

Mark Scheme (Results)

Summer 2019

Pearson Edexcel GCE In Further Mathematics (9FM0) Paper 3B: Further Statistics 1

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- All candidates must receive the same treatment. Examiners must mark the first candidate in exactly the same way as they mark the last.
- Mark schemes should be applied positively. Candidates must be rewarded for what they have shown they can do rather than penalised for omissions.
- Examiners should mark according to the mark scheme not according to their perception of where the grade boundaries may lie.
- There is no ceiling on achievement. All marks on the mark scheme should be used appropriately.
- All the marks on the mark scheme are designed to be awarded. Examiners should always award full marks if deserved, i.e. if the answer matches the mark scheme. Examiners should also be prepared to award zero marks if the candidate's response is not worthy of credit according to the mark scheme.
- Where some judgement is required, mark schemes will provide the principles by which marks will be awarded and exemplification may be limited.
- When examiners are in doubt regarding the application of the mark scheme to a candidate's response, the team leader must be consulted.
- Crossed out work should be marked UNLESS the candidate has replaced it with an alternative response.

Qu	Scheme	Marks	AO
1 (a)	[Let $X = no.$ of prizes Andreia wins] $X \sim B(40, 0.02)$	M1	3.3
	[Require $P(X \ge 3) = 1 - P(X \le 2)$] = 0.04567 awrt <u>0.0457</u>	A1	1.1b
		(2)	
(b)	[Let $Y = no.$ of the bar when Barney wins] $Y \sim NegBin(3, 0.02)$	M1	3.3
	$[P(Y=40) =] \binom{39}{2} \times 0.02^2 \times 0.98^{37} \times 0.02$	M1	3.4
	= 0.0028071 awrt 0.00281	A1	1.1b
		(3)	
(c)	$E(Y) = \frac{3}{0.02} = \underline{150}$	B1	1.1b
		(1)	- .
		(6 m	arks)
	Notes		
(a)	M1 for selecting a suitable model i.e. B(40, p) where p is any probability Written or used, may be implied by a correct ans or 0.037429 from 1	P(X - 3)	
	A1 for awrt 0.0457 (correct answer only $2/2$)	$(\mathbf{A} = \mathbf{J})$	
(b)	1^{st} M1 for selecting a suitable model (NB(3, 0.02)) May be implied by a con-	rect expre	ssion
	2^{nd} M1 for use of model to form a correct expression		
SC	p \neq 0.02 Allow prob of the form $\binom{39}{2} p^3 (1-p)^{37}$ where $0 score$	s M0M1	
			2 (23
	A1 for awrt 0.00281 (accept awrt 2.81×10^{-3}) [correct answer with no work	ting score	s 3/3]

Qu	Scheme	Marks	AO
2(a)	{Let $C = no of calls in a 20 min period}$ $C \sim Po()$	M1	3.3
	80 calls per 4-hour period gives $\frac{20}{3}$ per 20 mins i.e. C ~Po($\frac{20}{3}$) [P(C > 4)]= 1 - P(C \le 4)	M1	3.4
	= 0.79437 awrt <u>0.794</u>	A1 (3)	1.1b
(b)	{X = no. of 5 min periods with no calls } $X \sim B(4, e^{-\frac{5}{3}})$ P(X = 3) = 0.02186125 awrt 0.0219	M1 A1 (2)	3.3 1.1b
(c)	P(exactly one call) $e^{-\frac{5}{3}} \times \frac{5}{3}$ or $e^{-5} \times 5$	M1	2.1
	P(exactly one call in each break) = $\left(e^{-\frac{5}{3}} \times \frac{5}{3}\right) \times \left(e^{-5} \times 5\right)$	M1	1.1b
	= 0.0106052 awrt <u>0.0106</u>	A1 (3)	1.1b
		(8 mark	s)
	Notes	· · ·	,
(a)	1 st M1 for selecting a Poisson model – written or used. May be implied by 2 nd Answer.	M1 or a c	orrect
	2^{nd} M1 for the correct Poisson Po($\frac{20}{3}$) or Po(6.67) or better seen		
	A1 for awrt 0.794 (correct ans with no incorrect working scores 3/3)	- P(C ≤	4)
(b)	M1 for selecting a correct model B(4, 0.189) or better (calc: 0.188875) A1 for using the model to get awrt 0.0219 (correct ans with no incorrect work	king score	es 2/2)
(c)	1 st M1 for <u>a</u> correct prob of 1 call (expressions in e or values) (allow 0.31479 or awrt 0.315 <u>or</u> 0.033689 or awrt 0.0337)		
	2 nd M1 for a correct probability statement or expression. E.g. $P(S = 1 S \sim Po(\frac{5}{3})) \times P(T = 1 T \sim Po(5))$		
SC	e.g. F ~ Po(λ) used in (b) to find P(F = 0) Then if we see Y~Po(3 λ) and statement P(F = 1)×P(Y=1) award M0M2	l	
	A1 for awrt 0.0106 (correct ans with no incorrect working scores 3/3)		

Qu	Scheme	Marks	AO
3.	{ Let X = the number when the spinner is spun} $\mu = 3$	B1	1.1b
	$\left[E(X^2) = \right] 0.3 + 4 \times 0.1 + 9 \times 0.2 + 16 \times 0.1 + 25 \times 0.3 [= 11.6 \text{ or } \frac{58}{5}]$	M1	1.1b
	$\sigma^2 \left[= 11.6 - 3^2 = \right] \mathbf{\underline{2.6}}$	A1	1.1b
	$\overline{\mathbf{X}} \approx \mathbf{N}\left("3", \sqrt{\frac{"2.6"}{80}}^2\right)$	M1	2.1
		A1ft	1.1b
	$P(\bar{X} > 3.25) = [P(Z > 1.3867) =]0.0827589(calc)$ awrt <u>0.0828</u>	A1	3.4
		(6 mark	(s)
	Notes		
	B1 for stating or using mean $= 3$		
	1^{st} M1 for using the given model to attempt E(X ²) with at least 3 correct pr	oducts se	en
