Question Number	Scheme	Marks
1(a)	$\sum d^2 = 1+1+4+1+0+1+0+9+1[=18]$	M1
	$r_s = 1-\dfrac{6\times'18'}{9\left(9^2-1\right)} = 0.85$	M1A1
		(3)
(b)	$H_0 : \rho = 0 \quad H_1 : \rho > 0$	B1
	Critical Value $r_s = 0.6$ or CR: $r_s \geqslant 0.6$	B1
	Reject H_0 or significant or does lie in the critical region	M1
	There is evidence to suggest that there is a **positive relationship** between the position in the 100 m freestyle and the position in the 200 m freestyle	A1
		(4)
(c)	The value of n will decrease	B1
	$\sum d^2$ would decrease/the difference in ranks for C and H would decrease [So SRCC will increase]	B1
		(2)

	Notes	**Total 9**
(a)	**M1**	for finding the difference between the position in the 100 m freestyle and the 200 m freestyle and evaluating $\sum d^2$. May be implied by 18. (Allow one error)
	M1	for using $1-\dfrac{6\sum d^2}{9\left(9^2-1\right)}$ with their $\sum d^2$
	A1	Cao **NB** 0.85 scores 3/3 (unless from obvious incorrect working)
(b)	**B1**	for both hypotheses correct. Must be in terms of ρ or ρ_s. Must be attached to H_0 and H_1 Condone use of p
	B1	for CV of 0.6
	M1	a correct statement ft part (a) and their CV – no context needed but do not allow contradicting non contextual statements. This may be implied by a correct contextual conclusion on its own. If part a not answered and/or no CV stated then M0
	A1	A correct contextual conclusion which is rejecting H_0. Allow there is **positive correlation** or a description of the relationship e.g. The higher the position in 100 m race the higher the position in the 200 m race oe
(c)	**B1**	For a correct comment about n decreasing e.g. $n\left(n^2-1\right)$ decreases **NB This is M1 on epen**
	B1	a correct explanation about what would happen to $\sum d^2$ or a comment about the difference in ranks for C and H **NB This is A1 on epen**

Question Number	Scheme	Marks
2(a)	$\frac{115\times130}{250}=59.8$	M1A1
		(2)
(b)	H_0 : There is no association between **salary** and university **education** H_1 : There is an association between the **salary** and university **education**	B1
	Observed: 52; Expected: "59.8"; $\frac{(O-E)^2}{E}$: $\frac{(52-"59.8")^2}{"59.8"}=1.017...$	M1
	$\sum\frac{(O-E)^2}{E}=2.908+"1.017"=3.925$	M1A1
	$\nu=(2-1)(2-1)=1$	B1
	$\chi^2_1(0.05)=3.841 \Rightarrow$ CR: $X^2 \geqslant 3.841$	B1ft
	[In the CR/Significant/Reject H_0] There is evidence of an association between the **salary** and **education**	A1ft
		(7)

		Notes	Total 9
(a)	**M1**	for use of $\frac{\text{Row total}\times\text{Column total}}{\text{Total}}$ May be implied by 59.8	
	A1	Cao	
(b)	**B1**	both hypotheses correct with salary and education. May be written in terms of independence	
	M1	for use of $\frac{(O-E)^2}{E}$ ft their expected value in part (a) May be implied by 3.925 or 3.93	
	M1	for 2.908 + 1.017 ft their $\frac{(O-E)^2}{E}$ May be implied by 3.925 or 3.93	
	A1	for 3.925 Allow 3.93	
	B1	$\nu=1$ Implied by 3.841	
	B1ft	for 3.841 or ft their DoF [For reference $\nu=2$: 5.991 $\nu=3$: 7.815 $\nu=4$: 9.488]	
	A1ft	This mark is independent of the hypotheses. The conclusion must be consistent for the correct hypotheses. For a correct contextual conclusion ft their $\sum\frac{(O-E)^2}{E}$ **and** their CV. Must include salary and education. May be in terms of independence.	

Question Number	Scheme	Marks
3(a)	$\left[\ \bar{y} = \frac{3780}{90} \Rightarrow\right]\ \bar{y} = 42$	B1
	$\left[s_y^{\ 2} =\right] \frac{164599.29 - 90(42)^2}{90-1}$	M1
	$= 65.61$	A1
		(3)
(b)	$H_0 : \mu_W - \mu_E = 0 \qquad H_1 : \mu_W - \mu_E < 0$	B1
	$z = \frac{40 - "42" - 0}{\sqrt{\frac{18.49}{90} + \frac{"65.61"}{90}}}$	M1A1ft
	$= -2.0689\ldots$	A1
	One tailed CV: $Z = -1.6449$ **or** CR: $Z \leqslant -1.6449$	B1
	In CR/Significant/Reject H_0	M1
	Sufficient evidence to support the **zoologist's claim**	A1ft
		(7)
(c)	Assumed that $s^2 = \sigma^2$ for **both** samples	B1
		(1)

