid comparison of z's or area's
	No evidence that (mean) mass is less than 1.01	A1 FT	Correct conclusion FT their z
(ii)	Distr of X normal (so distr of $\overline{X}$ normal) Must state or imply No	B1	X/parent population

Question 51

3(i)	$\overline{x} = 27/150$ $(= 0.18)$	B1	
	$s = \sqrt{\frac{150}{149}} \times \sqrt{\frac{5.01}{150} - 0.18^2}$ or variance $(= 0.031729)$ (var = 3/2980 = 0.0010067)	M1	or var = $1/149(5.01 - 27.0^2/150)$
	H_0: Pop mean = 0.185 H_1: Pop mean < 0.185	B1	allow just 'μ'
	$\frac{0.18 - 0.185}{\frac{'0.031729'}{\sqrt{150}}}$	M1	standardising, need $\sqrt{150}$
	= (–) 1.930 (3 sfs) or 1.93	A1	
	Comp with $z = (-)\ 2.326$	M1	consistent signs or using probs $0.0268 > 0.01$ or $0.9732 < 0.99$ or using x_{crit} $0.18 > 0.17897$
	There is no evidence (at 1% level) that concentration with drug is less than without drug	A1 FT	conclusion FT no contradictions

(ii)	$\frac{cv - 0.185}{\frac{'0.031729'}{\sqrt{150}}}$ $(= -2.326)$	M1	must use 0.185 and $\sqrt{150}$
	= 0.17897 or 0.179	A1	acceptance region (for H_0) is > 0.179
	$\frac{"0.17897" - 0.175}{\frac{'0.031729'}{\sqrt{150}}}$ (=1.534)	M1	must use 0.175 and $\sqrt{150}$
	$1 - \phi$("1.534")	M1	indep mark
	= 0.0625 (3 sf)	A1	Accept 0.0610 to 0.0628

Question 52

(i)	H_0: mean no. sales = 3.5	B1	or " ... = 0.7 (per day)"
	H_1: mean no. sales > 3.5	M1	allow 'λ' or 'μ' but not just 'mean'
	$P(X \geqslant 5) = 1 - e^{-3.5}(1 + 3.5 + \frac{3.5^2}{2!} + \frac{3.5^3}{3!} + \frac{3.5^4}{4!})$	M1	
	= 0.275	A1	allow 0.274
	Comp with 0.10	M1	valid comparison using Poisson
	No evidence (at 10%) to believe that sales per day have increased	A1 FT	correct conclusion FT no contradictions
(ii)	$\lambda = 3.9$	B1	
	$e^{-3.9} \times \frac{3.9^2}{2!}$	M1	any λ ($\neq$ 0.7 or 0.6), single term
	= 0.154 (3 sf)	A1	

Question 53

(i)	(Po)(2.4)	**B1**	seen or implied
	$e^{-2.4}(1 + 2.4 + \frac{2.4^2}{2} + \frac{2.4^3}{3!})$	**M1**	allow + P(4)/one end error. Allow wrong λ
	= 0.779 (3 sfs)	**A1**	Final answer (Note: accept combination method)
		3	
(ii)	H_0: λ (or mean) = 3.6 (or 0.9) H_1: λ (or mean) < 3.6 (or 0.9)	**B1**	Accept μ for both
	$e^{-3.6}(1 + 3.6)$	**M1**	Allow any λ
	= 0.126	**A1**	
	0.126 > 0.1	**M1**	Valid comparison. (Comparison with 0.9 could recover previous **M1A1**)
	No evidence that fewer than usual sold	**A1FT**	Correct conclusion. No contradictions

Question 54

5(i)	H_0: P(Orange) = 0.17 H_1: P(Orange) < 0.17	B1	or H_0: $p = 0.17$ H_1: $p < 0.17$
5(ii)	Wrongly concluding that % age is less than 17%	B1	OE in context allow "fewer than 3 orange in packet even though average 17% is correct"
		1	
(iii)	B(30, 0.17) stated or implied	M1	eg by $0.17^p \times 0.83^q$ $(p + q = 30)$ or ${}^{30}C_r$ $(r < 30)$
	$(1 - 0.17)^{30} + 30(1 - 0.17)^{29} \times 0.17 + {}^{30}C_2(1-0.17)^{28} \times 0.17^2$	M1	correct, but allow $+ {}^{30}C_3(1-0.17)^{27} \times 0.17^3$
	= 0.0949 (3 sf)	A1	(SR: use of N(5.1,4.233) **M1** standardising (with or without cc) **M1** max 2/3)

5(iv)	P(⩾ 3 orange | $p = 0.05$)	M1	stated or attempted; can be implied
	$= 1-[(0.95)^{30} + 30(0.95)^{29} \times 0.05 + {}^{30}C_2(0.95)^{28} \times 0.05^2]$	M1	allow $+ {}^{30}C_3(0.95)^{27} \times 0.05^3$ in bracket, or ans 0.0608
	= 0.188 (3 sfs)	A1	

Question 55

5(i)	Assume (pop) sd same (0.3) H_0: Pop mean = 2.4	B1	
	H_1: Pop mean ≠ 2.4	B1	Allow 'μ' but not just 'mean'
	$\pm \frac{2.3-2.4}{\frac{0.3}{\sqrt{30}}}$	M1	Must have $\sqrt{30}$, Critical region approach (2.293, 2.507) or (2.193, 2.407)
	= ±1.826	A1	
	comp z = ±1.96	M1	Valid comparison (e.g. compare 0.034 with 0.025)
	No evidence that mean time changed	A1f	In context, allow accept H_0 if correctly defined, no contradictions. One-tail test can score B1, B0, M1, A1, M1, A0 Max 4/6
		6	
(ii)(a)	0.05	B1	
		1	
(ii)(b)	Concluding mean time has not changed when it has.	B1	OE, must have e.g. conclude/accept SR Allow mean has decreased if a one tailed test in Part **(i)**
		1	

Question 56

7(i)	H_0: P(10) = 0.1 H_1: P(10) > 0.1	**B1**	Both. Allow 'p' for P(10)
	B(9,0.1) $P(X \geqslant 3) =$ $1 - (0.9^9 + 9 \times 0.9^8 \times 0.1 + {}^9C_2 \times 0.9^7 \times 0.1^2)$	**M1**	Allow one extra term in bracket
	= 0.05297... or 0.053(0)	**A1**	
	comp 0.01	**M1**	Valid comparison. (comparison with 0.99 can recover previous M1 A1 for 0.9470)
	No evidence (at 1% level) to reject H_0 Claim not justified	**A1ft**	No contradictions
		5	
(ii)	H_0 not rejected oe	**B1**	
		1	
(iii)	$P(X \geqslant 4)$ $= "0.05297" - {}^9C_3 \times 0.9^6 \times 0.1^3$	**M1**	or $1 - (0.9^9 + 9 \times 0.9^8 \times 0.1 + {}^9C_2 \times 0.9^7 \times 0.1^2 + {}^9C_3 \times 0.9^6 \times 0.1^3)$
	= 0.00833	**A1**	Note: 0.05297 and 0.00833 both needed in **(i)** or **(iii)** to justify CV
	Hence crit value is 4	**B1**	Allow without working. Or in **(i)** May be implied by attempt at $P(X < 4)$ below
	B(9,0.5) $P(X < 4)$	**M1**	stated or implied
	$= 0.5^9 + 9 \times 0.5^8 \times 0.5 + {}^9C_2 \times 0.5^7 \times 0.5^2 + {}^9C_3 \times 0.5^6 \times 0.5^3$	**M1**	Attempt $P(X < 4)$ with $p = 0.5$
	P(Type II) = 0.254 (3 sf)	**A1**	
		6	

Question 57

7(i)	Po(1.0)	**B1**	Seen or implied
	$e^{-1}(1 + 1 + \frac{1^2}{2})$	**M1**	Allow any λ. Allow one end error.
	= 0.920 (3 sfs)	**A1**	
		3	
7(ii)	$P(X > 3) = 1 - e^{-1.5}(1+1.5+ \frac{1.5^2}{2} + \frac{1.5^3}{3!})$	**M1**	Allow any λ. Allow one end error
	= 0.0656	**A1**	
		2	
iii)(a)	Incorrectly concluding that more absences than usual when there are not oe	**B1**	In context
		1	
iii)(b)	$H_0: \lambda = 1.5$ (or 0.3) $H_1: \lambda > 1.5$ (or 0.3)	**B1**	Or μ Both
	$P(X > 4) =$ "0.0656" $- e^{-1.5} \times \frac{1.5^4}{4!}$ = 0.0186 (3 sf)	**M1**	or $1 - e^{-1.5}(1+1.5+ \frac{1.5^2}{2} + \frac{1.5^3}{3!} + \frac{1.5^4}{4!})$
	P(Type I) = 0.0186 or 0.0185	**A1ft**	Ft their $P(X > 4)$ if less than 0.05
		3	
iii)(c)	$P(X > 3) =$ "0.0656"	**B1ft**	Ft their **(ii)**
	0.0656 > 0.05	**M1**	
	No evidence of more than usual male absences	**A1ft**	Ft their P(X>3). Correct conclusion. No contradictions.

Question 58

(i)	$\frac{14 - 14.2}{\frac{3.1}{\sqrt{50}}}$ (= – 0.456)	**M1**	For stand'n; must have √50
	1 – Φ("0.456")	**M1**	for area consistent with their working
	= 0.324 (3 sfs)	**A1**	
		3	
(ii)	No because *n* large	**B1**	Accept n > 30
		1	
(iii)	H_0: $\mu = 14.2$ H_1: $\mu < 14.2$	**B1**	or 'pop mean', but not just 'mean'
	$\frac{13.5 - 14.2}{\frac{3.1}{\sqrt{100}}}$	**M1**	For stand'n; must have √100
	= –2.258	**A1**	
	comp –2.054 (or –2.055)	**M1**	Valid comparison of z values or areas (0.0119 < 0.02)
	There is evidence (at 2% level) that mean mass in this area < 14.2	**A1ft**	Ft their z. Correct conclusion no contradictions
		5	

Question 59

(i)	H_0: $\mu = 51$ H_1: $\mu < 51$	**B1**	Or popn mean …
	$\bar{x} = \frac{7480}{150} = 49.8667 = 49.9$	**B1**	
	$s^2 = \frac{150}{149}\left(\frac{380000}{150} - \left(\frac{748}{15}\right)^2\right)$ = 46.9620 = 47.0 or s = 6.85	**M1**	Correct subst in s^2 or $\sqrt{s^2}$ formula Biased var scores M0
	$\frac{49.8667 - 51}{\sqrt{\frac{'46.962'}{150}}}$ allow $\frac{49.9 - 51}{\sqrt{\frac{'47'}{150}}}$	**M1**	Allow 49.8667 to 49.9 in numerator Need sqrt 150
	= (–) 2.025 = (–) 1.965	**A1**	Accept 2.02 or 2.03 Accept –2.0264 –1.9651 provided correct working
	comp z = 1.96	**M1**	or comp 1 – ϕ(2.025) with 0.025
	There is evidence that $\mu < 51$	**A1 ft**	no contradictions biased var B1B1M0M1A0M1A1ft (max 5/7) accept cv method x_{crit} = 49.9028 M1A1 49 867 < 49.9… M1A1

(ii)	$\frac{\bar{x}-51}{\frac{6.856}{\sqrt{150}}} = -1.96$	M1	Need 51 and sqrt 150 and correct form
	$\bar{x} = 51 - 1.097 = 49.9$ Rejection region is $\bar{x} < 49.9$	A1	This may have been found in part (i)
	$\frac{49.9-49}{\frac{6.856}{\sqrt{150}}}$ (= 1.608 to 1.614)	M1	Need 49 and sqrt 150 and correct form
	$P(\bar{x} > 49.9 \mid \mu = 49) = 1 - \Phi(\text{'1.608'})$	M1	
	P(Type II error) = 0.0539	A1	Allow 0.0533 to 0.0539
		5	

Question 60

(i)	$H_0: p = \frac{1}{3}$ $H_1: p < \frac{1}{3}$	B1	
		1	
(ii)	0.0084 < 0.01	B1	Allow P(N ⩽ 36) < 0.01 or 1%
	There is evidence that p has decreased	B1 dep	Allow 'p has decreased' or $p < \frac{1}{3}$
		2	
(iii)	150	B1	
		1	

Question 61

(i)	$H_0: p = 0.15$ $H_1: p < 0.15$ (N(60 × 0.15, 60 × 0.15 × 0.85)) = N(9, 7.65)	B1	Accept $H_0: \mu = 9$ $H_1: \mu < 9$ Use of Normal approximation: (N(0.15, $\frac{0.15\times0.85}{60}$)) = N(0.15, 0.002125)
	$\frac{6.5-'9'}{\sqrt{'7.65'}}$	M1	For standardising (or $\frac{\frac{6}{60}+\frac{0.5}{60}-'0.15'}{\sqrt{'0.002125'}}$ = –0.904) Allow wrong or no cc
	= –0.904	A1	Accept ±
	'0.904' < 1.282	M1	Valid comparison of z values or ϕ('–0.904')= 0.183 > 0.1 ft their 0.904
	No evidence train late less often	A1ft	Use of Bin (60,0.15) to give Pr (< = 6) = 0.1848 M1A1 Valid comparison with 0.1 M1 Conclusion A1ft
		5	
(ii)	$0.1 + z \times \sqrt{\frac{0.1\times0.9}{60}} = 0.150$	M1	For √(0.1 × 0.9 / 60) seen
		M1	for 0.1 + z × ... = 0.150 or 2z… = 0.1
	z = 1.291	A1	
	ϕ('1.291') (= 0.90(16))	M1	for correct method to find α
	α = 80	A1ft	ft their z. Must be a +ve non-zero integer < 100
		5	

Question 62

(i)	$\hat{\mu} = \frac{126}{70}$ or $\frac{9}{5}$ or 1.8 oe	B1	
	$\Sigma x^2 f = 286$	B1	Seen or implied
	Est(σ^2) = $\frac{70}{69}(\frac{\Sigma x^2 f}{70} - '1.8'^2)$	M1	oe attempted
	= 0.858 or 296 / 345	A1	Note: Final answer for var 0.846 (biased) and no working implies B1 for 286
		4	
(ii)	$H_0: \mu = 1.9$ $H_1: \mu < 1.9$	B1	Or 'pop mean'; not just 'mean'
	$\frac{1.8-1.9}{\sqrt{\frac{'0.858'}{70}}}$	M1	Standardise with their values from **(i)**. Must have sqr 70. No SD / Var mix
	= –0.903	A1	Accept ±
	0.903 < 1.645	M1	comp 1.645 allow comp 1.96 if $H_1: \mu \neq 1.9$ or comp 1 – ϕ('0.903')=0.182 or 0.183 with 0.05 (or 0.025 if $H_1: \mu \neq 1.9$)
	No evidence that mean no courts in S is less than in N	A1ft	No contradictions. ft their 0.903, but not comp 1.96 i.e. no ft for a 2 tail test Accept cv method: cv = 1.718 M1A1 1.718 < 1.8 M1 conclusion A1 (cv centred on 1.8 gives 1.982 M1A1 and M1 for 1.982 > 1.9 A1 conclusion)
		5	
(iii)	Type II because H_0 was not rejected	B1ft	ft their conclusion, i.e. if H_0 rejected, 'Type I because H_0 rejected' B1 Answer must be consistent with their conclusion. No conclusion in **(ii)** will score B0
		1	