	1 st A1 for Var(X) = 2.6 or $\sigma = \sqrt{2.6} = 1.6124$ (awrt 1.61)		
ALT	Use of pgf (B1 when mean = 3 seen) (M1 when correct $G''(t)$ seen with atten	npt at G"	(1))
	$G(t) = 0.3t + 0.1t^2 + 0.2t^3 + 0.1t^4 + 0.3t^5$		
	$G'(t) = 0.3 + 0.2t + 0.6t^2 + 0.4t^3 + 1.5t^4$		
	$G''(t) = 0.2 + 1.2t + 1.2t^{2} + 6t^{3}$ leading to $G''(1) = 8.6$		
	2 nd M1 for use of CLT – must use \overline{X} and normal <u>or</u> sight of N $\left("3", \sqrt{\frac{"2.6"}{80}}\right)$	$\left(\frac{1}{2}\right)$ with a	any letter
	2 nd A1ft for a correct mean and variance, ft their 3 and their 2.6		
	This M1A1ft may be implied by sight of correct st. dev. used in a state leading to $P(Z > 1.39)$ Must see correct use of Z	ndardisat	ion
	NB $\frac{2.6}{80} = 0.0325$ and $\sqrt{\frac{2.6}{80}} = 0.18027$ so allow e.g. N(3, awrt (0	.180) ²)	
	3 rd A1 for using the normal model to find probability awrt 0.0828		
ALT	Use of $\sum X$ (If see clear attempt at P($\Sigma X > 260$) condone P($\Sigma X > 260.5$) the	n:	
	$2^{nd} M1$ for $\Sigma X \sim N() \underline{or}$ any letter $\sim N(``240'', \sqrt{"2.6" \times 80}^2)$		
	2^{nd} A1ft for mean = "3"×80 = 240 and variance = "2.6"×80 = 208		
	May see P($\Sigma X > 260.5$) = 0.077597 but it will only score 2 nd M1 2 nd A1ft a	and 3rd A	0

Qu					cheme			Marks	AO
4 (a)	[T = no. o	of oak tr	tees in a \overline{s}	quare] T	'~ Bino			M1	3.3
						T ~ B(0	6, p)	A1	1.1b
a >	Even a - t - 1	fue	for for f	a 1000 41			E = 12.09	(2)	2.1
(b)		-	icy for 6	is less the	in 5 so p	0001: new	$E_i = 13.08$	M1	2.1
	$\frac{\left(O_{i}\!-\!E_{i}\right)^{2}}{E_{i}}$	0.051	2.51	0.0654	3.84	1.85	$\sum (0, -E_i)^2 = 0.212$		1 11 0
	$\frac{O_i^2}{E_i}$	4.521	29.617	21.805	7.599	24.771	$\sum \frac{(O_i - E_i)^2}{E_i} = 8.313$	M1,A1	1.1b x2
							7.015	D1 D10	1 11 0
	-					2=3; cv	/.815	B1,B1ft	1.1b x2
	Significa	nt result	, so Liam	s <u>model</u>	is not s	uitable		M1,A1 (7)	1.1b2.2b
(c)	$[\mathbf{R} = \mathbf{n}_0]$	of oak tr	ees in a s	quare for	· Simone	e's model] R ~ Po(3.3)	M1 (7)	3.3
(C)	Correct e			-		, s model] K 10(0.0)	M1	3.4
		r		-		and t =	9.62	A1,A1	1.1b x2
								(4)	
(d)	H ₀ : Poiss	-						B1	2.5
	H ₁ : Poiss	on is no	t a good f	it (for no	o. of oak	trees per	square)		
	No pooli	ng naad	ad so dag	roos of fr	aadam i	a 6 2 -	Λ	(1) B1	1.1b
(e)	No poolin Critical v	-	-			s - 2 - 4	4	B1 B1	1.10 1.1a
			,	-	· ·	nodel is su	uitable	B1	2.2b
	i tot sigin	iicuiit st	1 0155011	(or bline	, iie 5) ii	10401 15 50		(3)	2.20
(f)	Poisson r	nodel ha	as better f	it so sugg	gests tha	t oak tree	s occur at random	B1	2.2b
				• •		or cultivat			
	Therefore	e the for	est is like	ly to be v	wild not	cultivated	d	B1	3.5a
								(2)	I)
						Notes		(1911	narks)
(a)	M1 for	choosing	p binomia	al Alfo	or B(6, r		n words and allow B(6,	0.55)	
(4)	1011		5) •••••		0.00)	
(b)	1 st M1 fo								
							Either row to at least 2 s	f	
		r awrt 8.	31 (8.31)	gets $3/3$	INR no				
	1° B1 for						gives awrt 16.8458 and	implies M	
1		or 3 deg	rees of fre	eedom 2	2 nd B1ft	for criti	cal value of 7.815 (e.g.	implies M v = 4 use 9	9.488)
	3^{rd} M1 f	or 3 deg or a corr	rees of fro rect concl	eedom 2 usion (no	2 nd B1ft on-conte	for criti xtual igno	cal value of 7.815 (e.g. ore any contradictory co	implies M v = 4 use 9	9.488)
	3 rd M1 fo	or 3 deg or a corr or this m	rees of fro ect concl ark) base	eedom 2 usion (no d on their	2 nd B1ft on-conte r cv and	for criti xtual igno their test	cal value of 7.815 (e.g. ore any contradictory co statistic	implies M v = 4 use 9 ontextual co	9.488) omments
	3 rd M1 fo fo This man	or 3 deg or a corr or this m rk can be	rees of fre rect concl ark) base e implied	edom 2 usion (no d on thei by a full	2 nd B1ft on-conte r cv and y correc	for criti- xtual igno their test t solution	cal value of 7.815 (e.g. ore any contradictory co statistic ending with correct con	implies M v = 4 use 9 ontextual co	9.488) omments
	3 rd M1 fo fo This man 2 nd A1 fo	or 3 deg or a corr or this m rk can be or correc	rees of fre rect concl ark) base e implied ct conclus	eedom usion (no d on thei by a full ion in co	2 nd B1ft on-conte r cv and y correc ontext wi	for criti xtual igno their test t solution ith all oth	cal value of 7.815 (e.g. ore any contradictory co statistic ending with correct con er marks scored	implies M v = 4 use 9 ontextual co	9.488) omments
(c)	3 rd M1 fo fo This man 2 nd A1 fo 1 st M1 fo	or 3 deg or a corr or this m tk can be or correct or select	rees of fre rect concl ark) base e implied ct conclus ing a corr	eedom (no usion (no d on thei by a full ion in co ect mode	2 nd B1ft on-conte r cv and y correc ontext with el Po(3.3	for criti- xtual igno their test t solution ith all oth 3) [Allow	cal value of 7.815 (e.g. ore any contradictory co statistic ending with correct con er marks scored v Po(awrt 3.3)]	implies M v = 4 use 9 ontextual co	9.488) omments
