Mark Scheme (Results)

Summer 2017

Pearson Edexcel International A Level in Statistics S3 (WST03/01)

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General Marking Guidance

- 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.

EDEXCEL IAL MATHEMATICS

General Instructions for Marking

1. The total number of marks for the paper is 75.

2. The Edexcel Mathematics mark schemes use the following types of marks:

- **M** marks: method marks are awarded for 'knowing a method and attempting to apply it', unless otherwise indicated.
- **A** marks: Accuracy marks can only be awarded if the relevant method (M) marks have been earned.
- **B** marks are unconditional accuracy marks (independent of M marks)
- Marks should not be subdivided.

3. Abbreviations

These are some of the traditional marking abbreviations that will appear in the mark schemes.

- bod – benefit of doubt
- ft – follow through
- the symbol $\surd$ will be used for correct ft
- cao – correct answer only
- cso - correct solution only. There must be no errors in this part of the question to obtain this mark
- isw – ignore subsequent working
- awrt – answers which round to
- SC: special case
- oe – or equivalent (and appropriate)
- dep – dependent
- indep – independent
- dp decimal places
- sf significant figures
- $*$ The answer is printed on the paper
- $\underline{}$ The second mark is dependent on gaining the first mark

4. All A marks are 'correct answer only' (cao.), unless shown, for example, as A1 ft to indicate that previous wrong working is to be followed through. After a misread however, the subsequent A marks affected are treated as A ft, but manifestly absurd answers should never be awarded A marks.

5. For misreading which does not alter the character of a question or materially simplify it, deduct two from any A or B marks gained, in that part of the question affected.

6. If a candidate makes more than one attempt at any question:
   - If all but one attempt is crossed out, mark the attempt which is NOT crossed out.
   - If either all attempts are crossed out or none are crossed out, mark all the attempts and score the highest single attempt.

7. Ignore wrong working or incorrect statements following a correct answer.

Question Number	Scheme	Marks
1. (a)		

Parrot	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*
Rank Age	3	6	2	1	7	8	4	5
Rank Breeder	5	6	4	1	8	7	2	3

M1

$\sum d^2 = 4 + 0 + 4 + 0 + 1 + 1 + 4 + 4 = 18$ — For finding the difference between each of the ranks and evaluating $\sum d^2$ — M1

$\sum d^2 = 18$ — A1

$r_S = 1 - \frac{6(18)}{8(8^2 - 1)}; = 0.78571429...$ — For use of the correct formula with their $\sum d^2$ — dM1;

$\frac{11}{14}$ or awrt 0.786 — A1

[5]

(b)	$H_0 : r = 0, \quad H_1 : r > 0$	Both hypotheses stated correctly	B1
	Critical Value = 0.8333 or CR: $r_S \geqslant 0.8333$	Critical value of 0.8333	B1
	Since $r_S = 0.7857...$ does not lie in the CR (or 0.7857... < 0.8333), do not reject H_0	see notes	M1
	Either conclude that • the breeder does not have the ability to correctly order parrots by age, after examining them. • there is insufficient evidence that the breeder can correctly order parrots by age.		A1ft
			[4]
			9

Notes

(a)

1st M1 — Attempt to rank for actual ages or breeder's estimates of ages. (At least 4 correct in either row- allow reverse rankings)
Independent of 1st M1 but these must be ranks.

2nd M1 — ***is dependent on 1st M1*** for use of $1 - \frac{6(18)}{8(8^2 - 1)}$ with their $\sum d^2$.

3rd dM1

(b)

1st B1 — Both hypotheses correct in terms of r or r_S.

2nd B1 — Critical value of 0.8333

M1 — For a correct statement relating their r_S $(|r_S| < 1)$ with their c.v. where $|\text{their c.v.}| < 1$

A1ft — For a contextualised comment which is accepting H_0, which must mention "breeder", "order", "parrots", which conveys the idea that the breeder cannot order them correctly.
All previous marks in part (b) must have been scored to award this one.