Question 63

(i)	Test is for "difference" oe	**B1**	Test is not for 'increase' or 'decrease' oe No contradictions
		1	
(ii)	0.05	**B1**	
	Conclude mean time is different when it is not	**B1**	oe, in context
		2	
(iii)	Assume $\sigma = 6.4$	**B1**	
	H_0: pop mean = 91.4 H_1: pop mean ≠ 91.4	**B1**	Allow μ, but not 'mean'
	$\bar{x} = \frac{568.5}{6}$ (= 94.75)	**B1**	
	$\frac{\text{'94.75'} - 91.4}{\frac{6.4}{\sqrt{6}}}$	**M1**	Must have √6
	= 1.282 cv of z = 1.96	**A1**	
	'1.282' < 1.96	**M1**	Valid comparison or comp ϕ("1.282") with 0.975 0.9(001) < 0.975 or 0.0999 (or 0.1) > 0.025 consistent use of one tail test can score M1 for comparison with 1.645oe but not A1ft oe. No contradictions. ft their z.
	No evidence mean time different	**A1 ft**	CV method x = 96.52 M1 A1 94.75 < 96.52 M1 Conc A1
		7	

Question 64

H_0: $\lambda = 32$ H_1: $\lambda < 32$	**B1**	Accept 'population mean' (μ)
$X \sim N(32, 32)$	**B1**	seen or implied
$\frac{21.5 - 32}{\sqrt{32}}$	**M1**	Standardise with their values. Allow with no or wrong cc
= –1.856 cv of z = –2.054 (or –2.055 or –2.053)	**A1**	
'1.856' < 2.054	**M1**	Valid comparison or comp ϕ("1.856") with 0.98 i.e. 0.9682 < 0.98 oe
No evidence that fewer accidents at B than at A	**A1f**	No contradictions Note Use of CV method x = 20.38 M1 A1 comparison 21.5 > 20.38 M1 conc A1
	6	

Question 65

(i)	H_0: $p = \frac{1}{4}$ H_1: $p > \frac{1}{4}$	**B1**	
	${}^{10}C_6(\frac{1}{4})^6(\frac{3}{4})^4 + {}^{10}C_7(\frac{1}{4})^7(\frac{3}{4})^3 + {}^{10}C_8(\frac{1}{4})^8(\frac{3}{4})^2 + 10(\frac{1}{4})^9(\frac{3}{4}) + (\frac{1}{4})^{10}$	**M1**	Correct terms, allow one term incorrect or omitted or extra or summing all correct terms from 0 to 5 allow one term incorrect or omitted or extra
	= 0.0197	**A1**	or 0.9803
	comp '0.0197' with 0.01	**M1**	Valid comparison with 0.01 or valid comparison with 0.99
	No evidence to conclude $p > \frac{1}{4}$	**A1**	**FT** No contradictions Use of two-tail test can score BOM1A1M1(comparison with 0.005) A0
		5	
(ii)	${}^{10}C_7(\frac{1}{4})^7(\frac{3}{4})^3 + {}^{10}C_8(\frac{1}{4})^8(\frac{3}{4})^2 + 10(\frac{1}{4})^9(\frac{3}{4}) + (\frac{1}{4})^{10}$	**M1**	Their $P(X \geqslant 6) - {}^{10}C_6(0.25)^6(0.75)^4$
	P(Type I) = 0.00351 (3 sf)	**A1**	Accept 0.00348 to 0.00351
		2	
(iii)	C.R is $X \geqslant 7$ P(Type II) = $1 - P(X \geqslant 7 \mid p = \frac{3}{5}) =$	**M1**	May be implied
	$1 - ({}^{10}C_7(\frac{3}{5})^7(\frac{2}{5})^3 + {}^{10}C_8(\frac{3}{5})^8(\frac{2}{5})^2 + 10(\frac{3}{5})^9(\frac{2}{5}) + (\frac{3}{5})^{10})$	**M1**	Accept $1 - P(X \geqslant 8 \mid p = \frac{3}{5})$ or $1 - P(X \geqslant 6 \mid p = \frac{3}{5})$
	= 0.618	**A1**	
		3	

Question 66

H_0: Pop mean = 20 H_1: Pop mean ≠ 20	**B1**	Accept μ
$\frac{\Sigma x}{6}$ $\quad (= \frac{126.9}{6} = 21.15)$	**M1**	Attempted or 126.9 and 11.64 attempted
$\frac{'21.15'-20}{\sqrt{\frac{1.94}{6}}}$	**M1**	Must have $\sqrt{6}$ or $\frac{120-126.9}{\sqrt{11.64}}$ no mixed method
= 2.022	**A1**	
2(1 - ϕ('2.022')) 2 (1 – '0.9784)' = 0.0432)	**M1**	**FT** $2\times(1-'.9784')$
α = 4.32 (3 sf)	**A1**	**FT** Allow 4.3 or 4, if correct working seen, or clearly implied, as far as 0.0216 **FT** their z, no error seen One-tail test scores maximum 3/6
	6	

Question 67

(i)	Max no. of passengers plane can take oe	**B1**	oe e.g. No of passengers who bought tickets
		1	
(ii)	$\lambda = 3.2$	**B1**	
	$e^{-3.2}(\frac{3.2^3}{3!} + \frac{3.2^4}{4!} + \frac{3.2^5}{5!})$	**M1**	Any λ. Allow one end error
	= 0.5146 = 0.515 (3 sfs)	**A1**	SR Use of Bin(640,0.005) scores B1 (only) for 0.516
		3	
(iii)	$n > 50$	**B1**	Accept n is large
	$np = 1.6$, which is < 5 or p=0.005 which is <0.1	**B1**	Allow $np = 3.2$
		2	
(iv)	H_0: Pop mean (for 5 days) = 8 H_1: Pop mean (for 5 days) < 8	**B1**	or Pop mean (for 1 day) = 1.6 Pop mean (for 1 day) < 1.6 Allow λ or μ but not just 'mean'
	$e^{-8}(1 + 8 + \frac{8^2}{2!})$	**M1**	Any λ ($\neq$ 1.6) No end errors. Accept use of Bin(1600,0.005) P(0,1,2)=0.0136
	= 0.0138	**A1**	
	Comp 0.025	**M1**	Valid comparison
	Evidence that mean no. failing to arrive has decreased	**A1**	**FT** their '0.0138' or '0.0136'. No contradictions
		5	

Question 68

(i)	H_0: $p = 0.1$ H_1: $p < 0.1$	**B1**	
		1	
(ii)	B(40, 0.1) stated or implied by use of	**B1**	e.g. by ${}^{40}C_x$ or $0.9^p \times 0.1^q$ ($p + q = 40$)
	$0.9^{40} + 40 \times 0.9^{39} \times 0.1$	**M1**	Correct working (if seen). If working not seen, M1 may be implied by 0.0805
	= 0.0805	**A1**	
		3	
(iii)	$z = 1.645$	**B1**	seen
	$\frac{6}{80} \pm z\sqrt{\frac{\frac{6}{80} \times \frac{(80-6)}{80}}{80}}$	**M1**	Formula of correct form. Must be a 'z'
	= 0.0266 to 0.123 (3 sfs)	**A1**	Allow 0.03 to 0.12 or better Must be an interval
		3	
(iv)	10% (or manufacturer's claim) is within CI Hence no reason to question claim	**B1**	**FT** Allow '10% is within CI, accept claim' oe Must include both parts. No contradictions. **FT** their CI Note if CI is centred on 0.1 allow ft 0.075 is within CI, accept claim
		1	

Question 69

(i)	Est(μ) = 1.85	**B1**	
	Est(σ^2) = $\frac{50}{49}\left(\frac{175.25}{50} - '1.85'^2\right)$	**M1**	Allow $\sqrt{\frac{50}{49}\left(\frac{175.25}{150} - '1.85'^2\right)}$ or 0.0290 for M1
	= 0.0842 (3 sf) or $\frac{33}{392}$	**A1**	Cao If $\frac{50}{49}$ omitted (giving var = 0.0825 or sd = 0.287) M0A0
		3	
(ii)	H_0: Pop mean time = 1.9 (h) H_1: Pop mean time < 1.9 (h)	**B1**	Allow 'μ' but not just 'mean'
	$\pm\frac{1.85-1.9}{\sqrt{\frac{'0.0842'}{50}}}$	**M1**	$\pm\frac{1.85-1.9}{\frac{'0.290'}{\sqrt{50}}}$ Accept totals method (92.5–95) / $\sqrt{4.21}$
	= –1.22	**A1**	= –1.22
	comp z = –1.645	**M1**	Or other valid comparison 0.888 or 0.889 < 0.95 OR 0.111 or 0.112>0.05
	No evidence that mean time < 1.9 h	**A1**	**FT** their z. Correct conclusion. No contradictions If $\frac{50}{49}$ not used in (1): var = 0.8225, sd = 0.907, cr = 1.17 can score all marks in **(ii)** Note- 2 tail test can score B0 M1 A1 M1 (comparison with 1.96) A0 (no ft) max3/5
		5	

Question 70

(i)	H_0: P(6) = $\frac{1}{6}$ H_1: P(6) < $\frac{1}{6}$	**B1**	
	$(\frac{5}{6})^{30} + 30(\frac{1}{6}) \times (\frac{5}{6})^{29} + {}^{30}C_2(\frac{1}{6})^2 \times (\frac{5}{6})^{28}$	**M1**	Allow one term incorrect, omitted or extra
	= 0.103	**A1**	
	'0.103' > 0.05	**M1**	
	No evidence (at 5% level) that die biased	**A1ft**	oe No contradictions
		5	
(ii)	$(\frac{5}{6})^{30} + 30(\frac{1}{6}) \times (\frac{5}{6})^{29}$	**M1**	
	P(Type I) = 0.0295	**A1**	
		2	

Question 71

(i)	Assume sd still 4.8 or is unchanged	**B1**	or Assume the 150 times can be treated as a random sample / are independent
	H_0: Pop mean = 26.5 H_1: Pop mean > 26.5	**B1**	Allow 'μ' but not just 'mean'
	$\frac{27.5-26.5}{\frac{4.8}{\sqrt{150}}}$	**M1**	Standardise, with √ Accept CV method
	= 2.552	**A1**	
	Comp with z-value '2.552' > 2.326	**M1**	or comp 1 – Φ('2.552') with 0.01 1 – 0.9946 = 0.0054 < 0.01
	There is evidence time has increased	**A1ft**	oe No contradictions (2 tail test scores max. B1 B0 M1 A1 M1 (for comparison with 2.576) A0 no ft)
		6	

!(ii)	No because pop is normal so distr of $\bar{X}$ is normal	**B1**	Condone just 'No because pop is normal'
		1	

Question 72

'(i)	H_0: Pop mean=546 H_1: Pop mean>546	**B1**	Both. Allow just μ, but not just 'mean'
	$\dfrac{581-546}{\frac{120}{\sqrt{40}}}$	**M1**	Standardising. Need $\frac{120}{\sqrt{40}}$
	=1.845 allow 1.844	**A1**	Allow 1.84 or 1.85 AWRT
	1.845<1.96	**M1**	OE. Or area comparison 0.0325>0.025 or large probabilities
	No evidence that mean weekly income has increased	**A1FT**	No contradictions. If H_1: ≠, and 2.241 used, max B0M1A1M1A0
		5	
(ii)	$\dfrac{a-546}{\frac{120}{\sqrt{40}}}=1.96$	**M1**	Standardise to find a. Need $\frac{120}{\sqrt{40}}$ **and** 546 **and** a value of z
	a = 583.19	**A1**	Allow 583 to 3sf
	$\dfrac{\text{'583.19'}-595}{\frac{120}{\sqrt{40}}}(=-0.622)$	**M1**	Standardise. Need $\frac{120}{\sqrt{40}}$ and 595
	ϕ('–0.622')=1 – ϕ('0.622')	**M1**	Consistent area
	0.267	**A1**	
		5	

Question 73

Assume trains are independent OR probability of being on time is constant	**B1**	Must be in context
H_0: P(on time)=0.92 H_1: P(on time)<0.92	**B1**	Both. Allow 'p' or π
$1-\left({}^{20}C_{17}\times0.92^{17}\times0.08^3+{}^{20}C_{18}\times0.92^{18}\times0.08^2+20\times0.92^{19}\times0.08+0.92^{20}\right)$	**M1**	Allow one end error Must have 1 – …
=0.0706 (3 sf)	**A1**	
Compare with 0.05	**M1**	Valid comparison needed
No evidence that percentage less than 92%	**A1FT**	OE No contradictions. <u>Method using normal approximation:</u> If the first B1B1 is earned then: CV $-1.566\left(\text{from}\dfrac{16.5-20\times0.92}{\sqrt{20\times0.92\times0.08}},\text{with continuity correction}\right)$ **or** CV=1.978 (without continuity correction) comp z=1.645 No evidence that % decreased (1.566) or evidence that % decreased (1.978) is awarded **SC2** after B marks
	6	

Question 74

(i)	H_0: Pop mean (or λ or μ) is 1.1 H_1: Pop mean (or λ or μ) is more than 1.1	**B1**	
	$P(X \geqslant 4) = 1 - e^{-1.1}\left(1 + 1.1 + \frac{1.1^2}{2} + \frac{1.1^3}{3!}\right)$	**M1**	Correct expression for either $P(X \geqslant 4)$ or $P(X \geqslant 5)$
	0.0257	**A1**	Correct value of either $P(X \geqslant 4)$ or $P(X \geqslant 5)$
	$P(X \geqslant 5) = 0.0257 - e^{-1.1} \times \frac{1.1^4}{4!} = 0.00544$	**B1**	B1 for the other value (Note use of $P(X < 4) = 0.9743$ and $P(X < 5) = 0.99456$ can score only if comparison with 0.99 seen)
	$0.00544 < 0.01 < 0.0257$	**M1**	OE stated (valid comparison)
	There is evidence mean has increased	**B1**	**SC** $P(X \geqslant 6) = 0.000968$ M1A1 Conclusion B1
		6	
(ii)	Concluding mean has increased when it has not	**B1**	In context
	'0.00544'	**B1FT**	FT *their* $P(X \geqslant 5)$, dep < 0.01
		2	
(iii)	$e^{-7.0}\left(1 + 7 + \frac{7^2}{2} + \frac{7^3}{3!} + \frac{7^4}{4!}\right)$	**M1**	Correct expression for $P(X \leqslant 4 \mid \lambda = 7.0)$
	0.173 (3 sf)	**A1**	
		2	