(c)	3 rd M1 fe fc This man 2 nd A1 fe 1 st M1 fe 2 nd M1 fe	or 3 deg or a corr or this m or can be or correct or select or use of	rees of fre rect concl ark) base e implied ct conclus ing a corr the mode	eedom usion (no d on thei by a full ion in co ect mode el with ar	2 nd B1ft on-conte r cv and y correc ontext with el Po(3.3 n expres	for criti- xtual igno their test t solution ith all oth B) [Allow sion or co	cal value of 7.815 (e.g. ore any contradictory co statistic ending with correct con er marks scored v Po(awrt 3.3)] orrect value for s or t	implies M v = 4 use 9 ontextual co	9.488) omments
(c)	3 rd M1 fe fc This man 2 nd A1 fe 1 st M1 fe 2 nd M1 fe	or 3 deg or a corr or this m or can be or correct or select or use of	rees of fre rect concl ark) base e implied ct conclus ing a corr the mode	eedom usion (no d on thei by a full ion in co ect mode el with ar	2 nd B1ft on-conte r cv and y correc ontext with el Po(3.3 n expres	for criti- xtual igno their test t solution ith all oth B) [Allow sion or co	cal value of 7.815 (e.g. ore any contradictory co statistic ending with correct con er marks scored v Po(awrt 3.3)]	implies M v = 4 use 9 ontextual co	9.488) omments
(c) (d)	3 rd M1 fe fo This man 2 nd A1 fe 1 st M1 fe 1 st A1 fe	or 3 deg or a corr or this m or can be or correct or select or use of or one co	rees of fre rect concl ark) base e implied ct conclus ing a corr the mode orrect 2	eedom dusion (no d on thei by a full ion in co ect mode el with ar nd A1 for	2 nd B1ft on-conte r cv and y correc ontext with el Po(3.3 n expres both co	for criti- xtual igno their test t solution ith all oth 3) [Allow sion or co prrect (al	cal value of 7.815 (e.g. ore any contradictory co statistic ending with correct con er marks scored v Po(awrt 3.3)] orrect value for s or t	implies M v = 4 use 9 ontextual co	9.488) omments
(d)	3 rd M1 fc fc This man 2 nd A1 fc 1 st M1 fc 1 st A1 fc B1 for	or 3 degi or a corr or this m tk can be or correct or select or use of or one co correct h	rees of fre rect concl ark) base e implied et conclus ing a corr the mode prrect 2 hypothese	eedom 2 usion (no d on their by a full ion in co rect mode el with ar nd A1 for es must m	2 nd B1ft on-conte r cv and y correc ontext wi el Po(3.3 n expres both co nention I	for criti- xtual igno their test t solution ith all oth 3) [Allow sion or co prrect (al Poisson: u	cal value of 7.815 (e.g. ore any contradictory co statistic ending with correct con er marks scored v Po(awrt 3.3)] orrect value for s or t low awrt 2dp)	implies M v = 4 use 9 ontextual co	9.488) omments
	3 rd M1 fc fc This man 2 nd A1 fc 1 st M1 fc 1 st A1 fc B1 for 1 st B1 fo	or 3 deg or a corr or this m or this m or correct or select or use of or one co correct l r correct	rees of fre rect concl ark) base e implied ct conclus ing a corr the mode orrect 2 nypothese t degrees	eedom 2 usion (no d on their by a full ion in co ect mode el with ar nd A1 for es must m of freedo	2^{nd} B1ft on-conte r cv and y correc ontext with el Po(3.3 n expres both co nention I	for criti- xtual igno their test t solution ith all oth 3) [Allow sion or co orrect (al Poisson: u	cal value of 7.815 (e.g. ore any contradictory co statistic ending with correct con er marks scored v Po(awrt 3.3)] orrect value for s or t low awrt 2dp) use of Po(3.3) is B0	implies M v = 4 use 9 ontextual co	9.488) omments
(d)	3 rd M1 fc fc This man 2 nd A1 fc 1 st M1 fc 1 st A1 fc B1 for 1 st B1 fo 2 nd B1 fo	or 3 deg or a corr or this m tk can be or correct or select or one co correct h r correct r selecti r selecti	rees of fre rect concl ark) base e implied et conclus ing a corre the mode orrect 2 hypothese t degrees ng correc	eedom 2 usion (no d on their by a full ion in co ect mode el with ar nd A1 for es must m of freedo t critical	2^{nd} B1ft on-conte r cv and y correc ontext with el Po(3.3 n expres both contention I om $v = 4$ value (9	for criti- xtual igno their test t solution ith all oth 3) [Allow sion or co prrect (al Poisson: u 4 only 9.488 only	cal value of 7.815 (e.g. ore any contradictory co statistic ending with correct con er marks scored v Po(awrt 3.3)] orrect value for s or t low awrt 2dp) use of Po(3.3) is B0	implies M v = 4 use 9 intextual contextual contextual co	9.488) omments nclusion