	Notes	**Total 11**
(a)	**B1**	for $\bar{y} = 42$
	M1	a correct method for finding an unbiased estimate of the variance e.g. $\frac{\Sigma y^2 - n(\bar{y})^2}{n-1}$
	A1	Cao
(b)	**B1**	both hypotheses correct. Allow equivalent hypotheses. Must be in terms of μ Allow other letters e.g. μ_x and μ_y
	M1	an attempt at $\frac{a-b-0}{\sqrt{\frac{c}{90}+\frac{d}{90}}}$ with at least 2 of a, b, c or d correct. Allow ±
	A1ft	$z = \frac{40 - "42" - 0}{\sqrt{\frac{18.49}{90} + \frac{"65.61"}{90}}}$ Allow ±
	A1	awrt –2.07 (Allow awrt 2.07)
	B1	1.6449 or better seen
	M1	A correct statement ft their test statistic and their CV – need not be contextual but do not allow contradicting non contextual comments. May be implied by a correct contextual statement on its own
	A1ft	A correct contextual statement ft their test statistic and their CV. Must contain zoologist's claim (allow belief) or a correct conclusion based on the zoologists claim with **weight**, **Western** and **Eastern** e.g. the [mean] **weight** of **Western** [grey kangaroos] is less than **Eastern** [grey kangaroos]
(c)	**B1**	for the assumption that sample variance = population variance for **both** samples

<table>
<tr><th>Question Number</th><th>Scheme</th><th>Marks</th></tr>
<tr><td>4(a)</td><td>$\mathrm{B}\left(4,\frac{1}{6}\right)$</td><td>B1
(1)</td></tr>
<tr><td>(b)</td><td>$\mathrm{H}_0:\mathrm{B}\left(4,\frac{1}{6}\right)$ is a good model $\quad$ $\mathrm{H}_1:\mathrm{B}\left(4,\frac{1}{6}\right)$ is not a good model</td><td>B1</td></tr>
<tr><td></td><td>$\mathrm{E}(X=0)=\left(\frac{5}{6}\right)^4\times 200=96.4506...$ $\quad$ $\mathrm{E}(X=1)=4\times\left(\frac{5}{6}\right)^3\times\left(\frac{1}{6}\right)\times 200=77.1604...$
$\mathrm{E}(X=2)=6\times\left(\frac{5}{6}\right)^2\times\left(\frac{1}{6}\right)^2\times 200=23.1481...$
$\mathrm{E}(X=3)=4\times\left(\frac{5}{6}\right)\times\left(\frac{1}{6}\right)^3\times 200=3.0864...$ $\quad$ $\mathrm{E}(X=4)=\left(\frac{1}{6}\right)^4\times 200=0.15432...$</td><td>M1M1A1</td></tr>
<tr><td></td><td><table><tr><th>O</th><th>E</th><th>$\frac{(O-E)^2}{E}$</th><th>$\frac{O^2}{E}$</th></tr><tr><td>110</td><td>96.45</td><td>1.9036…</td><td>125.4…</td></tr><tr><td>64</td><td>77.16</td><td>2.2444…</td><td>53.0…</td></tr><tr><td>26</td><td>26.39</td><td>0.005473…</td><td>25.6…</td></tr></table></td><td>M1M1</td></tr>
<tr><td></td><td>$\sum\frac{(O-E)^2}{E}=4.153...$ or $\sum\frac{O^2}{E}-200=4.153...$</td><td>A1</td></tr>
<tr><td></td><td>$\nu=2$ CR: $\chi^2>9.21$</td><td>B1B1ft</td></tr>
<tr><td></td><td>Insufficient evidence that $\mathrm{B}\left(4,\frac{1}{6}\right)$ is not a good model</td><td>dA1</td></tr>
<tr><td></td><td></td><td>(10)</td></tr>
<tr><td>(c)(i)</td><td>Use the data to estimate p/ p may not be $\frac{1}{6}$</td><td>B1</td></tr>
<tr><td>(ii)</td><td>Degrees of freedom reduced by 1 or critical value will decrease/critical region will increase</td><td>B1</td></tr>
<tr><td></td><td></td><td>(2)</td></tr>
<tr><td></td><td>Notes</td><td>Total 13</td></tr>
<tr><td>(a)</td><td>B1</td><td>binomial with $n=4$ and $p=\frac{1}{6}$</td></tr>
<tr><td>(b)</td><td>B1</td><td>both hypotheses correct. $\mathrm{B}\left(4,\frac{1}{6}\right)$ only needs to be mentioned once. Condone H_0 : Binomial is a suitable model H_1 : Binomial is not a suitable model provided $p=\frac{1}{6}$ is seen in part (a)</td></tr>
<tr><td></td><td>M1</td><td>a correct binomial probability seen (May be implied by a correct expected value)</td></tr>
<tr><td></td><td>M1</td><td>a correct method to find an expected value (May be implied by a correct expected value)</td></tr>
<tr><td></td><td>A1</td><td>At least 4 expected values correct to 3 significant figures or better</td></tr>
<tr><td></td><td>M1</td><td>for combining (2, 3 and 4) to ensure that all expected frequencies are > 5 May be implied by awrt 4.15</td></tr>
<tr><td></td><td>M1</td><td>for a correct method to find either $\frac{(O-E)^2}{E}$ or $\frac{O^2}{E}$ (May be implied by a correct value)</td></tr>
</table>