Question 75

(i)(a)	Assume standard deviation for the region is 7.1	**B1**	Or standard deviation is same as for whole population OE
	$\frac{63.2 - 65.2}{\frac{7.1}{\sqrt{n}}} = -2.182$	**M1**	Attempt to find correct equation (accept +2.182)
	$n = \{-2.182 \times 7.1 \div (-2)\}^2$	**A1**	Any correct expression for n or $\sqrt{n}$. SOI
	$n = 60$	**A1**	CWO. Must be an integer
		4	
(i)(b)	H_0: population mean (or μ) = 65.2 H_1: population mean (or μ) < 65.2	**B1**	Not just 'mean'
	$2.182 > 1.751$	**M1**	Or valid area comparison.
	There is evidence that animals are shorter in this region	**A1**	CWO. No contradictions
		3	

(ii)	Population unknown or population not given as normal	**B1**	Allow population not normal. Accept distribution of X unknown.
		1	

Question 76

(a)	$P(X \leqslant n)$ $(n \leqslant 20)$ attempted, using B(20, 0.95)	**M1**	OE
	$P(X \leqslant 17)$ <u>or</u> $P(X \leqslant 16)$ attempted, using B(20, 0.95)	**M1**	OE
	$(P(X \leqslant 17)) = 0.0755$ <u>and</u> $(P(X \leqslant 16)) = 0.0159$	**A1**	OE (0.925 and 0.984) both correct
	Rej region is $X \leqslant 16$ or $X < 17$	**A1**	Dependent on M1M1 and previous answers correct to at least 0.075/0.076 and 0.016 **or** 0.92/0.93 and 0.98 Correct unsupported answers of 0.0755 and 0.0159 OE scores M1 M1 A0
		4	
(b)	0.0159	**B1**	FT *their* rejection region, from Binomial in *a*, if $P(X$ in rejection region$) < 0.025$
		1	
(c)	Use of B(20, 0.7)	**M1**	
	$P(X > 16 \mid p = 0.7)$	**M1**	Correct method using B(20, 0.7)
	= 0.107	**A1**	
		3	

Question 77

(a)	est $(\mu) = 37.6$ or $\frac{1504}{40}$ or $\frac{188}{5}$	**B1**	
	est $(\sigma^2) = \frac{40}{39}\left[\frac{57760}{40} - 37.6^2\right] = 31.0154 = \frac{2016}{65}$	**M1**	Correct substitution in any correct formula $\frac{1}{39}\left[57760 - \frac{1504^2}{40}\right]$
	= 31.(0) (3 sf)	**A1**	Accept $\frac{2016}{65}$ or $31\frac{1}{65}$
		3	
(b)	H_0: Pop mean (or μ) = 39.2 H_1: Pop mean (or μ) < 39.2	**B1**	Both. Not just 'mean'
	$\dfrac{'37.6' - 39.2}{\frac{\sqrt{'31.0154'}}{\sqrt{40}}}$	**M1**	Allow use of biased variance (30.2), must have $\sqrt{40}$
	= –1.817	**A1**	**SC** FT use of biased = –1.840 for A1
	'1.817' > 1.645 OE	**M1**	Valid comparison '*their* 1.817' with 1.645 or valid area comparison 0.0346 < 0.05 OE
	There is evidence that mean time has decreased	**A1FT**	FT *their* 1.817; in context, not definite, no contradictions **SC** For 2 tail test: H_1: $\mu \neq 39.2$ and comp 1.96, max B0M1A1M1A0 (no FT for final mark)
		5	

Question 78

'(a)	Later customers might spend times different from first ones	B1
		1
'(b)	0.02	B1
	Concluding that $\mu \neq 6.0$, when actually $\mu = 6.0$	B1
		2
(c)	H_0: $\mu = 6.0$ H_1: $\mu \neq 6.0$	B1
	$\dfrac{6.8-6.0}{\sqrt{\dfrac{4.8}{50}}}$	M1
	2.582	A1
	comp 2.326	M1
	Evidence that $\mu \neq 6.0$	A1
		5
(d)	Population distribution unknown	B1
		1

Question 79

H_0: $\lambda = 104$ (or 5.2) H_1: $\lambda > 104$ (or 5.2)	B1
N(104, 104) stated or implied	B1
$\dfrac{124.5-104}{\sqrt{104}}$	M1
2.010	A1
$2.010 > 1.96$	M1
There is evidence that λ has increased	A1
	6

Question 80

(a)	$E(X) = 2$	**B1**
	$0.2 \times 1 + 0.4 \times 2^2 + 0.2 \times 3^2 + 0.1 \times 4^2 - 2^2$ (= 1.2) **AG**	**B1**
		2
(b)	$\frac{a-2}{\sqrt{1.2 \div 200}} = \phi^{-1}(0.9)$ (**M1** for LHS, **M1** for RHS)	**M1** **M1**
	$a = 2 + \sqrt{1.2 \div 200} \times 1.282$	**M1**
	2.10 (3 sf)	**A1**
		4
(c)	Yes, because X is not normally distributed.	**B1**
		1
(d)	H_0: pop mean = 2 H_1: pop mean < 2	**B1**
	$\frac{1.86-2}{\sqrt{1.2 \div 200}}$	**M1**
	1.807	**A1**
	comp $z = 1.645$	**M1**
	There is evidence that the spinner is biased so that mean is less than 2	**A1**
		5

Question 81

(a)	H_0: Proportion = 0.05 H_1: Proportion > 0.05	**B1**
		1
(b)	$1 - (0.95^{25} + 25 \times 0.95^{24} \times 0.05 + {}^{25}C_2 \times 0.95^{23} \times 0.05^2 + {}^{25}C_3 \times 0.95^{22} \times 0.05^3)$	**M1**
	Completely correct expression	**A1**
	0.0341	**A1**
		3
(c)	Type II	**B1**
	Will conclude proportion not increased	**B1**
		2

Question 82

(a)	$(1^2+2^2+3^2+4^2+5^2)\div 5-3^2$ (= 2 **AG**)	**B1**
		1
(b)	N(3, 2)	**M1**
	$\frac{2.6-\text{"3"}}{\sqrt{\frac{2}{40}}}(=-1.789)$	**M1**
	$\Phi(\text{"}-1.789\text{"}) = 1-\Phi(\text{"}1.789\text{"})$	**M1**
	0.0367 to 0.0368	**A1**
		4
(c)	Concluding that spinner is unbiased when it is biased	**B1**
		1

Question 83

(a)	Assume standard deviation unchanged or standard deviation = 0.08	**B1**
	Assume yields normally distributed	**B1**
		2
(b)	H_0: Population mean yield (or μ) = 0.56 H_1: Population mean yield (or μ) > 0.56	**B1**
	$\frac{0.61-0.56}{\frac{0.08}{\sqrt{10}}}$	**M1**
	1.976	**A1**
	Comp 1.96	**M1**
	There is evidence that mean yield has increased	**A1**
		5

Question 84

(a)	$\frac{40-38.4}{\frac{6.9}{\sqrt{30}}} = 1.270$ $\quad \frac{38-38.4}{\frac{6.9}{\sqrt{30}}} = -0.3175$	**M1** **A1** **A1**
	$\Phi(\text{'}1.270\text{'}) - (1-\phi(\text{'}0.3175\text{'})$	**M1**
	= 0.523 (3 sf) or 0.522	**A1**
		5

(b)(i)	2-tail because looking for 'change', not decrease or increase	**B1**
		1

(b)(ii)	H_0: Population mean journey time (or μ) = 38.4 H_1: Population mean journey time (or μ) $\neq$ 38.4	**B1**
	$\dfrac{40.2-38.4}{\dfrac{6.9}{\sqrt{30}}}$	**M1**
	= 1.429	**A1**
	'1.429' < 1.645	**M1**
	There is no evidence that mean journey time has changed.	**A1 FT**

(b)(iii)	Yes, because population distribution unknown.	**B1**
		1

Question 85

(a)	$\sqrt{2.1}$ or 1.45 (3 sf)	**B1**
		1
(b)	$\lambda = 4.2$	**B1**
	$1 - e^{-4.2}(1 + 4.2)$	**M1**
	$= 0.922$ (3 sf)	**A1**
		3
(c)	$\lambda = 6.3$ $e^{-6.3}\left(\frac{6.3^5}{5!}+\frac{6.3^6}{6!}+\frac{6.3^7}{7!}\right)$	**M1**
	$= 0.455$ (3 sf)	**A1**
		2
(d)	H_0: $\lambda = 6.3$ H_1: $\lambda < 6.3$	**B1**
	$P(X \leqslant 2) = e^{-6.3}\left(1+6.3+\frac{6.3^2}{2!}\right)$	**M1**
	$= 0.0498$ or 0.0499	**A1**
	'0.0498' < 0.1	**M1**
	There is evidence that mean number of absences has decreased.	**A1 FT**
		5
(e)	H_0 rejected	***B1 FT**
	Hence Type I error possible	**DB1 FT**
		2

Question 86

(a)	H_0: P(contains offer) = $\frac{1}{3}$ H_1: P(contains offer) < $\frac{1}{3}$	**B1**
	P(0,1 or 2 offers in 20 | H_0) $= \left(\frac{2}{3}\right)^{20} + 20\left(\frac{2}{3}\right)^{19}\left(\frac{1}{3}\right) + {}^{20}C_2\left(\frac{2}{3}\right)^{18}\left(\frac{1}{3}\right)^2$	**M1**
	= 0.0176 (3sf)	**A1**
	'0.0176' < 0.1	**M1**
	(Reject H_0) No evidence (at 10% level) to support manufacturers claim	**A1 FT**
		5
(b)	$1 - P(X \leqslant 3)$	**M1**
	$=1-\left[\left(\frac{6}{7}\right)^{20}+20\left(\frac{6}{7}\right)^{19}\left(\frac{1}{7}\right)+{}^{20}C_2\left(\frac{6}{7}\right)^{18}\left(\frac{1}{7}\right)^2+{}^{20}C_3\left(\frac{6}{7}\right)^{17}\left(\frac{1}{7}\right)^3\right]$	**A1**
	= 0.318 (3sf)	**A1**
		3
(c)	Concluding that prop is 1 in 3 when it is actually less(1 in 7)	**B1**
		1

Question 87

$\text{est}(\mu) = \frac{1850}{200}$ or 9.25	**B1**
$\text{est}(\sigma^2) = \frac{200}{199}\left(\frac{17850}{200} - \left(\frac{1850}{200}\right)^2\right)$ or $\frac{1}{199}\left(17850 - \frac{1850^2}{200}\right)$	**M1**
$= 3.71$ or 3.7060 or $\frac{1475}{398}$	**A1**
$H_0: \mu = 8.9$ $H_1: \mu \neq 8.9$	**B1**
$\dfrac{\frac{1850}{200} - 8.9}{\sqrt{\frac{"3.706"}{200}}}$	**M1**
$= 2.57$(3sf) (or using areas $0.00507 - 0.0051$)	**A1**
$2.24 < 2.57$ or $0.00507 < 0.0125$	**M1**
(Reject H_0) There is evidence that μ is not 8.9	**A1 FT**
	8

Question 88

(a)	H_0: population proportion = 0.08 OE H_1: population proportion > 0.08 OE	**B1**	Allow '$p = 0.08$' etc.
	$P(X \geq 4) = 1 - P(X \leq 3) =$ $1 - (0.92^{25} + 25 \times 0.92^{24} \times 0.08 + {}^{25}C_2 \times 0.92^{23} \times 0.08^2 + {}^{25}C_3 \times 0.92^{22} \times 0.08^3)$	**M1**	Allow 1 – (one term omitted or extra or wrong).
	0.135 (3 sf)	**A1**	
	$0.135 > 0.05$	**M1**	Valid comparison. Note: '0.865'<0.95 can score M1 A1 and can recover previous M1 A1 for 0.865.
	There is no evidence that proportion owning Chantor has increased	**A1 FT**	In context. Not definite, e.g. not 'Proportion not increased'. No contradictions.
		5	
(b)	H_0 was not rejected.	***B1 FT**	H_0 was rejected (consistent with **(a)**).
	Hence Type II might have been made.	**DB1 FT**	Type I error.
		2	
(c)	$P(X \geq 5) = 1 - P(X \leq 4)$ $= 1 - \left((1 - 0.1351) + {}^{25}C_4 \times 0.92^{21} \times 0.08^4\right)$ [= 0.0451]	***M1**	Attempted. Note: If critical region method used in **(a)** marks can be awarded here.
	$0.0451 < 0.05$	**A1**	Comparison of 0.045[1] with 0.05. Note: If critical region method used in **(a)** marks can be awarded here.
	P(Type I error) = 0.0451 or 0.0452	**A1**	Dependent on M1* only. **SC** Unsupported answers score: **B1** for 0.0451<0.05 and **B1** for final answer 0.0451 only.
		3	

Question 89

(a)	One-tail because investigating whether "higher"	**B1**	OE. Must have both parts.
		1	
(b)	H_0: Population mean (or μ) in city same as for others H_1: Population mean (or μ) in city greater than for others	**B1 FT**	If **(a)** two-tail: H_0: Pop mean (or μ) in city same as for others. H_1: Pop mean (or μ) in region different from others.
	$2.41 > 2.326$ or $0.008 < 0.01$ or $0.992 > 0.99$	**M1**	If **(a)** two-tail: $2.41 < 2.576$ or $0.992 < 0.995$.
	There is evidence that buildings are higher [on average].	**A1 FT**	In context, not definite. No contradictions. If **(a)** two-tail: There is no evidence that the [average] height of buildings is different.
		3	

Question 90

(a)(i)	H_0: $\lambda = 2.4$ H_1: $\lambda > 2.4$	**B1**	Accept λ or μ Accept 2.4 or 0.8 (per year)
		1	
(a)(ii)	$1 - e^{-2.4}(1 + 2.4 + \frac{2.4^2}{2} + \frac{2.4^3}{3!} + \frac{2.4^4}{4!})$	**M1**	Any λ; allow one end error
	0.0959 (3 sf)	**A1**	**SC** unsupported answer 0.0959 scores B1 only not M1A1
	$0.0959 > 0.05$	**M1**	Valid comparison Use of $0.9041 < 0.95$ can recover either M1A1 or B1
	There is evidence that Jane's claim not justified or There is insufficient evidence to support Jane's claim	**A1 FT**	OE. In context, not definite, e.g. not 'Jane is wrong', no contradictions. Condone omission of Jane.
		4	
3(b)	Mean not constant so Poisson model not valid	**B1**	
		1	

Question 91

(a)	Conclude (mean) (journey) time has not decreased when in fact it has.	**B1**	OE in context
		1	
(b)	H_0: Pop mean (or μ) = 1.4 H_1: Pop mean (or μ) < 1.4	**B1**	May be seen in **(a)**
	$\frac{1.36 - 1.4}{\frac{0.12}{\sqrt{50}}}$	**M1**	Accept totals method $\frac{68 - 70}{\sqrt{50} \times 0.12}$ No mixed methods or no standard deviation/variance mixes
	–2.357 or – 2.36	**A1**	Correct z or correct area if used
	$-2.357 < -1.96$ or $0.0092 < 0.025$ or $0.9908 > 0.975$ Or CV method $1.36 < 1.367$	**M1**	valid comparison
	There is evidence that (mean) (journey) times have decreased	**A1 FT**	in context not definite no contradictions NB use of two tail test scores max B0M1A1M1A0 no ft for two tail test
		5	
(c)	H_0 was rejected OE	***B1 FT**	FT H_0 was accepted OE
	Type I	**DB1 FT**	FT Type II
		2	