(d)	3 rd M1 fc fc This man 2 nd A1 fc 1 st M1 fc 1 st A1 fc B1 for 1 st B1 fo 2 nd B1 fo	or 3 deg or a corr or this m tk can be or correct or select or one co correct h r correct r selecti r selecti	rees of fre rect concl ark) base e implied et conclus ing a corre the mode orrect 2 hypothese t degrees ng correc	eedom 2 usion (no d on their by a full ion in co ect mode el with ar nd A1 for es must m of freedo t critical	2^{nd} B1ft on-conte r cv and y correc ontext with el Po(3.3 n expres both contention I om $v = 4$ value (9	for criti- xtual igno their test t solution ith all oth 3) [Allow sion or co prrect (al Poisson: u 4 only 9.488 only	cal value of 7.815 (e.g. ore any contradictory co statistic ending with correct con er marks scored v Po(awrt 3.3)] orrect value for s or t low awrt 2dp) use of Po(3.3) is B0	implies M v = 4 use 9 intextual contextual contextual co	9.488) omments nclusion
(d) (e)	3 rd M1 fc fc This man 2 nd A1 fc 1 st M1 fc 1 st A1 fc B1 for 1 st B1 fo 2 nd B1 fo 3 rd B1 fc	or 3 deg or a corr or this m tk can be or correct or select or one co correct h r correct r selecti or not sig	rees of fre rect concl ark) base e implied et conclus ing a corre the mode orrect 2 hypothese t degrees ng correc <u>gnificant</u> of	eedom 2 usion (no d on their by a full ion in co ect mode el with ar nd A1 for es must m of freedo t critical conclusio	2^{nd} B1ft on-conte r cv and y correc ontext with el Po(3.3 n expres both context of n ention I om $v = 4$ value (9 on based	for criti- xtual igno their test t solution ith all oth 3) [Allow sion or co prrect (all Poisson: u 4 only 0.488 only on 8.749	cal value of 7.815 (e.g. ore any contradictory co statistic ending with correct con er marks scored v Po(awrt 3.3)] orrect value for s or t low awrt 2dp) use of Po(3.3) is B0	implies M v = 4 use 9 intextual contextual context	9.488) omments nclusion 3) here)
(d)	3 rd M1 fc fc This man 2 nd A1 fc 1 st M1 fc 1 st A1 fc B1 for 1 st B1 fo 3 rd B1 fc 1 st B1 fo	or 3 degr or a corr or this m tk can be or correct or select or one co correct l r correct r selecti or not sig	rees of fre rect concl ark) base e implied et conclus ing a corre the mode orrect 2 hypothese t degrees ng correct gnificant of ng Poisso	eedom 2 usion (no d on their by a full ion in co ect mode el with ar nd A1 for es must m of freedo t critical conclusion	2^{nd} B1ft on-conte r cv and y correc ontext with el Po(3.3 n expres both contention I om $v = 4$ value (9 on based er <u>or</u> stat	for criti- xtual igno their test t solution ith all oth b) [Allow sion or co orrect (al Poisson: u l only 0.488 only on 8.749 ing Poiss	cal value of 7.815 (e.g. ore any contradictory co statistic ending with correct con er marks scored v Po(awrt 3.3)] orrect value for s or t low awrt 2dp) use of Po(3.3) is B0	implies M v = 4 use 9 intextual contextual context	9.488) omments nclusion 3) here) sultivated

$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	Qu	Scheme	Marks	AO
$ \begin{bmatrix} X = no. of accidents in a 3-month period] X -Po(7.5) \\ P(X \leq 2) = 0.0203 (calc: 0.020256) { or P(X \leq 3) = 0.0591 } \\ P(X \leq 13) = 0.9784 so P(X \geq 14) = 0.0216 (calc: 0.0215646) \\ { or P(X \geq 15) = 0.0103 } \\ \hline M & 1 & 3.4 \\ { or P(X \geq 15) = 0.0103 } \\ \hline M & 1 & 1.1t \\ X \geq 14 \\ \hline M & 1 & 1.1t \\ X \geq 14 \\ \hline M & 1 & 1.1t \\ M^{\sim} B(8, "0.0419") \\ \hline P(M \geq 2)] = 1 - P(M \leq 1) \\ P(M \geq 2)] = 1 - P(M \leq 1) \\ P(M \geq 2)] = 1 - P(M \leq 1) \\ = 0.04153(calc: 0.041394) \\ P(Type II error) = P(3 \leq Y \leq 13) \text{ or } P(Y \leq 13) - P(Y \leq 2) \\ I = 0.9446 \\ = 0.9446 \\ P(Type II error) = P(3 \leq Y \leq 13) \text{ or } P(Y \leq 13) - P(Y \leq 2) \\ I = 0.9446 \\ = 0.9446 \\ P(Type II error) = P(3 \leq Y \leq 13) \text{ or } P(Y \leq 13) - P(Y \leq 2) \\ I = 0.9446 \\ P(Type II error) = P(3 \leq Y \leq 13) \text{ or } P(Y \leq 13) - P(Y \leq 2) \\ I = 0.9446 \\ P(Type II error) = P(3 \leq Y \leq 13) \text{ or } P(Y \leq 13) - P(Y \leq 2) \\ I = 0.9446 \\ P(Type II error) = P(3 \leq Y \leq 13) \text{ or } P(Y \leq 13) - P(Y \leq 2) \\ I = 0.9446 \\ P(Type II error) = P(3 \leq Y \leq 13) \text{ or } P(Y \leq 13) - P(Y \leq 2) \\ I = 0.9446 \\ P(Type II error) = P(3 \leq Y \leq 13) \text{ or } P(Y \leq 13) - P(Y \leq 2) \\ I = 0.9446 \\ P(Type II error) = P(3 \leq Y \leq 13) \text{ or } P(Y \leq 13) - P(Y \leq 2) \\ I = 0.9446 \\ P(Type II error) = P(3 \leq Y \leq 13) \text{ or } P(Y \leq 13) - P(Y \leq 2) \\ I = 0.9446 \\ P(Type II error) = P(3 \leq Y \leq 13) \text{ or } P(Y \leq 13) - P(Y \leq 2) \\ I = 0.9446 \\ P(Type II error) = P(3 \leq Y \leq 13) \text{ or } P(Y \leq 13) - P(Y \leq 2) \\ I = 0.9446 \\ P(Type II error) = P(3 \leq Y \leq 13) \text{ or } P(Y \leq 13) - P(Y \leq 2) \\ I = 0.9446 \\ P(Type II error) = P(3 \leq Y \leq 13) \text{ or } P(Y \leq 13) - P(Y \leq 2) \\ I = 0.9446 \\ P(Type II error) = P(3 \leq Y \leq 13) \text{ or } P(Y \leq 13) - P(Y \leq 2) \\ I = 0.9446 \\ P(Type II error) = P(3 \leq Y \leq 13) \text{ or } P(Y \leq 13) - P(Y \leq 2) \\ I = 0.9446 \\ P(Type II error) = P(3 \leq Y \leq 13) \text{ or } P(Y \leq 13) - P(Y \leq 13) + P(Y \leq 13) +$		$H_0: \lambda = 2.5 \text{ (or } \mu = 7.5)$ $H_1: \lambda \neq 2.5 \text{ (or } \mu \neq 7.5)$	B1	2.5