Note — Follow through their r_S with 0.8333

Note — **Two-tailed test**
Applying a two-tailed test scores a maximum of B0B1M1A0
So Award SC B0B1 for $H_0 : \rho = 0$, $H_1 : \rho \neq 0$ followed by critical value $r_s = (\pm)\, 0.881$ and allow access to the M1 mark only.

Question Number	Scheme	Marks
2.	H_0: There is no association between gender and (inspirational) message (independent) H_1: There is an association between gender and (inspirational) message (dependent)	B1
	Expected / **A** / **B** / **C** / **Total** **Male** 27.106… 41.373… 38.52 107 **Female** 29.893… 45.626… 42.48 118 **Total** 57 87 81 225 Some attempt at $\frac{\text{(Row Total)(Column Total)}}{\text{(Grand Total)}}$	M1
		A1
	Observed / Expected / $\frac{(O-E)^2}{E}$ / $\frac{O^2}{E}$ 25 27.11 0.1642… 23.0542… 37 41.37 0.4616… 33.0916… 45 38.52 1.0901… 52.5701… 32 29.89 0.1489… 34.2589… 50 45.63 0.4185… 54.7885… 36 42.48 0.9885… 30.5085… Totals 3.2718… 228.2718… At least 2 correct terms for $\frac{(O-E)^2}{E}$ or $\frac{O^2}{E}$ or correct expressions with their E_i. Accept 2 sf accuracy for the dM1 mark.	dM1
	At least 5 correct $\frac{(O-E)^2}{E}$ or $\frac{O^2}{E}$ terms to either 1 dp or better. Allow truncation.	A1
	$X^2 = \sum \frac{(O-E)^2}{E}$ or $\sum \frac{O^2}{E} - 225$; = awrt 3.27 For applying either $\sum \frac{(O-E)^2}{E}$ or $\sum \frac{O^2}{E} - 225$	dM1
	awrt **3.27**	A1
	$\nu = (2-1)(3-1) = 2$ $\nu = 2$	B1
	$\chi^2_2(0.10) = 4.605 \Rightarrow$ CR: $X^2 \geqslant 4.605$ **4.605**	B1ft
	[does not lie in the CR/not significant/Do not reject H_0]	
	Either conclude that • there is insufficient evidence to support the headteacher's belief. • there is no association between gender and inspirational message. (They are independent)	A1
		[10]
		10

Notes

1st B1	For both hypotheses. Must mention "gender" ***and*** "message" oe at least once. Use of "relationship" or "correlation" or "connection" or "link" is B0.
1st M1	Can be implied by at least one correct E_i to 1 d.p.
1st A1	At least 5 expected frequencies correct awrt or trunc. 2 d.p. [No fractions]
2nd dM1	Dependent on 1st M1 for at least 2 correct terms or correct expressions with their E_i
2nd A1	At least 5 correct terms to either 1 d.p. or awrt/trunc. 1.d.p. (may be implied by awrt 3.27)
3rd dM1	Dependent on 2nd M1 For applying either $\sum \frac{(O-E)^2}{E}$ or $\sum \frac{O^2}{E} - 225$
Note	If awrt 3.27 is seen (from a calculator) **without** the expected frequencies stated then award **special case** M0A0M1A1M1A1.
2nd B1	$\nu = 2$. This mark can be implied by a correct critical value of 4.605
3rd B1ft	4.605 or ft their ν
4th A1	Dependent on 3rd M1 and 4.605. A correct contextualised conclusion which is accepting H_0. Must mention either "headteacher's belief" or "gender" ***and*** "message".
Note	Contradictory statements score A0. E.g. "significant, do not reject H_0"
Note	Condone "relationship" or "connection" here but **not** "correlation".
Note	Hypotheses the wrong way round is A0