Question 92

(a)	Conclude that (population) mean time has changed (or is not 42.4) although μ has not changed (or is still 42.4)	B1	OE. In context.
		1	
(b)	H_0: population mean (or μ) = 42.4 H_1: population mean (or μ) $\neq$ 42.4	B1	Not just 'mean'. (could be seen in **(a)**)
	$\pm \dfrac{45.6-42.4}{\sqrt{38.2 \div 20}}$	M1	For standardising (must have $\sqrt{20}$)
	$\pm$ 2.315	A1	
	2.240 < '2.315'	M1	For valid comparison (accept 2.241) or P(z > 2.315) = 0.0103 < 0.0125 oe
	There is evidence that μ or mean time has changed	A1 FT	FT *their z* In context, not definite. No contradictions. **Note:** Accept correct alternative methods **SC**: One tail test no FT. Can score B0 M1 A1 M1 (comparison with 1.96) A0 (maximum 3 out of 5)
		5	

Question 93

(a)	H_0: $p = \dfrac{1}{4}$ H_1: $p \neq \dfrac{1}{4}$	B1	or H_0: μ = 25 or H_1: $\mu \neq$ 25
		1	
(b)	$N\left(25, \dfrac{75}{4}\right)$	B1	SOI. Allow B1 for $N\left(25, \dfrac{75}{4}\right)$ or N(0.25,0.001875) SOI.
	$\pm \dfrac{15.5-25}{\sqrt{\dfrac{75}{4}}}$ or $\dfrac{\dfrac{15.5}{100}-0.25}{\sqrt{\dfrac{0.25\times 0.75}{100}}}$	M1	Standardise with *their* N(25,…) Allow with no or wrong continuity correction.
	$\pm$ –2.194 (2.19)	A1	
	–2.326 < –2.194 or 0.0141 > 0.01 or 0.9859 < 0.99	M1	For valid comparison (accept 2.326 to 2.329)
	No evidence to reject that the probability is $\dfrac{1}{4}$	A1 FT	OE must be in context and not definite, e.g. not 'Claim untrue'. No contradictions. FT *their z* ; dependent on two–tailed test (one-tailed test can score B1 M1 A1 M1 A0) **SC** for use of Binomial B(100,0.25) P = 0.0111 for B1 and then comparison with 0.01 and correct conclusion for B1, maximum 2 out of 5 marks.
		5	

Question 94

(a)	Not representative (of all students in the school)	**B1**	OE idea of 'not being representative' e.g. different grades in the school have different characteristics/proportions.... Don't accept 'not random' or 'biased' without further explanation.
		1	
(b)	H_0: P(not correct uniform) = 0.15 H_1: P(not correct uniform) < 0.15	**B1**	Allow "p"
		1	
(c)	Any two probs attempted using B(50,0.15)	**M1**	
	$P(X \leqslant 3) = 0.85^{50} + 50 \times 0.85^{49} \times 0.15 + {}^{50}C_2 \times 0.85^{48} \times 0.15^2 + {}^{50}C_3 \times 0.85^{47} \times 0.15^3$	**M1**	Attempt the tail probability P(0,1,2,3) with B(50,0.15) must be added.
	$P(X \leqslant 4) = 0.04605 + {}^{50}C_4 \times 0.85^{46} \times 0.15^4$	**M1**	OE. *Their* $P(X \leqslant 3) + P(X = 4)$ or P(0,1,2,3,4) with B(50,0.15) must be added.
	$P(X \leqslant 3) = 0.0460$ or 0.0461 [<0.05] $P(X \leqslant 4) = 0.112$ or [>0.05]	**A1**	Both correct. OR if $P(X \leqslant 4)$ not seen; P(4)=0.06606 **and** 0.06606>0.05 **and** $P(X \leqslant 3)$=0.0460 scores M1 A1
	P(Type I) = 0.0460 or 0.0461 (3 sf)	**A1**	Dependent on second M1. **SC** If M1M1M1A0 scored allow A1FT for incorrect $P(X \leqslant 3)$ as long as <0.05
		5	
(d)	4 is outside critical region ($\leqslant$3) OE or $P(X \leqslant 4) = 0.112$ which is > 0.05	**M1**	FT working from **(c)**.
	No evidence that proportion not wearing the correct uniform has decreased (Accept Ho)	**A1**	In context not definite, e.g. not 'Proportion has not decreased'. No contradiction.
		2	
(e)	Not rejected H_0	***B1 FT**	FT If Reject H_0 in **(d)**
	Type II	**DB1 FT**	FT Type I
		2	

Question 95

(a)	$H_0: \mu = 64.6$ $H_1: \mu < 64.6$	**B1**	Allow population mean, not just 'mean'.
	$[\pm]\frac{63.5-64.6}{5.2\div\sqrt{100}}$	**M1**	Standardising. Must have $\sqrt{100}$.
	$[\pm]-2.115$	**A1**	Accept -2.12 (3sf)
	'2.115' > 1.96 or '–2.115' < –1.96 [do not accept H_0]	**M1**	Valid comparison (0.0172 < 0.025 for area comparison).
	There is evidence that $\mu < 64.6$	**A1 FT**	Not definite, e.g. not '$\mu < 64.6$'. in context. No contradictions. Accept critical value method leading to 63.5 < 63.58 or 64.6 > 64.52.
		5	
(b)	$\frac{m-64.6}{5.2\div\sqrt{100}} = -1.96$	**M1**	Finding the critical value using $N\left(64.6, \frac{5.2}{\sqrt{100}}\right)$ and a z value.
	$m = 63.5808$	**A1**	
	$\frac{63.5808-62.7}{5.2\div\sqrt{100}}$ [= 1.694]	**M1**	Standardising using $N\left(62.7, \frac{5.2}{\sqrt{100}}\right)$ and a critical value.
	$1 - \Phi$('1.694')	**M1**	For area consistent with *their* values.
	0.0451	**A1**	Accept answers that round to 0.045.
		5	

Question 96

(a)(i)	Po(0.025)	**B1**	For Poisson and correct parameter.
	$n = 2500 > 50$, $np = 0.025 < 5$	**B1**	Must show 2500 and 0.025. Accept $p = \frac{1}{100000} < 0.1$ in place of $np = 0.025 < 5$.
		2	
(a)(ii)	$1 - e^{-0.025}$	**M1**	Allow any λ. FT *their* **(a)(i)** if normal; must have continuity correction.
	0.0247 (3sf)	**A1**	Must be from Poisson. Unsupported correct answer scores **B1** instead of **M1 A1**.
		2	
(b)	$H_0: p = 0.3$ $H_1: p < 0.3$	**B1**	
	$0.7^{28} + 28 \times 0.7^{27} \times 0.3 + {}^{28}C_2 \times 0.7^{26} \times 0.3^2 + {}^{28}C_3 \times 0.7^{25} \times 0.3^3 + {}^{28}C_4 \times 0.7^{24} \times 0.3^4$	**M1**	Use of B(28, 0.3). Addition of terms must be intended. Allow one term wrong or omitted or extra.
	0.0474	**A1**	Unsupported correct answer scores **B1** instead of **M1 A1**.
	0.0474 > 0.02 [Not reject H_0]	**M1**	Valid comparison.
	No evidence that suspicion is true.	**A1 ft**	Not definite e.g. not 'Suspicion is not true', in context, no contradictions. SC use of N(8.4, 5.88) leading to 0.054 > 0.2 OE can score **B1** only for comparison and correct conclusion. Correct hypotheses with p will also score B1.
		5	

Question 97

(a)	H_0: $P(0) = \frac{1}{10}$ H_1: $P(0) < \frac{1}{10}$	**B1**	Accept p.
		1	
(b)	For B(30,0.1)	**M1**	Used not just stated.
	$P(X = 0) = 0.9^{30}$ [= 0.0424] [<0.1]	**M1**	
	$P(X = 0 \text{ or } 1) = 0.9^{30} + 30\times0.9^{29}\times0.1=0.184$ [>0.1]	**B1**	Accept 0.184 or 0.183.
	Rejection region is 0 zeros	**A1**	Dependent on **M1 M1** and at least one comparison, no errors seen. **SC** One unsupported correct answer 0.0424/0.184(or 0.183) and correct rejection region scores **B1**; with comparison with 0.1 scores **B2**. Two unsupported correct answers 0.0424 and 0.184(or 0.183) and correct rejection region scores **B2** or if with one comparison with 0.1 scores **B3**.
		4	
(c)	0.0424	**B1**	FT *their* **(b)** must have a critical region (only follow though Binomial), dependent on answer < 0.1.
		1	
(d)	Bin(30, $\frac{1}{40}$)	**B1**	SOI
	$1 - 0.975^{30}$	**M1**	FT *their* rr and with Bin(30, 1/40)).
	0.532 (3dp)	**A1**	SC Unsupported correct answer scores **B2** only.
		3	
(e)	Not concluding that the probability is less than $\frac{1}{10}$, when in fact it is.	**B1**	In context.
		1	

Question 98

(a)	Fireworks are destroyed when tested.	**B1**	
		1	
(b)	H_0: Pop mean time lasted (or μ) = 30 H_1: Pop mean time lasted (or μ) < 30	**B1**	Not just 'mean'.
	$\pm \dfrac{29-30}{\frac{5}{\sqrt{100}}}$	**M1**	For standardising. Must have $\sqrt{100}$. Use of totals N(3000,2500) giving $\dfrac{(2900-3000)}{\sqrt{2500}}$ scores **M1**. No mixed methods.
	± -2	**A1**	
	$-2 > -2.326$ [Do not reject H_0]	**M1**	Accept –2.326 to –2.329. Valid comparison or area comparison 0.0228>0.01 or 0.9772<0.99. Accept CR method 28.837<29 or 30.163>30.
	There is not enough evidence that mean time lasted is less than 30 seconds OR Not enough evidence to support the inspector's suspicion	**A1 FT**	In context (if used need mean or time / condone average instead of mean), not definite, e.g. not 'mean time lasted is not less than 30 seconds'. No contradictions. **Note** 2 tailed test can score **B0 M1 A1 M1** (comparison with 2.574–2.579) **A0** (no FT).
		5	
(c)	Yes. Because population distribution is unknown [condone not Normal].	**B1**	Both needed. Condone X for parent population.
		1	

Question 99

(a)	$H_0: \mu = 64.6$ $H_1: \mu < 64.6$	**B1**	Allow population mean, not just 'mean'.
	$[\pm]\dfrac{63.5 - 64.6}{5.2 \div \sqrt{100}}$	**M1**	Standardising. Must have $\sqrt{100}$.
	$[\pm]-2.115$	**A1**	Accept -2.12 (3sf)
	'2.115' > 1.96 or '–2.115' < –1.96 [do not accept H_0]	**M1**	Valid comparison (0.0172 < 0.025 for area comparison).
	There is evidence that $\mu < 64.6$	**A1 FT**	Not definite, e.g. not '$\mu < 64.6$'. in context. No contradictions. Accept critical value method leading to 63.5 < 63.58 or 64.6 > 64.52.
		5	
(b)	$\dfrac{m - 64.6}{5.2 \div \sqrt{100}} = -1.96$	**M1**	Finding the critical value using $N\left(64.6, \dfrac{5.2}{\sqrt{100}}\right)$ and a z value.
	$m = 63.5808$	**A1**	
	$\dfrac{63.5808 - 62.7}{5.2 \div \sqrt{100}}$ [= 1.694]	**M1**	Standardising using $N\left(62.7, \dfrac{5.2}{\sqrt{100}}\right)$ and a critical value.
	$1 - \Phi$('1.694')	**M1**	For area consistent with *their* values.
	0.0451	**A1**	Accept answers that round to 0.045.
		5	

Question 100

(a)(i)	Po(0.025)	**B1**	For Poisson and correct parameter.
	$n = 2500 > 50$, $np = 0.025 < 5$	**B1**	Must show 2500 and 0.025. Accept $p = \dfrac{1}{100000} < 0.1$ in place of $np = 0.025 < 5$.
		2	
(a)(ii)	$1 - e^{-0.025}$	**M1**	Allow any λ. FT *their* **(a)(i)** if normal; must have continuity correction.
	0.0247 (3sf)	**A1**	Must be from Poisson. Unsupported correct answer scores **B1** instead of **M1 A1**.
		2	
(b)	$H_0: p = 0.3$ $H_1: p < 0.3$	**B1**	
	$0.7^{28} + 28 \times 0.7^{27} \times 0.3 + {}^{28}C_2 \times 0.7^{26} \times 0.3^2 + {}^{28}C_3 \times 0.7^{25} \times 0.3^3 + {}^{28}C_4 \times 0.7^{24} \times 0.3^4$	**M1**	Use of B(28, 0.3). Addition of terms must be intended. Allow one term wrong or omitted or extra.
	0.0474	**A1**	Unsupported correct answer scores **B1** instead of **M1 A1**.
	0.0474 > 0.02 [Not reject H_0]	**M1**	Valid comparison.
	No evidence that suspicion is true.	**A1 ft**	Not definite e.g. not 'Suspicion is not true', in context, no contradictions. SC use of N(8.4, 5.88) leading to 0.054 > 0.2 OE can score **B1** only for comparison and correct conclusion. Correct hypotheses with p will also score B1.
		5	

Question 101

(a)	$H_0: \mu = 25.5$ $H_1: \mu < 25.5$	**B1**	
	$\frac{23.7-25.5}{5.2 \div \sqrt{40}}$	**M1**	Must have √40
	$= -2.189$	**A1**	
	'2.189' < 2.326	**M1**	For valid comparison For two-tailed test: allow compare 2.576 if $H_1: \mu \neq 25.5$
	[Accept H_0] No evidence that mean time has decreased	**A1 FT**	In context, not definite, no contradictions FT *their* 2.189 but no FT for two-tailed test **N.B.** Use of two-tailed test can score max B0 M1 A1 M1 A0 Condone use of critical value method (23.59 M1 A1 and 23.7 > 23.59 M1 A1 correct conclusion or 25.612 M1 A1 and 25.5 < 25.612 M1 A1 with correct conclusion)
		5	
(b)	No, because H_0 was not rejected	**B1 FT**	FT *their* conclusion in **(a)**
		1	

Question 102

$B(300, \frac{1}{5}) \rightarrow N(60,48)$	**B1**	SOI
$\frac{45.5-60}{\sqrt{48}}$	**M1**	Condone with wrong or no continuity correction
$= -2.093$	**A1**	
'2.093' > 1.96	**M1**	Valid comparison Note: $\phi('-2.093')$ (= 0.0182), 0.0182< 0.025
[Evidence to reject H_0] There is evidence that P(landing on blue) $\neq \frac{1}{5}$	**A1 FT**	Allow 'There is evidence that the spinner is biased.' In context, not definite, no contradictions Condone critical values method (critical value 46.42 M1 A1 and 45.5 < '46.42' M1 for valid comparison A1 for correct conclusion)
		SC: 0.0182 unsupported: 0.0182 < 0.025 And there is evidence that the spinner is biased. In context, not definite B1 only
	5	