$\begin{array}{c c c c c c c c c c c c c c c c c c c $			M1	3.3
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$		$P(X \leq 2) = 0.0203 \text{ (calc: } 0.020256) \{ \text{ or } P(X \leq 3) = 0.0591 \}$		
Giving Critical region of: $\mathbf{X} \leq 2$ $\mathbf{X} \geq 14$ (b) $[0.0203 + 0.0216] = awrt 0.0419$ or (calc: 0.041821366 $awrt 0.0418$) B1ft (1) (1) (c) $[Let M = no of 3-month periods with a significant result]$ $M \sim B(8, "0.0419")$ (1) $M \sim B(8, "0.0419")$ (1) $M = 1, 3.3$ $[P(M \geq 2)] = 1 - P(M \leq 1)$ $[= 1 - 0.9584]$ = 0.04153(calc: $0.041394)$ [0.04139- 0.04154] A1cso 1.1t (3) M1 3.3 P(Type II error) = P($3 \leq Y \leq 13$) or $P(Y \leq 13) - P(Y \leq 2)$ M1 3.4 [= 0.9446] awrt 0.049846] = 0.9446 awrt 0.049846] $= 0.9446$ awrt 0.0498 bit for use of Po(7.5) may be implied by 2 nd M1 2 nd M1 for selecting the correct Po model. Sight or use of Po(7.5) may be implied by 2 nd M1 2 nd M1 for a fully correct CR A1low any letter, even CR ≤ 2 or set notation but not P(X ≤ 2 Can have X < 3 and X > 13 etc (b) B1ft for a wrt 0.0419 or awrt 0.0418 or fully and X < 3 and X > 13 etc (c) 1^{nt} M1 for selecting a correct binomial model, ft their answer to part (b) 2 nd M1 for a correct probability statement of $1 - P(M \leq 1)$ dep on a binomial selected A1cso for answer in range [0.04139, 0.04154] dep on use of B(8, "0.0419") or better (d) 1^{nt} M1 for selecting a Po(6.3) model			M1	3.4
X ≥ 14 A11.1t(b) $[0.0203 + 0.0216] = awrt 0.0419$ or (cale: $0.041821366 awrt 0.0418$)B1ft1.2(c) $[Let M = no of 3-month periods with a significant result] M ~ B(8, "0.0419")M13.3[P(M \ge 2)] = 1 - P(M \le 1)M11.1t= 0.04153(cale: 0.041394)[0.04139 - 0.041541]Alcso= 0.04153(cale: 0.041394)[0.04139 - 0.041541]Alcso= 0.04153(cale: 0.041394)[0.04139 - 0.041541]Alcso= 0.04153(cale: 0.041394)[0.04139 - 0.041541]Alcso= 0.04153(cale: 0.041394)[0.04139 - 0.041541]Alcso(3)P(Type II error) = P(3 \le Y \le 13) or P(Y \le 13) - P(Y \le 2)M13.4= 0.9446awrt 0.945A11.1t(3)[3.4][-0.9945147 0.049846]awrt 0.945= 0.9446awrt 0.945A11.1t(3)[3.4][-0.9945147 0.049846]awrt 0.945= 0.9446awrt 0.945A11.1t(3)[3.4][-0.9945147 0.049846]awrt 0.945= 0.9446awrt 0.945A11.1t(3)[3.4][-0.9945147 0.049846][-0.9945147 0.049846]= 0.9446awrt 0.945A1[.1t]2^{rd} M1for selecting the correct Po model. Sight or use of Po(7.5) may be implied by 2^{rd} M12^{rd} A1for a fully correct CRAllow any letter, even CR \le 2 or set notation but not P(X \le 2$				
(b) $\begin{bmatrix} 0.0203 + 0.0216 \end{bmatrix} = awrt 0.0419$ or $(calc: 0.041821366 awrt 0.0418)$ $B1ft \\ (1) \end{bmatrix}$ (c) $\begin{bmatrix} Let M = no of 3-month periods with a significant result] M ~ B(8, "0.0419") M ~ B(8, "0.0419") M1 3.3 M1 1.1t \\ [= 1 - 0.9584] = 0.04153(calc: 0.041394) [0.04139~0.04154] A1cso 1.1t \\ (3) M1 3.4 \\ [= 0.9945147 0.049846] = 0.9446 awrt 0.945 M1 3.4 \\ [= 0.9945147 0.049846] = 0.9446 awrt 0.945 M1 3.4 \\ A1 \\ (3) (12 marks) M1 3.4 \\ [= 0.9446 awrt 0.945 M1] (12 marks) M1 3.4 \\ M1 \\ (3) (12 marks) M1 3.4 \\ M1 \\ (3) (12 marks) M1 3.4 \\ M1 \\ (3) (12 marks) M1 \\ (4) (12 marks) M1 \\ (5) (12 marks) M1 \\ (6) (12 marks) M1 \\ (7) (12 marks) M1 \\ (12 marks) M1 \\ (13 marks) M1 \\ (14 marks) M1 \\ (14 marks) M1 \\ (15 marks) M1 \\ (15 marks) M1 \\ (16 marks) M1 \\ (17 marks) M1 \\ (18 marks) M1 \\ (18 marks) M1 \\ (19 marks) M1 \\ (19 marks) M1 \\ (19 marks) M1 \\ (10 marks) M1 \\ (11 marks) M1 \\ (11 marks) M1 \\ (12 marks$				1.1b
(b) $[0.0203 \pm 0.0216] = \operatorname{awrt} 0.0419$ or $(\operatorname{calc}: 0.041821366 \operatorname{awrt} 0.0418)$ B1ft 1.2 (1) (c) $[\operatorname{Let} M = \operatorname{no} \operatorname{of} 3\operatorname{-month} \operatorname{periods} \operatorname{with} a significant result]$ $M \sim B(8, "0.0419")$ $[P(M \ge 2)] = 1 - P(M \le 1)$ [= 1 - 0.9584] $= 0.04153(\operatorname{calc}: 0.041394)$ $[0.04139 \sim 0.04154]$ A1cso $1.1t$ (d) $Y \sim \operatorname{Po}(6.3)$ M1 3.3 $P(\operatorname{Type} \operatorname{II} \operatorname{error}) = P(3 \le Y \le 13) \text{ or } P(Y \le 13) - P(Y \le 2)$ [= 0.9945147 0.049846] = 0.9446 awrt 0.945 A1 $1.1t(3)(12 marks)(a) B1 for both hypotheses