Question Number	Scheme	Marks
3. (a)	$H_0 : m = 30$ $H_1 : m \neq 30$	B1
	$z = \dfrac{28.2 - 30}{\dfrac{8.5}{\sqrt{75}}}$; $= -1.833936...$ $\pm \dfrac{28.2 - 30}{\dfrac{8.5}{\sqrt{75}}}$ or equivalent.	M1;
	awrt -1.83	A1
	Two tailed c.v.'s $Z = \pm 1.6449$ or CR: $Z \leqslant -1.6449$ or $Z \geqslant 1.6449$ or p-value = awrt 0.033 or awrt 0.034 < 0.05	B1
	[in the CR/significant/Reject H_0/"[0.033, 0.034]" < 0.05]	
	Conclude either • that the mean age of gym customers is not 30 years. • that the manager's claim is not correct.	A1
		[5]
(b)	$\bar{X}$ is (approximately) normally distributed	B1
		[1]
(c)	Assumed $s^2 = \sigma^2$ or variance of sample = variance of population.	B1
		[1]
		7

Notes

(a)

1st B1	Both hypotheses correct.
M1	For standardising with 28.2, 30 and $\dfrac{8.5}{\sqrt{75}}$ (or awrt 0.981) [Allow use of $8.5 \times \sqrt{\frac{74}{75}}$ (=awrt 8.44)]
2nd B1	Critical value of -1.6449 (compatible with sign of their test statistic) **or** a correct probability comparison.
2nd A1	Dependent on M1 scored for a correct contextualised comment which is rejecting H_0 which is based on their *z*-value and their critical value with compatible signs, where $1.64 \leq \lvert\text{c.v.}\rvert \leq 1.65$ Contradictory statements score final A0. E.g. "significant, do not reject H_0".

Alternative method for the "M1A1B1" marks: Let $\bar{X}_C$ be the critical value of the sample mean.

$-1.6449 = \dfrac{\bar{X}_C - 30}{\dfrac{8.5}{\sqrt{75}}}$

So $\bar{X}_C = 28.38883812...$

M1: For $\dfrac{c - 30}{\dfrac{8.5}{\sqrt{75}}} = -1.6449 / -1.645 / -1.64 / -1.65$

A1: $\bar{X}_C$ = awrt 28.4

B1: Critical value of -1.6449

Note

One tailed test
SC: Applying a one-tailed test scores a maximum of B0M1A1B1A0
(Allow ±1.2816 to score the 2nd B1)

(b) Allow in words e.g "**sample mean** is normally distributed"

(c) B1 | Also allow $s = \sigma$ or standard deviation of sample = standard deviation of population.

Question Number	Scheme	Marks
4. (a)	$\widehat{\lambda} = \dfrac{0(3)+1(13)+2(14)+3(15)+4(10)+5(8)+6(8)+7(6)+8(3)}{80} \left\{= \dfrac{280}{80}\right\} = 3.5^*$	B1cso *
		[1]
(b)	$r = 80 \times \dfrac{e^{-3.5}(3.5)^3}{3!} \{= 17.26283752...\}$ **or** $r = 80 \times (0.5366 - 0.3208) \{= 17.264\}$ $s = 80 - (2.42 + 8.46 + 14.80 + \text{their } r + 15.10 + 10.57 + 6.17 + 3.08) \{= 2.14 \text{ or } 2.13716...\}$ **or** $s = 80 \times (1 - 0.9733) \{= 2.136\}$	M1
	$r = 17.26$ (2dp), $s = 2.14$ (2dp) — At least one of either $r =$ awrt 17.26 or $s =$ awrt 2.14	A1
	Both awrt $r = 17.26$ and awrt $s = 2.14$	A1
		[3]
(c)	H_0: Poisson distribution is a suitable model. H_1: Poisson distribution is not a suitable model.	B1
	See table below	M1
		M1
	$X^2 = \sum \dfrac{(O-E)^2}{E}$ or $\sum \dfrac{O^2}{E} - 80$; = awrt 8.38 — awrt **8.38** or awrt **8.39**	A1
	$n = 7 - 1 - 1 = 5$	B1ft
	$\chi^2_5(0.05) = 11.070 \Rightarrow$ CR: $X^2 \geqslant 11.070$	B1ft
	[not in the CR/not significant/Do not reject H_0]	
	Poisson distribution is a suitable model. (oe)	A1
		[7]
		11