Question 103

(a)	Batteries unusable after testing or Population too big or too costly or too time consuming to use the whole population oe	**B1**	
		1	
(b)	H_0: $\mu = 150$ H_1: $\mu < 150$	**B1**	Or population mean = 150; not just 'mean' = 150
	$\frac{147-150}{\sqrt{225} \div \sqrt{120}}$	**M1**	Allow with continuity correction Need $\sqrt{120}$
	–2.191	**A1**	Condone – 2.19
	–2.191 < –2.054 [or –2.055]	**M1**	OE. For valid comparison with 2.054 or 2.055 Or 0.0143 (or 0.0142) < 0.02 For two tail test allow comp –2.326 OE if H_1: $\mu \neq 150$ (can score B0M1A1M1A0 max 3/5)
	[Reject Ho] There is evidence that the (mean) life of type *B* is less than type *A* (or less than 150)	**A1 FT**	In context, not definite with no contradictions Accept critical value method 147.19 M1A1 147 < 147.19 M1 conclusion A1 Or 150 > 149.81
		5	
(c)	$147 \pm z \times \frac{15}{\sqrt{120}}$	**M1**	Expression of correct form must be a *z* value
	z = 1.881 [or 1.882]	**B1**	
	144 to 150 (3 s.f.)	**A1**	Must be an interval Incorrect *z* value can only score M1B0A0
		3	

Question 104

(a)	Conclude more than 10% of the students are left handed when this is not true	**B1**	OE. Must be in context (accept use of p). Need the context of one tail test.
		1	
(b)	$1 - (0.9^{20} + 20 \times 0.9^{19} \times 0.1 + {}^{20}C_2 \times 0.9^{18} \times 0.1^2 + {}^{20}C_3 \times 0.9^{17} \times 0.1^3 + {}^{20}C_4 \times 0.9^{16} \times 0.1^4)$	**M2**	M2: fully correct M1: attempt 1 – P(X = 0, 1, 2, 3, 4); allow 1 – P(X = 0,1,2,3,4,5) or 1 – P(X = 0,1,2,3) need 1 – … the method mark cannot be implied
	0.0432 (3 s.f.)	**A1**	If M0 awarded allow SC B2 for 0.0432
		3	
(c)	$0.7^{20} + 20 \times 0.7^{19} \times 0.3 + {}^{20}C_2 \times 0.7^{18} \times 0.3^2 + {}^{20}C_3 \times 0.7^{17} \times 0.3^3 + {}^{20}C_4 \times 0.7^{16} \times 0.3^4$	**M1**	Attempt to find $P(\leqslant 4)$ using B(20,0.3) Allow one end error The method mark cannot be implied
	0.238 or 0.237 (3 s.f.)	**A1**	If M0 awarded allow SC B1for 0.238 or 0.237
		2	

Question 105

(a)	H_0: Pop mean = 4.6 [or 9.2] H_1: Pop mean < 4.6 [or 9.2]	**B1**	or $\lambda = 4.6$ or μ (Not just 'mean') or $\lambda < 4.6$
		1	
(b)	Use of Poisson with $\lambda = 9.2$	**B1**	SOI
	$P(X \leqslant 3) = e^{-9.2}(1 + 9.2 + \frac{9.2^2}{2} + \frac{9.2^3}{3!}) = 0.0184$ or 0.018 [< 0.02]	**M1**	At least one of these attempted correct λ (with Poisson expression seen not implied)
	$P(X \leqslant 4) = 0.0184 + e^{-9.2} \times \frac{9.2^4}{4!} = 0.0486$ or 0.049 [> 0.02]	***A1**	Both correct SC Use of $\lambda = 4.6$ scores B1 for $P(X = 0) = 0.01[0][1]$ and $P(X \leqslant 1) = 0.056[3]$only
	CR is $X \leqslant 3$	**DA1**	From CWO and at least one comparison seen SC If M0 awarded allow *B1 for both 0.018 and 0.049 or better and DB1 for correct critical region from CWO and at least one comparison seen.
		4	
(c)	5 is not in critical region OR $P(X \leqslant 5) = 0.104 > 0.02$ so [not reject H_0] no evidence that number of cars arriving is now fewer	**M1** **A1 FT**	For a comparison (i.e. 5 > 3) OE In context, not definite No contradictions e.g. not 'No. of cars arriving is not fewer' ft *their* critical region if used (but must be from Poisson and integers)
		2	
(d)	No, because H_0 was not rejected	**B1 FT**	OE, FT *their* **(c)**
		1	
(e)	N(276, 276)	**B1**	SOI
	$\frac{300.5 - 276}{\sqrt{276}}$ [= 1.475]	**M1**	Standardising with *their* values Allow with wrong or no continuity correction
	$1 - \phi(\text{'}1.475\text{'}) = 0.0701$ (3 s.f.)	**A1**	SC Use of Poisson: B1 for answer 0.0727 (3 sf)
		3	

Question 106

H_0: Pop mean height = 2.3 H_1: Pop mean height > 2.3	**B1**	Not just 'mean' Allow μ
$\frac{2.4 - 2.3}{\frac{0.4}{\sqrt{60}}}$	**M1**	For standardising, must have $\sqrt{60}$
1.936 or 1.937 or 1.94	**A1**	
'1.936' < 1.96	**M1**	Valid comparison with 1.96 Or 2.64% > 2.5% OE Accept 1.936 < 2.24 or 2.64% > 1.25% OE if $H_1 \mu \neq 2.3$
[Do not reject H_0] No evidence that (mean) height (with fertiliser) is more than without	**A1 FT**	FT *their z* In context, not definite. E.g. not 'Mean height is not greater' with no contradictions No FT for 2 tail test (max B0 M1 A1 M1 A0 3/5) Accept critical values method 2.401 (M1 A1) 2.4 < 2.401 (M1) Condone 2.299 (M1 A1) < 2.3 (M1) A1 conclusion
	5	

Question 107

(a)	H_0: pop mean run time = 28.2 mins H_1: pop mean run time < 28.2 mins	B1	Allow 'μ'. Not 'mean journey time'
		1	
(b)	$\frac{27-28.2}{4/\sqrt{40}}$ [= –1.897]	M1	For standardising Must have $\sqrt{40}$
	$\Phi(<$ '–1.897'$) = 1 - \Phi($'1.897'$)$	M1	For correct area consistent with these values
	0.0289 (3 sf)	A1	
		3	
(c)	H_0 is not rejected so…	M1	
	Type II error can be made and Type I error cannot be made	A1	Both needed (accept 'only a Type II error could be made')
		2	

Question 108

H_0: P(correct) = $\frac{1}{6}$ H_1: P(correct) > $\frac{1}{6}$	B1	Allow $p = \frac{1}{6}$ Allow $p > \frac{1}{6}$
$1 - ({}^{15}C_4 \times (\frac{5}{6})^{11} \times (\frac{1}{6})^4 + {}^{15}C_3 \times (\frac{5}{6})^{12} \times (\frac{1}{6})^3 + {}^{15}C_2 \times (\frac{5}{6})^{13} \times (\frac{1}{6})^2 + 15 \times (\frac{5}{6})^{14} \times \frac{1}{6} + (\frac{5}{6})^{15})$	M1	Expression must be seen Allow one end error
0.0898 or 0.0897 (3 sf)	A1	SC if M0 scored allow SCB1 for 0.0898 or 0.0897
0.0898 < 0.1	M1	Valid comparison For valid comparison with 0.9 (0.9102 > 0.9 seen the previous M1and A1 can be recovered
[Reject H_0] There is evidence (at the 10% level) that Arvind can predict scores	FTA1	Not definite, e.g. not 'He can predict' or 'Claim true' In context and no contradictions
	5	

Question 109

(a)	H_0: P(red) = 0.2 H_1: P(red) < 0.2	B1	Allow H_0: $p = 0.2$ H_1: $p < 0.2$.
	$P(X \le 4) = 0.8^{40} + 40\times0.8^{39}\times0.2 + {}^{40}C_2\times0.8^{38}\times0.2^2 + {}^{40}C_3\times0.8^{37}\times0.2^3 + {}^{40}C_4\times0.8^{36}\times0.2^4$	M1	For full expression seen. Allow one term omitted, incorrect or extra.
	0.0759	A1	**SC** 0.0759 without working B1.
	their '0.0759' > 0.05	M1	Valid comparison (from binomial probs) of their $P(X \leqslant 4)$ with 0.05.
	[Do not reject H_0]. Not enough evidence that it lands on red fewer times than if it were fair or not enough evidence to suggest that the spinner is biased	A1 FT	FT their 0.0759. In context, not definite, no contradictions.
		5	
(b)	$P(X \leqslant 3)$ = ` 0.0759 ` – ${}^{40}C_4\times0.8^{36}\times0.2^4$	M1	OE Attempted. Must be using $B(40, 0.2)$. Method could be implied by correct answer here.
	= 0.0285 or 0.0284	*A1	
	Largest value of r is 3	DA1	
		3	

Question 110

(a)	H_0: Population mean time (or μ) = 32.5 H_1: Population mean time (or μ) < 32.5	**B1**	Not just "mean".
	$\pm\dfrac{31.8-32.5}{3.1\div\sqrt{50}}$	**M1**	Must have $\sqrt{50}$. Could be implied.
	$= \pm -1.597$	**A1**	
	'–1.597' < –1.406 [or '1.597' > 1.406]	**M1**	Valid comparison of their z_{calc} with ±1.406. or 0.0551 < 0.08 (or 0.0552 < 0.08).
	[reject H_0] There is evidence that [population] [mean] **time** has **decreased**	**A1 FT**	In context, not definite, no contradictions. Note: Accept critical value method 31.88 (31.9) **M1 A1** and 31.8 < 31.88 **M1** conclusion **A1**.
		5	
(b)	$\dfrac{a-32.5}{3.1\div\sqrt{50}} = -1.406$	**M1**	Standardise with 32.5 and $\sqrt{50}$ and z value on RHS.
	a = 31.88 or 31.9	**A1**	May be seen in part **(a)**. Can score M1A1 here as well using a similar approach to **(a)**.
	$\dfrac{their\text{'}31.88-31.5}{3.1\div\sqrt{50}}$ [= 0.8668 to 0.8760]	**M1**	Standardise with *their* cv and mean = 31.5. Must have $\sqrt{50}$.
	1 – Φ('0.8668')	**M1**	For area consistent with their working.
	= 0.190 to 0.193 (3 sf)	**A1**	
		5	

Question 111

H_0: Population mean length = 10.3 cm H_1: Population mean length < 10.3 cm	**B1**	or $\mu = 10.3$ (not just 'mean'). $\mu < 10.3$
$\pm\dfrac{9.8-10.3}{2.6/\sqrt{100}}$	**M1**	If ± 1.923 (or 0.0272) seen allow M1 implied.
$= -1.923$	**A1**	Accept ± . Accept 3sf.
–1.923 > –2.054 or –2.055	**M1**	OE For a valid comparison. Or compare 1 – ϕ('1.923'') with 0.02 e.g. 0.0272 > 0.02 Use of CV 9.8 > 9.766 scores M1 A1 for 9.766 and M1 for comparison.
[Not reject H_0] No evidence that [mean] **length** has **decreased**	**A1 FT**	FT *their* z. No contradictions, not definite, in context.
	5	

Question 112

(a)	H_0: Population mean = 7.2 or 2.4 H_1: Population mean < 7.2 or 2.4	**B1**	or λ or μ = 7.2 or 2.4 (Not just 'mean'). or λ or μ < 7.2 or 2.4
		1	
(b)	$\lambda = 7.2$	**B1**	SOI
	$[P(X \leqslant 2)] = e^{-7.2}\left(1 + 7.2 + \frac{7.2^2}{2}\right)$ or $e^{-7.2}(1 + 7.2 + 25.92)$ or 0.0007465 + 0.0053754 + 0.01935 [= 0.0255] $[P(X \leqslant 3)] = \text{'0.0255'} + e^{-7.2} \times \frac{7.2^3}{3!}$ or '0.0255' $+e^{-7.2}$ (62.21) or '0.0255' +0.04644 [= 0.0719]	**M1**	Both expressions needed, allow any λ If $\lambda \neq 7.2$ allow P(X ⩽ n) for 2 consecutive values of n with P(X ⩽ n) < 0.05 and P(X ⩽ n + 1) > 0.05.
	P(Type I) = 0.02547 or 0.0255 (3 sf)	**B1**	
		3	
(c)	3 > 2 or $P(X \leqslant 3) > 0.05$ or '0.0719' > 0.05	**M1**	For a valid comparison or 3 outside critical region. FT *their* CR in **(b)**.
	[Not reject H_0] No evidence that [mean] **number of faults** has **decreased**	**A1 FT**	No contradictions. In context, not definite.
		2	
(d)	$1 - e^{-1.5}(1 + 1.5 + 1.5^2 / 2)$ or $1 - e^{-1.5}(1 + 1.5 + 1.125)$ or 1 – (0.2231 + 0.3347 + 0.2510)	**M1**	Must see expression. FT *their* CR in **(b)**.
	= 0.191 (3 sf)	**A1**	
		2	

Question 113

(a)	H_0: Population mean time (or μ) = 32.5 H_1: Population mean time (or μ) < 32.5	**B1**	Not just "mean".
	$\pm\frac{31.8 - 32.5}{3.1 \div \sqrt{50}}$	**M1**	Must have $\sqrt{50}$. Could be implied.
	= ± –1.597	**A1**	
	'–1.597' < –1.406 [or '1.597' > 1.406]	**M1**	Valid comparison of their z_{calc} with ±1.406. or 0.0551 < 0.08 (or 0.0552 < 0.08).
	[reject H_0] There is evidence that [population] [mean] **time** has **decreased**	**A1 FT**	In context, not definite, no contradictions. Note: Accept critical value method 31.88 (31.9) **M1 A1** and 31.8 < 31.88 **M1** conclusion **A1**.
		5	
(b)	$\frac{a - 32.5}{3.1 \div \sqrt{50}} = -1.406$	**M1**	Standardise with 32.5 and $\sqrt{50}$ and z value on RHS.
	a = 31.88 or 31.9	**A1**	May be seen in part **(a)**. Can score M1A1 here as well using a similar approach to **(a)**.
	$\frac{\textit{their}\text{'}31.88 - 31.5}{3.1 \div \sqrt{50}}$ [= 0.8668 to 0.8760]	**M1**	Standardise with *their* cv and mean = 31.5. Must have $\sqrt{50}$.
	1 – Φ('0.8668')	**M1**	For area consistent with their working.
	= 0.190 to 0.193 (3 sf)	**A1**	
		5	