in terms of \lambda or \mu (either way around)1^{st} M1 for selecting the correct P0 model. Sight or use of Po(7.5) may be implied by 2^{nd} M12^{nd} M1 for one end correct 2^{nd} A1 for on end correct CR \leq 2 or set notation but not P(X \le 2 2^{nd} A1 for a fully correct CR \leq 2 or set notation but not P(X \le 2 2^{nd} A1 for a fully correct CR \leq 2 or set notation but not P(X \le 2 2^{nd} A1 for a fully correct CR \leq 1 and N \ge 13 etc(b) B1ft for awrt 0.0419 or awrt 0.0418or ft addition of their two probs provided both are 0 < \operatorname{prob} < 0.025 (awrt 3sf)(c) 1^{st} M1 for selecting a correct binomial model, ft their answer to part (b)2^{nd} M1 for a correct probability statement of 1 - P(M \le 1) dep on a binomial selectedA1cso for answer in range [0.04139, 0.04154] dep on use of B(8, "0.0419") or better(d) 1^{st} M1 for selecting a Po(6.3) model$		$\mathbf{X} \geqslant 14$		1.1b
(c)[Let M = no of 3-month periods with a significant result] M ~ B(8, "0.0419") [P(M ≥ 2)] = 1 - P(M ≤ 1) [= 1 - 0.9584] = 0.04153(calc: 0.041394)(1) M 1(d)(1)[I = 1 - 0.9584] = 0.04153(calc: 0.041394)(I - 0.04139- 0.04154] (I - 0.04139- 0.04154]A1 cso (I - 1.1k (I - 0.04139- 0.04154](d)(1)Y~Po(6.3) [I = 0.9945147 0.049846] = 0.9446Y~Po(6.3) M1M1(a)B1 for both hypotheses in terms of λ or μ (either way around) Is M1 for selecting the correct Po model. Sight or use of Po(7.5) may be implied by 2 nd M1 2 nd M1 for using the correct model to find one of these probs with correct label (2sf or better)1st A1 for one end correct 2 nd A1 for a fully correct CRAllow any letter, even CR ≤ 2 or set notation but not P(X ≤ 2 Can have X < 3 and X > 13 etc(b)B1ft or f t addition of their two probs provided both are 0 < prob < 0.025 (awrt 3sf)(c)1st M1 or f t addition of their two probs provided both are 0 sprot < 0.025 (awrt 3sf)(c)1st M1 or f t addition of their two probs provided both are 0 < prob < 0.025 (awrt 3sf)(d)1st M1 for selecting a correct binomial model, ft their answer to part (b) 2 nd M1 for a correct probability statement of 1 - P(M ≤ 1) dep on a binomial selected A1 cso for answer in range [0.04139, 0.04154] dep on use of B(8, "0.0419") or better(d)1st M1 for selecting a Po(6.3) model	(b)	[0, 0.203 + 0, 0.216] -awert 0,0410 or (cale: 0,041821366 awert 0,0418)		1 2
(c)[Let M = no of 3-month periods with a significant result] M ~ B(8, "0.0419") [P(M ≥ 2)] = 1 - P(M ≤ 1) [= 1 - 0.9584] = 0.04153(calc: 0.041394)M1 (0.04139~0.04154] M13.3 M1(d)Y~Po(6.3) P(Type II error) = P(3 $\leq Y \leq 13$) or P(Y ≤ 13) - P(Y ≤ 2) [= 0.9945147 0.049846] = 0.9446M1 3.3 M13.4 A1 (3)(d)Y Type II error) = P(3 $\leq Y \leq 13$) or P(Y ≤ 13) - P(Y ≤ 2) [= 0.9945147 0.049846] = 0.9446M1 (3)3.4 (12 marks)(a)B1 for both hypotheses in terms of λ or μ (either way around) 1st M1 for selecting the correct Po model. Sight or use of Po(7.5) may be implied by 2nd M1 2nd M1 for using the correct model to find one of these probs with correct label (2sf or better)1st A1 for one end correct 2nd A1 for a fully correct CRAllow any letter, even CR ≤ 2 or set notation but not P(X ≤ 2 2nd h1 for a fully correct CR(b)B1ft for awrt 0.0419 or awrt 0.0418 or ft addition of their two probs provided both are 0 < prob < 0.025 (awrt 3sf)(c)1st M1 for selecting a correct binomial model, ft their answer to part (b) 2nd M1 for a correct probability statement of 1 - P(M ≤ 1) dep on a binomial selected Alcso for answer in range [0.04139, 0.04154] dep on use of B(8, "0.0419") or better(d)1st M1 for selecting a Po(6.3) model	(U)	$[0.0203 + 0.0210] = awit \underline{0.0413} \underline{01} (caic. \ 0.041821300 \ awit \underline{0.0418})$		1.2
$ \begin{split} \begin{array}{ c c c c c } \hline M \sim B(8, ``0.0419^{$\overline{"}$}) & M1 & 3.3 \\ \hline M1 & [P(M \ge 2)] = 1 - P(M \le 1) & M1 & 1.1t \\ \hline [= 1 - 0.9584] & 0.041394) & [0.04139- 0.04154] & M1 & 1.1t \\ \hline M1 & 1.1t & Alcso & 1.1t \\ \hline M1 & 3.3 \\ \hline M1 & 3.4 & Alcso & Alc$	(c)	[Let $M = no of 3$ -month periods with a significant result]	(1)	
(d) $[= 1 - 0.9584]$ $= 0.04153(calc: 0.041394)$ $[0.04139-0.04154]$ $Y \sim Po(6.3)$ A lcso (3)(d)P(Type II error) = P(3 $\leq Y \leq 13$) or P(Y ≤ 13) - P(Y ≤ 2) $[= 0.9945147 0.049846]$ $= 0.9446$ Alt and the second state in the sec		· ·	M1	3.3
(d) $P(Type II error) = P(3 \le Y \le 13) \text{ or } P(Y \le 13) - P(Y \le 2)$ $I = 0.9945147 0.049846 I = 0.9446 awrt 0.945$ (a) B1 for both hypotheses in terms of λ or μ (either way around) I st M1 for selecting the correct Po model. Sight or use of Po(7.5) may be implied by 2 nd M1 2 nd M1 for a fully correct CR Allow any letter, even CR ≤ 2 or set notation but not P(X ≤ 2 Can have X < 3 and X > 13 etc (b) B1 for selecting a correct binomial model, ft their answer to part (b) 2 nd M1 for selecting a correct binomial model, ft their answer to part (b) 2 nd M1 for selecting a Po(6.3) model (d) I st M1 for selecting a Po(6.3) model		$[P(M \ge 2)] = 1 - P(M \le 1)$	M1	1.1b