# calls	O_i	E_i	Comb O_i	Comb E_i	$\frac{(O_i - E_i)^2}{E_i}$	$\frac{O_i^2}{E_i}$
0	3	2.42	16	10.88	2.4094…	23.5294…
1	13	8.46				
2	14	14.80	14	14.80	0.0432…	13.2432…
3	15	17.26	15	17.26	0.2959…	13.0359…
4	10	15.10	10	15.10	1.7225…	6.6225…
5	8	10.57	8	10.57	0.6249…	6.0549…
6	8	6.17	8	6.17	0.5428…	10.3728…
7	6	3.08	9	5.22	2.7372…	15.5172…
$\geqslant 8$	3	2.14				
				Totals	8.3759…	88.3759…

Notes

(a)	B1cso*	At least 2 non-zero products shown and divide by 80 to achieve 3.5*
(c)	1st B1	Must have both hypotheses and mention Poisson at least once. Inclusion of 3.5 for / in is 1st B0
	1st M1	For a correct method of pooling the classes at both ends [ft their s value]
	2nd M1	For an attempt at the test statistic, at least 3 correct expressions/values (to awrt/truncated 2 d.p.)
	1st A1	awrt 8.38 or awrt 8.39 (This implies the both M1 marks)
	2nd B1ft	For their evaluated $n - 1 - 1$. i.e. realising that they must subtract 2 from their n.
	3rd B1ft	Correct ft for their $\chi^2_k(0.05)$, where $k = n - 1 - 1$ from their n. (May see 9.488, 12.592, 14.067)
	2nd A1	Dep. on at least 1 M1 mark for a correct conclusion which is accepting H_0.
	Note	No follow through on their hypotheses if they are stated the wrong way round.
	Note	Contradictory statements score A0. E.g. "significant, do not reject H_0"
	Note	Condone the mention of Po(3.5) in conclusion.

Question Number	Scheme	Marks
5. (a)	Label beginners 1 – 452, intermediates 1 – 251, professionals 1 – 97 Use random numbers to select a ... Simple random sample of 28 beginners, 16 intermediates and 6 professionals.	M1 M1 A1 **[3]**
(b)	**Any one of** • Enables estimation of statistics/sampling errors for each strata. • Reduces variability. • More representative of the population/reflects population structure	B1 **[1]**
(c)	$H_0 : \mu_I - \mu_B = 3 \quad H_1 : \mu_I - \mu_B > 3$	B1; B1
	s.e. $= \sqrt{\frac{38.1}{60} + \frac{57.3}{80}}$ $\left\{= 1.162432794...\right\}$	M1
	$z = \frac{36.9 - 31.7 - 3}{"1.1624..."}$; $= 1.89258...$ awrt 1.89	dM1; A1
	One tailed c.v. $Z = 1.6449$ or CR : $Z \geqslant 1.6449$ or p-value = awrt $0.029 < 0.05$	B1
	[in the CR/significant/Reject H_0/"$0.029" < 0.05$]	
	Conclude either that the • mean score of intermediates is more than 3 greater than the mean score of beginners. (oe) • manager's belief is correct.	A1
		[7]
		11
	Alternative method for "2nd M1, 1st A1, 3rd B1" marks: Let $D = \bar{x}_I - \bar{x}_B$	
	$1.6449 = \frac{D - 3}{1.1624...}$ **dependent upon the 1st M1 for** $\frac{D - 3}{\text{their "1.1624..."}} = 1.6449 / 1.645 / 1.64 / 1.65$	dM1:
	So, $D = 4.912...$ $D =$ awrt 4.91 and $D_{obs} = 5.2$	A1
	$D_{obs} = 36.9 - 31.7 = 5.2$ [1.64, 1.65]	B1