Question 114

(a)	H_0: P(red) = 0.2 H_1: P(red) < 0.2	**B1**	Allow H_0: $p = 0.2$ H_1: $p < 0.2$.
	$P(X \le 4) = 0.8^{40} + 40\times0.8^{39}\times0.2 + {}^{40}C_2\times0.8^{38}\times0.2^2 + {}^{40}C_3\times0.8^{37}\times0.2^3 + {}^{40}C_4\times0.8^{36}\times0.2^4$	**M1**	For full expression seen. Allow one term omitted, incorrect or extra.
	0.0759	**A1**	**SC** 0.0759 without working B1.
	their '0.0759' > 0.05	**M1**	Valid comparison (from binomial probs) of their $P(X \leqslant 4)$ with 0.05.
	[Do not reject H_0]. Not enough evidence that it lands on red fewer times than if it were fair or not enough evidence to suggest that the spinner is biased	**A1 FT**	FT their 0.0759. In context, not definite, no contradictions.
		5	

(b)	$P(X \leqslant 3) =$ ` 0.0759 ` $- {}^{40}C_4\times0.8^{36}\times0.2^4$	**M1**	OE Attempted. Must be using $B(40, 0.2)$. Method could be implied by correct answer here.
	= 0.0285 or 0.0284	***A1**	
	Largest value of r is 3	**DA1**	
		3	

Question 115

(a)	He is expecting a **decrease** (in μ)	**B1**	OE
		1	
(b)	$-2.02 < -1.96$	**M1**	For valid comparison. Allow $2.02 > 1.96$ **or** $0.0217 < 0.025$ **or** $0.9783 > 0.975$
	(Reject H_0) There is evidence to suggest that this year's (mean) time is less than 25	**A1**	OE (such as evidence to support Akash's belief), in context, not definite. No contradictions.
		2	
(c)	$1 - \phi(2.14)$ [= 0.0162]	**M1**	
	1.62	**A1**	Allow 1.62% or 1.6 or 1.6%.
	$\alpha \geqslant 1.62$ (3 sf)	**A1ft**	FT *their* 1.62 . Allow $\alpha \geqslant 1.62\%$ or 1.6 or 1.6%. Condone >.
		3	
(d)	$\frac{24.8-m}{3.9\div\sqrt{10}}$	**M1**	For standardising.
	$\frac{24.8-m}{3.9\div\sqrt{10}} = -1.645$	**M1**	Equate *their* standardised value to −1.645 (signs must be consistent).
	$m = 25.4$ (3 sf)	**A1**	
		3	

Question 116

(a)	$e^{-5.7}(1 + 5.7 + \frac{5.7^2}{2!})$ **or** $e^{-5.7}(1 + 5.7 + 16.245)$ **or** $0.003346 + 0.01907 + 0.05436$	**M1**	Allow one end error. Must see this expression.
	= 0.0768 (3 sf)	**A1**	**SC B1** for unsupported answer of 0.0768 .
		2	
(b)	$e^{-0.9}(1 + 0.9 + \frac{0.9^2}{2!})$	**M1**	Attempted; allow one end error (must see expression).
	$= 1 - e^{-0.9}(1 + 0.9 + \frac{0.9^2}{2!}) = 1 - e^{-0.9}(1 + 0.9 + 0.405) = 1 - (0.4066 + 3659 + 0.1647)$	**A1**	Correct expression $P(X \geqslant 3)$ no end errors (must see expression).
	= 0.0629 (3 sf)	**A1**	**SC B2** for unsupported answer of 0.0629 .
		3	

Question 117

(a)	H_0: Pop mean no. people = 3.03 or 1.01 (per 20 min) H_1: Pop mean no. people > 3.03 or 1.01 (per 20 min)	**B1**	These must not just be 'mean', but allow just 'λ' or 'μ'.
	Use of Po(3.03)	**M1**	
	$= 1 - e^{-3.03}(1 + 3.03 + \frac{3.03^2}{2} + \frac{3.03^3}{3!} + \frac{3.03^4}{4!} + \frac{3.03^5}{5!})$ $= 1 - e^{-3.03}(1 + 3.03 + 4.5905 + 4.6364 + 3.5120 + 2.128)$ $= 1 - (0.04832 + 0.1464 + 0.2218 + 0.2240 + 0.1697 + 0.1028)$	**M1**	Allow incorrect λ. Allow one end error. Must see Poisson expression used.
	= 0.0870 (3sf) [0.0869727]	**A1**	Allow 0.087 .
	0.0870 > 0.05	**M1**	For a valid comparison.
	(Do not reject H_0) Insufficient evidence to believe (mean) number of people has increased	**A1FT**	Conclusion stated must be in context, not definite and include no contradictions (e.g. not 'mean number people has not increased').
		6	If only $P(x = 6)$ award max 2/6 (single term not valid). **SC** No working B1 B2 M1 A1. Award maximum 5/6.
(b)	$"0.0869727" - e^{-3.03} \times \frac{3.03^6}{6!}$ or $0.869727 - e^{-3.03}(1.0748)$ or $0.869727 - 0.05193$ or $1 - e^{-3.03}(1 + 3.03 + \frac{3.03^2}{2} + \frac{3.03^3}{3!} + \frac{3.03^4}{4!} + \frac{3.03^5}{5!} + \frac{3.03^6}{6!})$	**M1**	OE. Must see Poisson expression (may be in part (a)).
	0.0350 or 0.0351	**A1**	Accept 0.035. **SC** no working seen, award B1 for 0.0350, 0.0351 or 0.035.
		2	
(c)	Concluding that the (mean) number of people (using the path per 20 mins in the evening) has increased when it has not	**B1**	OE. Conclusion must be in context.
		1	
(d)	A value for the true mean	**B1**	Allow without context for this mark.
	Number of people using the path per 20 mins in the evening.	**B1**	Condone equivalent comment on three randomly chosen 20-minute periods.
		2	

Question 118

(a)	$\bar{x} = 1700/50 = 34$	**B1**	
	$\text{Est}(\sigma^2) = \frac{50}{49}\left(\frac{59050}{50} - 34^2\right)$ or $\frac{1}{49}\left(59050 - \frac{1700^2}{50}\right)$	**M1**	$\text{Est}(\sigma^2) = \frac{59050}{50} - 34^2$ biased scores M0.
	$= 25.5$ (3 sf) or $\frac{1250}{49}$	**A1**	= 25 scores A0.
		3	
(b)	H_0: Population mean time = 32.4 H_1: Population mean time $\neq$ 32.4	**B1**	Not just 'mean' but allow just 'μ'.
	$\dfrac{34 - 32.4}{\frac{\sqrt{'25.5'}}{\sqrt{50}}}$	**M1**	Must have $\sqrt{50}$ and not 50. FT *their* mean and var. Can be implied.
	= 2.24 (3 sf)	**A1**	or $P(\bar{T} > 34) = 0.0125$. **SC** use of biased var (25) $z = 2.26$ or $p = 0.0119$, allow M1A1.
	'2.24' < 2.326	**M1**	Or 0.0125 > 0.01 for a valid comparison.
	[Not reject H_0] Insufficient evidence that (mean) time has changed	**A1FT**	In context, not definite, e.g. not 'Time not changed'. No contradictions. Note: accept CV method $x_{cri} = 34.06$ for M1A1. Compares 34 < 34.06 for M1, conclusion for A1. Condone $x = 32.34$ M1A1: compares 32.4 > 32.34 for M1, conclusion for A1.
		5	**SC** for using a one-tail method. Award max 3/5 (B0 M1 A1 M1 A0).

Question 119

(a)	$(1 - \frac{1}{3})^{10}$	**M1**	
	= 0.0173 (3 sf)	**A1**	No working scores **SC B1**.
		2	
(b)	$1 - (1 - p)^{10} = 0.8926$	**M1**	Accept $1 - q^{10} = 0.8926$. Equation must be in p or in q but not both.
	$1 - p = 0.1074^{0.1}$ [= 0.800]	**M1**	For valid attempt to solve their (binomial) equation in p^{10} or q^{10}.
	$p = 0.200$ (3 sf) or 0.2	**A1**	
		3	

Question 120

(a)	Est (μ) = 3.25 = 13/4 or 1625/500	**B1**	
	$\text{Est}(\sigma^2) = \frac{500}{499}\left(\frac{5663.5}{500} - \text{"}3.25\text{"}^2\right)$ or $\frac{1}{499}\left(5663.5 - \frac{1625^2}{500}\right)$	**M1**	Expression of correct form.
	= 0.766 (3 sf) or 1529/1996	**A1**	Biased variance of 0.7645 scores M0A0.
		3	
(b)	H_0: Pop mean (or μ) = '3.25' H_1: Pop mean (or μ) $\neq$ '3.25'	**B1FT**	Not just 'mean'. FT their 3.25 .
	$\frac{2.95 - \text{"}3.25\text{"}}{\sqrt{\text{"}0.766\text{"} \div 60}}$	**M1**	Standardising with their values. Must have √60.
	= –2.655	**A1**	Or $P(\bar{X} < 2.95) = 0.0039$ or 0.00396 or 0.00397 . **SC** FT their biased est(σ^2), i.e. 0.7645 to give $z = 2.658$ A1.
	'2.655' > 2.576 or '–2.655' < –2.576	**M1**	For valid comparison, e.g. 0.0039 or 0.00396 or 0.00397 < 0.005, or 0.0078 < 0.01, or 0.00792 < 0.01 .
	[Reject H_0] There is evidence that (mean) mass in (country B) is different (from country A).	**A1FT**	OE. Must be in context and not definite, e.g., not 'Mean mass is not different', No contradictions. Context needs either 'mass' or 'countries' OE.
			SC, Use of one-tail test. '2.655' > 2.326 or 0.0039 < 0.01 M1A0 (Max B0M1A1M1A0 3/5).
			Accept critical value method. Either: Xcrit=2.959 M1A1 2.95<2.959 M1A1FT with correct conclusion, or Xcrit=3.241 M1A1 3.25>3,241 M1A1FT with correct conclusion.
		5	

Question 121

(a)	H_0: $\lambda = 7.6$ [or 1.9] H_1: $\lambda < 7.6$ [or 1.9]	**B1**	Or Population mean = 7.6 or μ (not just 'mean'). Or Population mean < 7.6 or μ.
		1	
'(b)	Mean = 7.6	**B1**	Seen.
	$P(X \leqslant 2) = e^{-7.6}\left(1 + 7.6 + \frac{7.6^2}{2}\right)$ [= 0.0188 or 0.0187]	**M1**	OE.
	$P(X \leqslant 3) = e^{-7.6}\left(1 + 7.6 + \frac{7.6^2}{2} + \frac{7.6^3}{3!}\right)$ [= 0.0554 or 0.0553]	**M1**	OE. Expression must be seen in at least one probability calculation.
	0.0188 or 0.0187 and 0.0554 or 0.0553	**A1**	A1 for both values.
	Critical region is $X \leqslant 2$	**A1**	Dep on both M marks. **SC** No Poisson expression seen in either prob scores B1 for 0.0188 or 0.0187 and B1 for 0.0554 or 0.0553 and B1 for CR.
	P(Type I error) = $P(X \leqslant 2)$ = 0.0188 or 0.0187 (3 sf)	**B1FT**	FT *their* $P(X \leqslant 2)$ or *their* CR.
		6	
'(c)	Concluding that the (mean) no. of accidents has reduced when it has not.	**B1**	OE. Must be in context. Accept: 'It is believed that the booklet has helped to improve safety when actually it has not'.
		1	
'(d)	3 not in critical region.	**M1**	FT their CR or $P(X \leq 3) = 0.0554 > 0.05$.
	No evidence mean number of accidents has decreased.	**A1FT**	In context. Cannot be a definite statement, e.g., 'mean number accidents has not decreased'.
		2	

Question 122

Assume SD still = 5.2	**B1**	OE i.e. 'Assume the SD remains unchanged'.
H_0: $\mu = 24.0$ H_1: $\mu > 24.0$	**B1**	Or population mean; not just mean.
$\frac{25.8-24.0}{\frac{5.2}{\sqrt{50}}}$	**M1**	For standardising (could be implied). Must have $\sqrt{50}$.
= 2.448	**A1**	Or $P(\overline{X} > 25.8) = 0.0071$.
'2.448' > 2.326	**M1**	Or 0.0071 < 0.01 . For valid comparison.
[Reject H_0] There is evidence that (mean) amount of wheat is greater.	**A1FT**	OE. FT their z_{calc}. In context, not definite, eg not 'Mean amount of wheat is greater' No contradictions CV method: CV= 25.71 M1A1 25.71<25.8 M1 A1FT or CV=24.09 M1 A1 24.09>24 M1 A1FT.
	6	

Question 123

(a)	Est (μ) = 23/50 = 0.46	**B1**	
	Est (σ) = $\sqrt{\frac{50}{49}} \times \sqrt{\frac{13.02}{50} - 0.46^2}$ or Est (σ^2) = $\frac{50}{49} \times \left(\frac{13.02}{50} - 0.46^2\right)$ oe Or estimated unbiased variance = $\frac{1}{49}\left(13.02 - \frac{(23.0)^2}{50}\right)$	**M1**	For an expression of the correct form for unbiased standard deviation or variance.
	Est (σ) = 0.22315 or Est (σ^2) = 0.0497959 = $\left(\frac{61}{1225}\right)$ or 0.0498	**A1**	
	$\frac{0.46 - 0.5}{\frac{'0.22315'}{\sqrt{50}}}$	**M1**	Standardising with their values.
	= −1.268 or -1.267 or = −1.27 (3sf)	**A1**	
	−1.268 > −1.645 or 0.102 to 0.103 > 0.05	**M1**	For a valid comparison.
	[Do not reject Ho] There is insufficient evidence [at 5% level] that the mean concentration is less than 0.5.	**A1 FT**	In context, not definite. E.g., not 'Mean concentration is not less than 0.5'. No contradictions.
		7	
(b)	$\frac{cv - 0.5}{\frac{'0.22315'}{\sqrt{50}}} = -1.645$	**M1**	
	cv = 0.448(1) or 0.448 (3 sf)	**A1**	
	$\frac{'0.448' - 0.4}{\frac{'0.22315'}{\sqrt{50}}}$ [=1.521 to 1.524]	**M1**	
	1 – ϕ('1.524')	**M1**	For area consistent with their working.
	= 0.0638 to 0.0642	**A1**	
		5	

Question 124

H_0: Population mean no. enquiries = 1.55 H_1: Population mean no. enquiries > 1.55	**B1**	Or "population mean no. enquiries = 0.31 (per minute)" oe. Allow 'λ = 1.55' or μ = '1.55'.
$P(X \geqslant 5) = 1 - e^{-1.55}(1 + 1.55 + \frac{1.55^2}{2!} + \frac{1.55^3}{3!} + \frac{1.55^4}{4!})$ or $1 - e^{-1.55}(1 + 1.55 + 1.20125 + 0.62065 + 0.24050)$ or 1 – (0.21225 + 0.32898 + 0.25496 + 0.13173 + 0.05105)	**M1**	Allow one end error, e.g. extra term: $e^{-1.55} \times \frac{1.55^5}{5!}$.
= 0.0210 (3 sf)	**A1**	Allow 0.021. **SC B1** no working scores B1 instead of M1A1.
0.0210 < 0.025	**M1**	For valid comparison.
[Reject H_0] There is sufficient evidence [at 2.5% level] to suggest that mean no. of enquiries has increased.	**A1 FT**	In context, not definite, e.g., not "Mean no. of enquiries has increased". No contradictions.
	5	Note: $e^{-1.55} \times \frac{1.55^5}{5!}$ = 0.0158 < 0.025: scores max B1