(d) $Y \sim Po(6.3)$ $M1$ 3.3 P(Type II error) = P($3 \leq Y \leq 13$) or P($Y \leq 13$) - P($Y \leq 2$) $[= 0.9945147 0.049846]$ $= 0.9446$ $M1$ 3.4 A1 $1.1t$ (3) (12 marks) (a)B1for both hypotheses in terms of λ or μ (either way around) 1^{st} M1 for selecting the correct Po model. Sight or use of Po(7.5) may be implied by 2^{nd} M1 2^{nd} M1 for using the correct model to find one of these probs with correct label (2sf or better) 1^{st} A1 for one end correct 2^{nd} A1 for a fully correct CRAllow any letter, even CR ≤ 2 or set notation but not P(X ≤ 2 Can have X < 3 and X > 13 etc(b)B1ft for awrt 0.0419 or awrt 0.0418 or fit addition of their two probability statement of $1 - P(M \leq 1)$ dep on a binomial selected A1cso for answer in range [0.04139, 0.04154] dep on use of B(8, "0.0419") or better(d) 1^{st} M1 for selecting a Po(6.3) model				
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P(Type II error) = P($3 \le Y \le 13$) or P(Y ≤ 13) - P(Y ≤ 2) [= 0.9945147 0.049846] = 0.9446M13.4 A1awrt 0.945 A11.1t (3)(a) B1 2 nd M1 for selecting the correct Po model. Sight or use of Po(7.5) may be implied by 2 nd M1 2 nd M1 for using the correct Po model. Sight or use of Po(7.5) may be implied by 2 nd M1 2 nd M1 for using the correct RAllow any letter, even CR ≤ 2 or set notation but not P(X ≤ 2 Can have X < 3 and X > 13 etc(b) B1ft 0ft for a fully correct CRAllow any letter, and X > 13 etc(c) 1st M1 0ft for a correct probability statement of 1 - P(M ≤ 1) A1 for a fully correct probability statement of 1 - P(M ≤ 1) A1 for a binomial selected A1 cos of ranswer in range [0.04139, 0.04154] dep on use of B(8, "0.0419") or better	(d)	$\mathbf{Y} \sim \mathbf{P}_0(63)$		33
Image: Image of the image o	(u)			
(3)(3)(12 marks)(a)B1for both hypotheses in terms of λ or μ (either way around)1st M11st M12nd M12nd M12nd M1for one end correct2nd A12nd A1for a fully correct CRAllow any letter, even CR ≤ 2 or set notation but not P(X ≤ 2 Can have X < 3 and X > 13 etc(b)B1ftfor awrt 0.0419 or awrt 0.0418or ft addition of their two probs provided both are 0 < prob < 0.025 (awrt 3sf)(c)1st M1for a correct probability statement of 1 - P(M ≤ 1) dep on a binomial selected A1cso for answer in range [0.04139, 0.04154] dep on use of B(8, "0.0419") or better(d)1st M1for selecting a Po(6.3) model				
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2 nd M1 for a correct probability statement of $1 - P(M \le 1)$ dep on <u>a</u> binomial selected A1cso for answer in range [0.04139, 0.04154] dep on use of B(8, "0.0419") or better (d) 1 st M1 for selecting a Po(6.3) model		$\underline{\text{or}}$ it addition of their two probs provided both are $0 < \text{prob} < 0.025$ (aw	/ft 381)	
2 nd M1 for a correct probability statement of $1 - P(M \le 1)$ dep on <u>a</u> binomial selected A1cso for answer in range [0.04139, 0.04154] dep on use of B(8, "0.0419") or better (d) 1 st M1 for selecting a Po(6.3) model	(c)	1 st M1 for selecting a correct binomial model. ft their answer to part (b)		
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2 nd M1 for a correct probability statement using their Poisson model and their CR in (a) which	(d)			
			CR 1n (a)	which
may have just one tail.A1for awrt 0.945				

Qu	Scheme	Marks	AO
6 (a)	$G(1) = 1 \implies k \ln 2 = 1$ so $k = \frac{1}{\ln 2}$	B1	2.1
(b)	$\left\{ G(t) = \frac{1}{\ln 2} \left[\ln 2 - \ln(2 - t) \right] \right\} \implies G'(t) = \frac{1}{\ln 2} \left[\frac{1}{2 - t} \right] \text{ or } \frac{1}{\ln 2} \left(2 - t \right)^{-1}$	(1) M1 A1	2.1 1.1b
	$[E(X) =] G'(1) = \frac{1}{\ln 2}$	A1	1.1b
	$\mathbf{G}''(\mathbf{t}) = \frac{1}{\ln 2} \times \left[\frac{1}{\left(2-\mathbf{t}\right)^2}\right]$	M1 A1	2.1 1.1b
	$Var(X) = G''(1) + G'(1) - [G'(1)]^2 = \frac{1}{\ln 2} + \frac{1}{\ln 2} - \left(\frac{1}{\ln 2}\right)^2$	M1	2.1
	$=\frac{1}{\ln 2}\left(2-\frac{1}{\ln 2}\right)$	A1	1.1b
(c)	$P(X=3) = \text{coefficient of } t^3$ by Maclaurin need G'''(0)	(7) M1	3.1a
	$G'''(t) = \frac{1}{\ln 2} \frac{2}{\left(2 - t\right)^3}$	A1ft	1.1b
	$P(X=3) = \frac{G''(0)}{3!}$	M1	3.2a
	$=\frac{\frac{1}{4\ln 2}}{6}=\frac{1}{24\ln 2}=0.0601122$ awrt <u>0.0601</u>	A1 (4)	1.1b
	0 24112	(12 m	arks)
(a)	Notes B1 for finding k (must be exact)		
(a)			
(b)	1 st M1 for an attempt to differentiate $G(t)$ e.g. $A(2-t)^{-1}$ (o.e.)		