		Notes
(a)	1st M1	for a suitable numbered/labelled list for each ability level
	2nd M1	for use of random numbers/sample to select beginners, intermediates and professionals.
	A1	**(dependent on either the 1st or the 2nd M1 mark)** For 28 beginners, 16 intermediates and 6 professionals.
(c)	1st B1	$H_0 : \mu_I - \mu_B = 3$ oe
	2nd B1	$H_1 : \mu_I - \mu_B > 3$ oe
	Note	If μ_1, μ_2 used then it must be clear which one refers to intermediates/beginners.
	1st M1	s.e. $= \sqrt{\frac{38.1}{60} + \frac{57.3}{80}}$. May be implied by s.e. = awrt 1.16
		Condone minor slips e.g. $\sqrt{\frac{38.1}{80} + \frac{57.3}{60}}$
	2nd dM1	Dependent upon the 1st M1. (follow through their s.e. if 1st M1 mark has been awarded)
	1st A1	awrt 1.89
	3rd B1	$1.64 \leq \lvert C.V. \rvert \leq 1.65$ (compatible sign with their test statistic) or a correct probability comparison.
	2nd A1	Dep. on all M1 and B1 marks scored for contextualised comment which is rejecting H_0.

Question Number	Scheme	Marks
6. (a)	$\bar{x} = 230.5$; 95% confidence limits for μ are	
	$230.5 \pm 1.96 \times \frac{1.2}{\sqrt{5}}$ their $\bar{x} \pm z \times \frac{1.2}{\sqrt{5}}$	M1
	$z = 1.96$	B1
	$= (229.44815..., 231.55185...) = \text{awrt}(229.4, 231.6)$ At least one end-point is correct.	A1
	Both end-points are correct.	A1
		[4]
(b)	{ Let X = number of confidence intervals that ***don't contain*** μ}	
	$\{\text{So } X \sim\}\ \text{B}(20, 0.05)$	M1
	$\{\text{P}(X > 3)\} = 1 - \text{P}(X \leqslant 3)$ or $1 - 0.9841$	A1
	$= 0.0159$ awrt **<u>0.0159</u>**	A1
		[3]
		7

	Notes	
(b)	**M1**	Writing or using either $X \sim \text{B}(20, 0.05)$ or $Y \sim \text{B}(20, 0.95)$
	1st A1	$1 - \text{P}(X \leqslant 3)$ or $1 - 0.9841$ or $\text{P}(Y \leqslant 16)$. Can be implied by the final answer.
	2nd A1	awrt 0.0159