Question 125

(a)	H_0: population mean [of H] = 4.23 H_1: population mean [of H] > 4.23	B1	Allow $\mu = 4.23$ or population mean of $h = 4.23$ but NOT $h = 4.23$ or $H = 4.23$ or $\bar{h} = 4.23$ or $\bar{H} = 4.23$.
		1	
(b)	$\dfrac{\bar{h} - 4.23}{\frac{0.67}{\sqrt{200}}} = 1.645$	M1	For standardising and forming an equation. Must have $\sqrt{200}$. Allow $\pm$ 1.645 or $\pm$ 1.96. Accept '>' and '<'. Allow $\bar{H}$ or any letter instead of $\bar{h}$.
	$\bar{h} = 4.31$ (3 sf)	A1	May be implied by $\bar{h} > 4.31$. Allow $\bar{h} < 4.31$ for this A1 only, condone 4.15 also seen.
	$\bar{h} > 4.31$ or $\bar{h} \geqslant 4.31$ (3 sf)	A1	Condone any letter instead of $\bar{h}$.
		3	
(c)	Incorrect, because the population of H is given as normally distributed [with known variance].	B1	Allow h instead of H or just 'The population is normal.' Must use 'population' or 'underlying distribution'.
		1	

Question 126

(a)(i)	Need to find $P(X \geqslant 8)$	B1	oe (e.g. invalid because it should be a tail probability compared with 0.05).
		1	
(a)(ii)	H_0: P(green) = 0.5 H_1: P(green) > 0.5	B1	Allow $p = 0.5$. Allow $p > 0.5$.
	$P(X \geqslant 8) = 0.0439 + {}^{10}C_9 \times (0.5) \times (0.5)^9 + 0.5^{10}$	M1	Attempt $0.0439 + P(X = 9) + P(X = 10)$. Must see Binomial expressions B(10,0.5).
	= 0.0547 or 0.0546 (3 sf)	A1	**SC B1** 0.0547 or 0.0546 with no working.
	$0.0547 > 0.05$	M1	Valid comparison of tail probability with 0.05.
	[Do not reject H_0] 'There is insufficient evidence [at the 5% level] to accept the hypothesis that boys prefer green.' Or 'There is sufficient evidence to support the **researcher's** claim.'	A1FT	In context, not definite. No contradictions. Allow 'There is insufficient evidence to reject the hypothesis that boys like green and orange equally'. Not definite, e.g. not 'They don't prefer green" or 'Researchers claim true' 'Magazine's claim untrue'. Any mention of 'claim' must be clear which claim it is.
		5	
(b)	H_0 was not rejected	B1	Mark independently.
		1	
(c)	${}^{10}C_9 \times (0.5) \times (0.5)^9 + 0.5^{10}$ or "0.0547" – 0.0439	M1	Finding P(9,10) using B(10,0.5). Could be seen in **(a)(ii)**.
	P(Type I error) = 11/1024 or 0.0107 (3 sf) or 0.0108	A1	
		2	

Question 127

(a)	0.01 or 1%	**B1**	Note: $x \leqslant 0.01$ scores B0.
		1	
(b)	$2.326 = \dfrac{\bar{h} - 163.21}{6.95 \div \sqrt{300}}$	**M1**	Accept any z (±).
	$\bar{h} = 164.14$ [Rejection region is $\bar{h} > 164.14$] [P(Type II) = P($\bar{h} < 164.14 \mid \mu = 164.91$)]	**A1**	Accept 3 sf accuracy here.
	$\dfrac{\textit{their}\text{ '164.14'} - 164.91}{6.95 \div \sqrt{300}}$ [= −1.919]	**M1**	For standardising 164.91 with their 164.14 (could be 163.21).
	Φ(*their*'−1.919') = 1 − Φ(*their*'1.919')	**M1**	For area attempt consistent with their values.
	= 0.0275 or 0.0276 or 0.028[0] (3.s.f)	**A1**	Accept anything in range 0.0275 to 0.028[0].
		5	

Question 128

(a)	[$e^{-0.2}$] = 0.819 (3 sf)	**B1**	Accept $e^{-0.2}$ as final answer.
		1	
(b)	$\lambda = 1.25$	**B1**	
	$e^{-1.25}\left(1 + 1.25 + \dfrac{1.25^2}{2}\right)$ or $e^{-1.25}(1 + 1.25 + 0.78125)$ or 0.2865 + 0.3581 + 0.2238	**M1**	Any λ Allow one end error. Must see expression (in any form). Accept correct Σ notation.
	= 0.868 (3 sf)	**A1**	**SC** Answer with no working seen scores B1 (could be implied).
		3	
(c)	$e^{-0.15} \times e^{-0.1}(0.1) = 0.077879$ $e^{-0.15} \times e^{-0.1}\left(\dfrac{0.1^2}{2}\right) = 0.003894$ $e^{-0.15} \times 0.15 \times e^{-0.1} \times \dfrac{0.1^2}{2} = 0.0005841$	**M1**	P(B = 0) × P(G = 1) 0.8607 × 0.09048 P(B = 0) × P(G = 2) 0.8607 × 0.004524 P(B = 1) × P(G = 2) 0.1291 × 0.004524 Note: P(B = 0) × P(G = 2) and P(B = 1) × P(G = 2) may be seen within P(G = 2) × P(B < 2). For one expression seen.
	$e^{-0.15} \times e^{-0.1}(0.1) + e^{-0.15} \times e^{-0.1}\left(\dfrac{0.1^2}{2}\right) + e^{-0.15} \times 0.15 \times e^{-0.1} \times \dfrac{0.1^2}{2}$ = 0.077879 + 0.00389036 + 0.0005841	**M1**	P(B = 0) × P(G = 1) + P(B = 0) × P(G = 2) + P(B = 1) × P(G = 2). For the three Poisson terms added (must be from a complete attempt at all 3 terms).
	= 0.0824 (3 sf)	**A1**	
	Alternative method for Question 5(c)		
	P(B = 0) × P(G > 0) $e^{-0.15} \times (1 - e^{-0.1})$ P(B = 1) × P(G > 1) $e^{-0.15} \times 0.15 \times (1 - e^{-0.1}(1 + 0.1))$	**M1**	For one expression seen.
	$e^{-0.15} \times (1 - e^{-0.1}) + e^{-0.15} \times 0.15 \times (1 - e^{-0.1}(1 + 0.1))$	**M1**	For adding their expressions.
	= 0.0824 (3 sf)	**A1**	
		3	

5(d)	H_0: $\lambda = 1.25$ or 0.25[per day] H_1: $\lambda > 1.25$ or 0.25[per day]	B1	Or μ or 'population mean'.
	$P(\geq 4 \text{ late}) = 1 - e^{-1.25}\left(1 + 1.25 + \frac{1.25^2}{2} + \frac{1.25^3}{3!}\right)$ or $1 - e^{-1.25}(1 + 1.25 + 0.7813 + 0.3255)$ or $1 - (0.2865 + 0.3581 + 0.2238 + 0.09326)$	M1	Any λ. No end errors. Expression must be seen (in any form). Accept correct Σ notation.
	= 0.0383	A1	**SC** 0.0383 with no working scores B1.
	$0.0383 < 0.05$	M1	For a valid comparison.
	[Reject H_0] 'Hence there is sufficient evidence to suggest that the teacher's claim is true' or 'There is sufficient evidence to suggest that more students are late on average'.	A1 FT	No contradictions. In context and not definite, e.g. not 'More students are late' or 'Claim is correct'. Ft their 0.0383.
		5	

Question 129

(a)	H_0: Population mean mass = 510 g H_1: Population mean mass < 510 g	B1	Allow 'μ' but not just 'mean'.
	$\pm\frac{508 - 510}{10 \div \sqrt{120}}$	M1	Standardising must have $\sqrt{120}$.
	$= \pm -2.191$ or -2.190	A1	
	$-2.191 < -1.96$ or $2.191 > 1.96$ Area comparison: 0.0143 or 0.0142 < 0.025	M1	OE For valid comparison. Inequality sign the wrong way round scores M1 A0.
	[Reject H_0] There is sufficient evidence to suggest that the [mean] mass has decreased	A1FT	OE In context (must be 'decreased' OE, not 'changed'); not definite. No contradictions. Condone 'there is sufficient evidence to support the inspector's claim'. NB: Accept alternative method using critical value (= 508.21) and comparison with 508. Condone 509.79 compared with 510. Two tail test scores maximum B0 M1 A1 M1 A0; must have comparison with 0.0125 or 2.24/2.241.
		5	
(b)	$\frac{cv - 510}{10 \div \sqrt{120}} = -1.96$	M1	Standardising to find critical value (must use 510 and $10 \div \sqrt{120}$). Accept $\pm$ 1.96.
	cv = 508.21	A1	Accept 3 sf if nothing better seen. Note: cv could be found in **(a)**.
	$z = \pm\frac{508.21 - 506}{10 \div \sqrt{120}}$ [= 2.421]	M1	Standardising with their 508.21 and 506 (must use $10 \div \sqrt{120}$).
	$P(\overline{X} > 508.21 \mid \mu = 506) = 1 - \Phi('2.421')$	M1	For area consistent with their working.
	= 0.0077 to 0.0080 (2sf)	A1	Note: $\frac{510 - 506}{10 \div \sqrt{120}}$ scores max M0 A0 M1 M1 A0.
		5	

Question 130

(a)	$H_0: p = 0.3$ $H_1: p < 0.3$	B1	
	B(31, 0.3), $P(X \leqslant 4) =$ $0.7^{31} + 31\times0.7^{30}\times0.3 + {}^{31}C_2\times0.7^{29}\times0.3^2 + {}^{31}C_3\times0.7^{28}\times0.3^3 + {}^{31}C_4\times0.7^{27}\times0.3^4$ $= 0.00001577 + 0.0002096 + 0.0013475 + 0.0055826 + 0.016748$	M1	No end errors.
	$= 0.0239$ (3sf)	A1	**SC** 0.0239 with no working scores **B1**.
	'0.0239' < 0.05	M1	Valid comparison.
	[reject H_0] 'There is sufficient evidence (at 5% level) to support Rita's suspicion', or 'There is sufficient evidence to suggest the probability of seeing this type of bird has decreased'	A1FT	In context. Not definite. No contradictions. FT *their* 0.0239.
		5	
(b)	$P(X \leq 5) = [\text{'0.0239'} + {}^{31}C_5\times0.7^{26}\times0.3^5] = 0.0627$ [which is > 0.05]	B1FT	Attempt $P(X \leqslant 5)$. Only FT if > 0.05. Only FT *their* 0.0239 if $P(X \leqslant 4)$ attempted in **(a)**; arithmetic error only.
	P(Type I error) = '0.0239'	B1FT	Only FT *their* 0.0239 if $P(X \leqslant 4)$ attempted in **(a)**; arithmetic error only and *their* $0.0239 < 0.05$.
		2	
(c)(i)	[λ=] 3.65	B1	Stated or implied.
	$e^{-3.65} \times \frac{3.65^4}{4!}$	M1	Must see expression. Any λ.
	$= 0.192$ (3sf)	A1	**SC**: Use of Binomial. 0.193 scores **B1**. **SC**: 0.192 with no working scores **B1 B1**.
		3	
(c)(ii)	$n = 365 > 50$ $np = 3.65 < 5$ or $p = 0.01 < 0.1$	B1	Explicit. Both needed. Note: and 'n large, p small' is insufficient.
		1	

Question 131

(a)	$\lambda = 6.6$	B1	
	$P(X \leq 2) = e^{-6.6}(1 + 6.6 + \frac{6.6^2}{2})$ [= 0.0400] [< 0.05] or $e^{-6.6}(1 + 6.6 + 21.78)$ or $0.001360 + 0.008978 + 0.02963$	M1	Expression must be seen. No end errors. Allow use of 3.3 here.
	$P(X \leq 3) = e^{-6.6}(1 + 6.6 + \frac{6.6^2}{2} + \frac{6.6^3}{3!})$ or $0.0400 + e^{-6.6}\times \frac{6.6^3}{3!} = 0.105$ [> 0.05]	B1	Condone unsupported 0.105.
	P(Type I error) = 0.0400 (3 sf)	A1	Allow 0.040 or 0.04 AWRT SC unsupported ans of 0.0400 can score max **B1B1B1.**
		4	
(b)	$H_0: \lambda = 6.6$, $H_1: \lambda < 6.6$	B1	May be seen in part (a) and award **B1** mark here. Accept μ or λ. Accept 3.3 or 6.6.
	[$P(X \leq 2) = 0.0400$] ` 0.04 ` < 0.05	M1	For comparing their $P(X \leq 2)$ any λ with 0.05.
	[Reject H_0] There is evidence to suggest that mean number of accidents has decreased	A1	In context, not definite. No contradictions. CWO.
		3	

'(c)	$P(X > 2)$ attempted, with any λ	**M1**	
	$P(X > 2) = 1 - e^{-1.2}(1 + 1.2 + \frac{1.2^2}{2})$ or $= 1 - e^{-1.2}(1 + 1.2 + 0.72)$ or $= 1 - (0.3012 + 0.3614 + 0.2169)$	**M1**	Expression must be seen. Correct λ. No end errors.
	0.121 (3 sf) or 0.120	**A1**	SC unsupported answer scores **B2**.
		3	
'(d)	N(18, 18) seen or implied	**B1**	
	$\frac{10.5-18}{\sqrt{18}}$ $[= -1.768]$	**M1**	Allow with no or incorrect continuity correction. Their 18.
	$P(X >$ '-1.768'$) = \Phi($'1.768'$)$	**M1**	ft *their* standardised value. Area consistent with their values.
	$= 0.961$ or 0.962 (3 sf)	**A1**	
		4	

Question 132

(a)	Two-tailed because looking for difference	**B1**	
		1	

ʾ(b)	H_0: $\mu = 12.7$ H_1: $\mu \neq 12.7$	**B1**	No ft from part **(a).**
	$\frac{\frac{597.1}{50} - 12.7}{\frac{2.3}{\sqrt{50}}}$	**M1**	
	$= -2.330$ Accept -2.336 or -2.337	**A1**	or 0.00989 or 0.0099. or 0.0097 if area comparison used.
	'-2.330' > -2.576 or '2.330' < 2.576 or '0.00989' > 0.005 or `0.0097` > 0.005	**M1**	Accept 2.574 to 2.579. Or use of CV. 12.7- 2.576 x (2.3 / sqrt 50) = 11.862 **M1A1**. 11.942 > 11.862 **M1A1**.
	[Not reject H_0] There is insufficient evidence to suggest that μ is not 12.7	**A1 FT**	OE ft their $z_{calc.}$ In context, not definite, e.g. not '$\mu = 12.7$'. No contradictions. SC use of 1 tailed test can score **B0M1A1M1** for comparison with 0.01 **A0** max 3/5.
		5	