	1 st A1 for a correct first derivative (condone k or use of $\frac{1}{\ln 2}$ = awrt 1.44) 2 nd A1 for correct E(X) or G'(1) (allow awrt 1.44 calc: 1.442695but not k)) seen anv	where
	2^{nd} M1 for attempting second derivative (ft their G'(t))	, seen any	where
	3^{rd} A1 for a correct 2^{nd} derivative (condone k or use of $\frac{1}{\ln 2}$ = awrt 1.44)		
	3^{rd} M1 for a correct method for Var(X) (some substitution into the correct formula (x, y)	ıla)	
	4 th A1 for $\frac{1}{\ln 2} \left(2 - \frac{1}{\ln 2} \right)$ o.e. but must simplify i.e. collect like terms		
	[Mark final answer – penalise incorrect NB 0.8040211 is A0 unless exact answer seen	log work	tetc]
(c)	 1st M1 for a suitable strategy to solve the problem (finding link with Maclaurin Need mention of coefficient of t³ and [G'''(t) or G'''(0)](condone G''(t)) 1st A1ft for 3rd derivative, ft their 2nd derivative in (b) (provided G''(t) not construct G'''(t)) or G'''(0) scores 1st M1 1st A1ft 2nd M1 for translating Maclaurin to probability (a correct expression) 	(1))	
	$2^{nd} A1$ for $\frac{1}{24 \ln 2}$ or awrt 0.0601		

ALT	Log series 1 st M1 attempt to write G(t) in suitable form as far as: $k[\ln 2 - \ln(2[1-\frac{t}{2}])]$
	1^{st}A1 reaching $-k \ln(1-\frac{t}{2})$
	2 nd M1 use of $-\ln(1-x)$ series (some correct substitution) NB $G(t) = \frac{1}{\ln 2} \left(\frac{t}{2} + \frac{t^2}{8} + \frac{t^3}{24} + \dots \right)$

Qu	Scheme	Marks	AO
7(a)(i)	$[B \sim Geo(\frac{1}{3})] P(B = 4) = (\frac{2}{3})^3 \times \frac{1}{3}$	M1	3.3
	$=\frac{8}{81}$	A1	1.1b
(ii)	$= \frac{\frac{8}{81}}{P(B \leq 5)} = 1 - P(B > 5) \underline{\text{or}} 1 - \left(\frac{2}{3}\right)^5$	M1	2.1
	$=\frac{211}{243}$	A1	1.1b
(b)	—	(4)	0.1
	$E(B^{2}) = Var(B) + [E(B)]^{2}$	M1	2.1
	From formula booklet: $E(B) = \frac{1}{\frac{1}{3}} = 3$ and $Var(B) = \frac{1 - \frac{1}{3}}{(\frac{1}{3})^2} = 6$	B1	1.1b
	So $E(B^2) = 6 + 9 = \underline{15}$	A1	1.1b
(c)	[Let R = no. of the spin when it first lands on red] X = R-Geo($\frac{2}{3}$)	(3) M1	3.3
(0)		101 1	
	Require $E(e^{X}) = \sum_{x=1}^{\infty} e^{x} \left(\frac{1}{3}\right)^{x-1} \frac{2}{3}$	M1	3.1a
	$= \frac{2e}{3} \sum_{x=1}^{\infty} \left(\frac{e}{3}\right)^{x-1}$	M1	2.1
	$=\frac{2e}{3}\times\frac{1}{1-\frac{e}{3}} \text{ or } \frac{2e}{3-e}$	A1	1.1b
	$E(e^{X}) = 19.297 \{> 15 = E(B^{2})\}$ so	A1	2.2a
	Tamara should choose red since it has the greater expected score	(5)	
			marks)
	Notes		
(a)(i)	M1 for selecting the correct model i.e. Geo(p) (May be implied by a correct A1 for $\frac{8}{81}$ (= 0.098765 accept awrt 0.0988)	expression	on)
(ii)	M1 for a suitable strategy to use the geometric model to find a correct expression $M1$	ession	
(11)	A1 for $\frac{211}{243}$ (= 0.868312accept awrt 0.868)		
(b)	M1 for a suitable strategy to find $E(B^2)$ [allow $G''(1) + G'(1)$]	10	
	B1 for use of the correct formulae to find $E(B) = 3$ and $Var(B) = 6$ or $G''(1$ A1 for 15)=12	
00	Formula for E(B ²) Allow M1B1A0 for E(B ²) = $\frac{2-p}{p^2}$ (o.e.)		
SC	Formula for E(B⁻) Allow MIDIAU for E(B) = $\frac{1}{p^2}$ (0.e.)		

Qu7	Notes
(c)	1 st M1 for choosing a suitable geometric model (sight of Geo($\frac{2}{3}$) or at least 3 correct
	probabilities)
	2^{nd} M1 for realising the need for appropriate expected value and using E(g(X)) [Need sum and
	f(x)]
	NB simply finding $e^{E(X)} = e^{1.5} = awrt 4.48$ is M0 and probably no more marks.
	3 rd M1 for a suitable strategy to turn the expression into a sum that can be found
	1 st A1 for correct use of sum to infinity of geometric series
	2 nd A1 for interpreting the outcome of the calculations in terms of a solution to the problem
	must
	choose red and see the awrt 19.3 (and allow ft of their $E(B^2) < 19$)

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