	A1	for awrt 4.15
	B1	for DoF = 2
	B1ft	for a correct CV ft their DoF [For reference $\nu = 1$: 6.635 $\nu = 3$: 11.345 $\nu = 4$: 13.277]
	dA1	Dep on 3rd M mark. For a correct conclusion. Allow Binomial is a good model
(c)(i)	**B1**	correct comment about p e.g. p will be 0.1587… (allow awrt 0.159)
(ii)	**B1**	correct comment about the **reduction** in DOF oe e.g. Degrees of freedom will decrease. Allow DOF = 1 if DOF was 2 in their test or a correct comments about the critical value/critical region Allow CV = 6.635 if CV was 9.210 in their test

Question Number	Scheme	Marks
5(a)	$\left[\frac{24.7034+26.8966}{2}=\right]25.8$	B1 (1)
(b)	$26.8966-24.7034=2\times1.6449\times\frac{\sigma}{\sqrt{36}}$ oe or $26.8966-"25.8"=1.6449\times\frac{\sigma}{\sqrt{36}}$ oe or $"25.8"-24.7034=1.6449\times\frac{\sigma}{\sqrt{36}}$ oe	M1B1
	$\frac{6(26.8966-24.7034)}{2(1.6449)}=\sigma$ oe or $\frac{6(26.8966-25.8)}{1.6449}=\sigma$ oe or $\frac{6(25.8-24.7034)}{1.6449}=\sigma$ oe or $\frac{3.2898}{6}\sigma=2.1932$ oe or $\frac{\sigma}{6}=\frac{2}{3}$ oe leading to $\sigma=4$*	A1*
		(3)
(c)	$2\times z\times\frac{4}{\sqrt{36}}=1.6$ oe	M1
	$z=1.2$	A1
	$P(Z>1.2)=0.1151$ or $P(Z<1.2)=0.8849$	M1
	Confidence level = $100\times(1-2\times0.1151)$ or $100\times(2\times0.8849-1)$	M1
	= 77 awrt 77	A1
		(5)
(d)	$2\times1.6449\times\frac{4}{\sqrt{n}}<0.6$ oe	M1
	$\sqrt{n}>\frac{8\times1.6449}{0.6}\left[\Rightarrow\sqrt{n}=21.932\right]$ or $\sqrt{n}>\frac{8\times1.64485...}{0.6}\left[\Rightarrow\sqrt{n}=21.9313...\right]$	dM1
	n = 481.01… so n = 482 or n = 480.98… so n = 481	A1
		(3)
	Notes	**Total 12**

Mark parts (a) and (b) together

(a)	**B1**	Cao
(b)	**M1**	for $26.78-24.82=2\times z$ value$\times\frac{\sigma}{\sqrt{36}}$ oe or $26.78-"25.8"=z$ value$\times\frac{\sigma}{\sqrt{36}}$ oe or $"25.8"-24.82=z$ value$\times\frac{\sigma}{\sqrt{36}}$ oe ft their 25.8
	B1	1.6449 or better
	A1*cso	at least one line of working from M1 to the given answer with no incorrect working seen (Allow 4.00)
(c)	**M1**	for $2\times z\times\frac{4}{\sqrt{36}}=1.6$ may be implied by z = 1.2
	A1	z = 1.2
	M1	for $P(Z>1.2)=0.1151$ or $P(Z<1.2)=0.8849$ ft their z may be implied by 0.7699 or awrt 77

	M1	for $100\times(1-2\times0.1151)$ ft their 0.1151 or $100\times(2\times0.8849-1)$ ft their 0.8849 May be implied by awrt 77
	A1	Awrt 77
(d)	**M1**	for $2\times z$ value $\times\frac{4}{\sqrt{n}}<0.6$ z value must either be correct or consistent with part (b) Condone = or $\leqslant$
	dM1	dependent on previous M mark. Correct rearrangement to get $\sqrt{n}>...$ or $n>\ldots$ Condone = or $\geqslant$
	A1	$n = 482$ or $n = 481$ (Must be clear that their answer matches their working)