Question 133

(a)	0.02 or 2%	**B1**	<0.02 **B0**
		1	
(b)	H_0: $\mu = 2.3$ H_1: $\mu > 2.3$	**B1**	Accept 'population mean' for μ (not just mean) If not seen here, can be awarded if correctly seen in part **(a)**
	$s^2 = \frac{100}{99}\left(\frac{580}{100} - (2.38)^2\right)$ or $1/99\ (580 - 238^2/100)$	**M1**	Correct substitution in s^2 or $\sqrt{s^2}$ formula.
	$= 0.137 = 113/825$ or $s = 0.370$ (3 sf) and $\bar{x} = 238/100$ [= 2.38]	**A1**	$\bar{x}$ and s^2 (or s) correct. (SC biased estimate 0.1356 and $\bar{x} = 2.38$ scores **B1**).
	$\frac{2.38-2.3}{\sqrt{\frac{'0.137'}{100}}}$ [=2.161 or 2.162]	**M1**	
	= 2.16 (3 sf) OR 0.0153/0.0154 if area comparison used	**A1**	
	'2.16' > 2.054 (or 2.055) OR '0.0153 or 0.0154'<0.02	**M1**	Valid comparison.
	[There is evidence to reject H_o.] There is sufficient evidence to suggest that the [mean] height [in scientist's region] is greater than 2.3 [m] OR there is sufficient evidence to suggest that the scientist's claim is justified.	**A1FT**	No contradictions. In context, non-definite. Accept CV method x = 2.376<2.38 or x = 2.304>2.3 **M1 A1** for x and M1 A1ft for comparison and conclusion Two tail test can score **B0 M1 A1 M1 A1 M1** (comparison with 0.01oe) A0ft max 5/7
		7	
(c)	Not possible since H_o was rejected.	**B1FT**	Need both. Accept No as H_0 was rejected. Follow through their conclusion in **(b)** . Condone a definite statement.
		1	

Question 134

(a)	H_0: $p = 0.8$ H_1: $p > 0.8$	**B1**	
	[Assuming H_0, $P(X \geqslant 23)$ =] ${}^{25}C_{23} \times 0.2^2 \times 0.8^{23} + {}^{25}C_{24} \times 0.2 \times 0.8^{24} + 0.8^{25}$ $= 0.070835 + 0.0236118 + 0.0037779$	**M1**	No end errors. Expression must be seen or supported by enough figures to be convinced B(25,0.8) used. Accept correct Σ notation.
	= 0.0982	**A1**	**SC B1** for 0.0982 unsupported.
	0.0982 < 0.1	**M1**	Valid comparison their 0.0982 must be a tail probability.
	[There is evidence to reject H_0] There is sufficient evidence to suggest that p has increased	**ftA1**	No contradictions. In context, non-definite. Condone 'there is sufficient evidence that the 'claim' is correct' and condone 'there is sufficient evidence that the number of employees (using the canteen) has increased' Note: CR method will include $P(X \geqslant 23)$ so **M1 A1** as above, and $P(X \geqslant 22) = 0.234 > 0.1$ with at least one probability comparison with 0.1 needed to find CR of 23,24,25 (so 23 in CR) **M1 A1ft** as above.
		5	
(b)	Not suitable as model does not allow for more than 25 employees to use the canteen/Not suitable as uses a sample instead of all employees/Not suitable doesn't include all employees /Not suitable as 30 is only just bigger than 25 should have used 30 OR Suitable as owner knows that not all employees use the canteen, or similar	**B1**	Need both (i.e. suitable or not suitable plus reason).
		1	

Question 135

(a)	B(35, 0.2) used	**B1**	May be implied.
	$0.8^{35} + 35\times0.8^{34}\times0.2 + {}^{35}C_2\times0.8^{33}\times0.2^2 + {}^{35}C_3\times0.8^{32}\times0.2^3$ OR $0.0004056 + 0.0035494 + 0.015085 + 0.0414838$	**M1**	No end errors. Accept fully correct sigma notation.
	= 0.0605 [so significance level is] 6.05% or 6.1% or 6% (or accept anything in range 6.05% to 14.3%)	**A1**	As final answer. Must see 0.0605. SC Unsupported correct answer 6.05% scores B1 B1.
		3	
(b)	0.0605	**B1**	Correct or FT their <=3 (from Bin) in 5**(a)** must be 3sf.
		1	
(c)	B(35, 0.05) used	**B1**	May be implied.
	$1 - (0.95^{35} + 35\times0.95^{34}\times0.05 + {}^{35}C_2\times 0.95^{33}\times0.05^2 + {}^{35}C_3\times 0.95^{32}\times0.05^3)$ $1 - (0.1661+0.3059 +0.2737 + 0.1585)$	**M1**	No end errors. Accept fully correct sigma notation.
	= 0.0958 (3 sf) accept 0.0957	**A1**	SC Unsupported correct answer scores B1 B1.
		3	

Question 136

(a)	$\hat{\mu} = 61.3 = 3678/60 = 613/10$	**B1**	
	$\sigma^2 = \frac{60}{59}\left(\frac{226313.36}{60} - {'61.3'}^2\right) = 1/59\ (226313.36 - 3678^2/60)\ [=361/25]$	**M1**	
	= 14.44 AG	**A1**	from correct expression must see 14.44.
(b)	H_0: Population mean = 62.4 H_1: Population mean < 62.4	**B1**	Allow 'μ' but not just 'mean'.
	$\frac{'61.3'-62.4}{\frac{\sqrt{14.44}}{\sqrt{60}}}$	**M1**	Standardise with their mean. Ignore cc for M1. Must have √60.
	$= -2.242$ (accept ±)	**A1**	Accept 3sf if nothing better seen.
	$2.242 > 2.054$ or $-2.242 < -2.054$ (accept 2.055)	**M1**	or compare $1 - \phi("2.242")$ with 0.02. i.e. $1 - 0.9876 = 0.0124$ or $0.0125 < 0.02$.
	[Reject H_0] There is sufficient evidence to suggest that (at 2% level) that the (mean) time has decreased.	**A1ft**	OE. Not definite, e.g. not 'The mean time has decreased' No contradictions. In context. Accept cv method 61.392 M1 A1 61.392>61.3 M1 A1 OR 62.308 M1 A1 62.4>62.308 M1 A1 (3sf accuracy) SC For 2-tail test B0 M1 A1 M1(with 2.326 OE) A0
		5	
(c)	Yes, because population distribution of times is unknown	**B1**	OE. Allow ' … is not normal' (Accept 'parent' dist Accept underlying distribution).
		1	

Question 137

(a)	B(35, 0.25)	**M1**	SOI.
	$0.75^{35} + 35\times0.75^{34}\times0.25 + {}^{35}C_2\times0.75^{33}\times0.25^2 + {}^{35}C_3\times0.75^{32}\times0.25^3$ $= 0.000042378 + 0.0004944 + 0.00280168 + 0.01027283$	**M1**	Attempt $P(r \leqslant 3)$ Expressions or terms.
	$= 0.0136$ (3 sf) [< 0.04]	**A1**	**SC** unsupported answer 0.0136 **B1**.
	'0.0136' $+ {}^{35}C_4\times0.75^{31}\times0.25^4 = 0.0136 + 0.0273942$	**M1**	Attempt $P(r \leqslant 4)$ Expressions or terms
	$= 0.041[0]$ (2 sf) [> 0.04]	**A1**	**SC** unsupported answer 0.041 **B1**.
	Maximum value of r is 3	**A1**	Dep on above two correct probabilities seen and at least one comparison with 0.04.
		6	
(b)	Concluding proportion has decreased when in fact it hasn't	**B1**	Or concluding that the director's belief is correct when in fact it isn't.
	0.0136	**B1**	**FT** their $P(r \leqslant 3)$, dep < 0.04 OE.
		2	
(c)	$1 - (0.95^{35} + 35\times0.95^{34}\times0.05 + {}^{35}C2\times0.95^{33}\times0.05^2 + {}^{35}C3\times0.95^{32}\times0.05^3)$ $= 1 - (0.16608 + 0.305943 + 0.2737385 + 0.158480)$	**M1**	Attempt $1 - P(r \leqslant 3)$ with B(35, 0.05). Expressions or terms.
	$= 0.0958$ (3 sf)	**A1**	**SC** unsupported answer 0.0958 **B1**.
		2	

Question 138

2(a)(i)	$\dfrac{10.03-10}{\frac{\sigma}{\sqrt{50}}} = 1.995$	**M1**	For standardising. Must have square root 50.
		M1	Equating to 1.995 (not phi 1.995).
	$= 0.106$ (3 sf)	**A1**	
		3	
(a)(ii)	H0: $\mu = 10$ H1: $\mu > 10$	**B1**	Accept if seen in part **(i)** but not in **(ii)**. Accept population mean but not just mean.
	$1.995 > 1.96$	**M1**	Valid comparison. $0.977 > 0.975$ or $0.023 < 0.025$. Accept 2.00 or $2.001 > 1.96$.
	[Reject H0] There is sufficient evidence [at 2.5% level] to suggest that mean length is greater than 10 cm. Or There is sufft evidence to support the inspectors thought /claim.	**A1**	No contradictions. In context. Not definite. Accept '….. that mean length has increased' Note 2 tail test scores **B0M1A0**.
		3	
2(b)	No, because population distribution [of lengths] is normal	**B1**	
		1	

Question 139

(a)	$H_0: p = \frac{1}{6}$ $H_1: p < \frac{1}{6}$	**B1**	
	$(\frac{5}{6})^{30} + 30(\frac{5}{6})^{29}(\frac{1}{6}) + {}^{30}C_2(\frac{5}{6})^{28}(\frac{1}{6})^2 = 0.00421272 + 0.0252763 + 0.07330$	**M1**	Expression or terms must be seen. No end errors.
	= 0.103	**A1**	**SC** Unsupported correct answer scores **B1**.
	'0.103' > 0.05	**M1**	Valid comparison (must be a tail comparison and from a Bin but not necessarily correct Bin).
	[Accept H_0] Insufficient evidence to suggest that the probability is less than $\frac{1}{6}$ Or Insufficient evidence to support Birgitte's suspicion	**A1FT**	**FT** their 0.103. No contradictions, in context and non-definite. Note: Condone 'Insufficient evidence to suggest that the dice is biased' scores **A1**.
		5	
(b)	$P(X \leqslant 1) = (\frac{5}{6})^{30} + 30(\frac{5}{6})^{29}(\frac{1}{6})$ (= 0.029489...)	**M1**	$P(X \leqslant 1)$ attempted using $B(30, \frac{1}{6})$. No end errors.
	P(Type I error) = 0.0295 (3 sf)	**A1**	P(0) and P(1) expression or terms may be seen in **(a)**. If not in **(a)** unsupported answer of 0.0295 scores **B1**.
		2	
(c)	P(Type II error) = $1 - P(X \leqslant 1 \mid p = 0.02)$	**M1**	Use of B(30,0.02) to find $1 - P(X \leqslant 1)$. May be implied.
	$= 1 - (0.98^{30} + 30 \times 0.98^{29} \times 0.02) = 1 - (0.54548 + 0.33397)$	**M1**	No end errors. Expression or terms must be seen.
	= 0.121 (3 sf)	**A1**	**SC** Unsupported correct answer scores **M1B1**.
		3	

Question 140

sd (σ) remains at 3.8, or is unchanged	**B1**	Or Var unchanged.
= 1.645	**M1**	Any z (**M0** if not a z value) Must have $\sqrt{10}$.
$z = \dfrac{\bar{x} - 10.5}{\frac{3.8}{\sqrt{10}}} = \pm 1.645$	**B1**	
[Smallest value of] $\bar{x} = 12.5$ (3 sf)	**A1**	ISW after 12.476… or 12.5 seen. Accept $\bar{x} > 12.476$ or $\bar{x} > 12.5$ as final answer.
	4	

Question 141

(a)	H0: Proportion (at college) owning Pumpkin phone = 0.25 H1: Proportion (at college) owning Pumpkin phone < 0.25	B1	Allow $p = 0.25$, $p < 0.25$. Allow 25%.
		1	
(b)	B(30, 0.1) and $P(X \geqslant 5)$ attempted	M1	May be implied.
	$1-(0.9^{30} + 30\times0.9^{29}\times0.1 + {}^{30}C_2\times0.9^{28}\times0.1^2 + {}^{30}C_3\times0.9^{27}\times0.1^3 + {}^{30}C_4\times0.9^{26}\times0.1^4)$ $= 1 - (0.042391 + 0.141304 + 0.22766 + 0.236088 + 0.177066)$	M1	For expression or terms. No end errors.
	= 0.175 (3 sf) accept 0.176	A1	**SC** Unsupported working and correct answer scores **M1B1**.
		3	
(c)	$\frac{1}{8} \pm z\sqrt{\frac{\frac{1}{8}\times\frac{7}{8}}{40}}$	M1	Any z must be a z. Only one side calculated can score **M1**.
	$z = 1.96$	B1	Seen.
	0.0225 to 0.227 (3 sf)	A1	Must be an interval.
		3	

Question 142

(a)	$\text{Est}(\mu) = \frac{2750}{60}$ or $\frac{275}{6}$ or 45.8 (3 sf)	B1	
	$\text{Est}(\sigma^2) = \frac{60}{59}\left(\frac{127000}{60} - \left(\frac{275}{6}\right)^2\right)$	M1	Or $\frac{1}{59}\left(127000 - \frac{2750^2}{60}\right)$ Note: σ (4.03) can score **M1** for correct expression Use of biased (15.97) **M0**.
	$=16.2$ (3 sf) or $\frac{2875}{177}$	A1	
		3	
(b)	H_o: Population mean time = 45 H_1: Population mean time > 45	B1	Allow 'μ' but not just 'mean'.
	$\frac{\frac{'275'}{6} - 45}{\sqrt{\frac{'16.24294'}{60}}}$	M1	Standardise using their values from **3(a)**. Must have $\sqrt{60}$ (ignore cc).
	= 1.602 to 1.595	A1	Accept 3sf 1.6(0) if nothing better seen. (or area = 0.0546 to 0.0553). **FT** Biased in **3(a)** scores **A1** for 1.608 to 1.615.
	'1.602' < 1.645	M1	Or compare areas. i.e. 0.0546 to 0.0553 > 0.05.
	[Accept H_0] There is insufficient evidence [at 5% level] to reject the company's claim OR There is insufficient evidence to accept the passenger's belief OR There is insufficient evidence that the mean time is more than 45 minutes	A1FT	OE. **FT** their z-calc. No contradictions, In context, Not definite, e.g. not 'Mean time is more than 45 mins'. Note: accept cv method (45.856 > 45.83 or 44.98 < 45).
		5	