Question Number	Scheme	Marks
6(a)	[Continuous] uniform on the interval [0, 15]	B1
		(1)
(b)	mean = 7.5	B1
	standard deviation = $\sqrt{\frac{(15-0)^2}{12}}$	M1
	$\frac{15}{\sqrt{12}} = 4.330...$	A1
		(3)
(c)	By the CLT $\bar{T} \sim \mathrm{N}\left(7.5,\ \frac{3}{8}\right)$	M1
	$\mathrm{P}\left(7.2 < \bar{T} < 7.8\right) = \mathrm{P}\left(\frac{7.2-"7.5"}{\sqrt{"\frac{3}{8}"}} < Z < \frac{7.8-"7.5"}{\sqrt{"\frac{3}{8}"}}\right) = \left[\mathrm{P}\left(-0.49 < Z < 0.49\right)\right]$	M1A1
	= 0.6879 – (1 – 0.6879) (Calculator gives 0.68789…)	M1
	= 0.3758 (Calculator gives 0.37579…) awrt 0.376	dA1
		(5)

	Notes		Total 9
(a)	**B1**	for the correct distribution stated (need uniform and correct interval) Allow U[0, 15] Condone U(0, 15) Must be seen in part (a)	
(b)	**B1**	Cao	
	M1	for a correct method for finding the standard deviation	
	A1	awrt 4.33 Condone $\frac{5\sqrt{3}}{2}$	
(c)	**M1**	for writing or using $\mathrm{N}\left(7.5,\ \frac{3}{8}\right)$ oe May be seen in a correct standardisation	
	M1	for standardising using either 7.2 or 7.8 and their mean and standard deviation. The standardisation must be shown for this mark	
	A1	for a fully correct expression for either 7.2 or 7.8. May be implied by ± awrt 0.49	
	M1	for $p - (1 - p)$ or $2(p - 0.5)$ oe	
	dA1	Dep on 2nd M mark for awrt 0.376	

Question Number	Scheme	Marks
7(a)	$\mathrm{E}(C) = 4\mu - 3\mu - \mu [= 0]$	M1
	$\mathrm{Var}(C) = 16\sigma^2 + 9\sigma^2 + \frac{\sigma^2}{3}\left[= \frac{76\sigma^2}{3}\right]$	M1
	$\mathrm{N}\left(0, \frac{76\sigma^2}{3}\right)$	A1
		(3)
(b)	$\mathrm{P}\left(Z < \frac{\sigma - "0"}{\sqrt{"\frac{76\sigma^2}{3}"}}\right)$	M1A1
	$= 0.5793$ Calc: 0.5787 awrt 0.579	dA1
		(3)
(c)	$4W_1 - 3W_2 - \overline{W} = \frac{11W_1 - 10W_2 - W_3}{3}$	M1
	$\mathrm{E}(Q) = 0$	B1
	$\mathrm{Var}(Q) = \frac{121\sigma^2 + 100\sigma^2 + \sigma^2}{9}\left[= \frac{222\sigma^2}{9} = \frac{74\sigma^2}{3}\right]$	M1
	$\mathrm{P}\left(Z < \frac{2\sigma - 0}{\sqrt{\frac{74\sigma^2}{3}}}\right)$	M1A1
	$= 0.6554$ Calc: 0.6564… awrt 0.655 – awrt 0.656	dA1
		(6)

	Notes	**Total 12**
(a)	**M1**	for a correct method to find E(C). May be implied by E(C) = 0
	M1	for a correct method to find Var(C). May be implied by Var(C) = $\frac{76\sigma^2}{3}$
	A1	Cao
(b)	**M1**	for standardising ft their mean and their standard deviation. Allow ± May be implied by ± awrt 0.199
	A1	for a fully correct standardisation using 0 and $\frac{76\sigma^2}{3}$ Allow ±May be implied by ± awrt 0.199
	dA1	dependent on previous A1 awrt 0.579
(c)	**M1**	for writing Q as a single fraction (May be implied by 2nd M1) Allow $4W_1 - 3W_2 - \frac{1}{3}W_1 - \frac{1}{3}W_2 - \frac{1}{3}W_3$ oe
	B1	for E(Q) = 0 May be seen in a standardisation
	M1	for a correct method to find Var(Q) May be seen in a standardisation. May be implied by Var(Q) = $\frac{74\sigma^2}{3}$
	M1	for standardising using 0 and their standard deviation

	A1	for a fully correct standardisation using 0 and $\frac{74\sigma^2}{3}$ oe
	dA1	Dependent on the previous A mark. For answer in the range awrt 0.655 to awrt 0.656