Question Number	Scheme	Marks
7. (a)	$A = \frac{X_1 + X_2 + X_3 + Y_1 + Y_2}{5}$, $X \sim N(30, 4.5^2)$, $Y \sim N(20, 3.5^2)$; X, Y are independent.	
	$E(A) = \frac{3(30) + 2(20)}{5}$ or $Var(A) = \frac{3(4.5)^2 + 2(3.5)^2}{25}$ A correct method for finding $E(A)$ or $Var(A)$	M1
	$E(A) = 26$ or $Var(A) = 3.41$ At least one of either $E(A) = 26$ or $Var(A) = 3.41$	A1
	Both $E(A) = 26$ and $Var(A) = 3.41$	A1
	{So $A \sim N(26, 3.41)$}	
	$\{P(A < 24) =\}$ $P\left(Z < \frac{24 - 26}{\sqrt{3.41}}\right)$ Standardising $(\pm)$ with their mean and their standard deviation	M1
	$= P(Z < -1.08306...)$	
	$= 1 - 0.8599$	M1
	$= 0.1401$ (or 0.139391...) **0.14** or awrt **0.140** or awrt **0.139**	A1
		[6]
(b)	$W \sim N(\mu, 2.8^2)$; $P(W - X < 4) = 0.1$ W, X are independent.	
	$\{E(W - X) = E(W) - E(X) = \mu - 30\} \Rightarrow E(W - X) = \mu - 30$ $E(W - X) = \mu - 30$	B1
	$\{Var(W - X) =\}$ $2.8^2 + 4.5^2$ $\{= 28.09\}$ $2.8^2 + 4.5^2$	M1
	{So $W - X$ $N(\mu - 30, 28.09)$} $\{P(W - X < 4) = 0.1\} \Rightarrow P\left(Z < \frac{4 - (\mu - 30)}{\sqrt{2.8^2 + 4.5^2}}\right) = 0.1$	
	$\frac{4 - (\mu - 30)}{\sqrt{2.8^2 + 4.5^2}} = k$ $(= -1.2816)$ Standardising $(\pm)$ with their mean which is in terms of μ and their standard deviation and setting the result equal to k, where $\lvert k \rvert$ is in the interval $[1.28, 1.29]$.	M1
	± 1.2816 or awrt ± 1.2816	B1
	Correct equation . See notes	A1
	$\{\mu = 34 + 1.2816(5.3) \Rightarrow\}$ $\mu = 40.792...$ $(= 40.784$ from using $-1.28)$ awrt **40.8**	A1
		[6]
		12

Notes

(a)	3rd M1	For a probability tail compatible with 24 and their mean
(b)	2nd M1	Allow $\pm \frac{4 - \text{their } E(W - X)}{\sqrt{\text{their } Var(W - X)}} = k$, where $\lvert k \rvert$ is in the interval [1.28, 1.29]
	2nd B1	For either -1.2816 or 1.2816
	1st A1	E.g. Allow $\frac{4 - (\mu - 30)}{\sqrt{2.8^2 + 4.5^2}} = [-1.29, -1.28]$ or $\frac{(\mu - 30) - 4}{\sqrt{2.8^2 + 4.5^2}} = [1.28, 1.29]$

Question Number	Scheme	Marks
8.	X follows a continuous unform distribution over $\left[a+3, 2a+9\right]$; $Y = \frac{2\bar{X}}{3} + k$	
(a)	$\left\{\mathrm{E}(\bar{X}) = m\right\} = \frac{2a+9+a+3}{2}$	M1
	$= \frac{3a}{2} + 6$ or $\frac{3a+12}{2}$ ¹ a. {So $\bar{X}$ is a biased estimator.}	A1
		[2]
(b)	bias $\left\{= \frac{3a}{2} + 6 - a\right\} = \frac{1}{2}a + 6$ or $\frac{a+12}{2}$ (allow ±)	B1ft
		[1]
(c)	$\left\{\mathrm{E}(Y) = \frac{2}{3}\mathrm{E}(\bar{X}) + k = a \Rightarrow\right\}$ $\frac{2}{3}\left(\frac{3a}{2} + 6\right) + k = a$	M1
	$\left\{a + 4 + k = a \ \text{Þ}\right\}$ $k = -4$ $k = -4$	A1
		[2]
(d)	$\left\{\hat{a} = \frac{2}{3}\bar{X} - 4 \Rightarrow\right\}$ $\hat{a} = \frac{2}{3}(7.8) - 4$ $\left\{=1.2\right\}$	M1
	Max value $= 2\left(1.2\right) + 9$	M1
	$= 11.4$ 11.4 or $11\frac{2}{5}$ or $\frac{57}{5}$	A1
		[3]
		8

Notes

(a)	M1	Using the formula $\left(\frac{b+a}{2}\right)$ or obtaining $\frac{3a+12}{2}$ or $\frac{3a}{2}+6$
	A1	$\frac{3a}{2} + 6$ or $\frac{3a+12}{2}$ **and** ¹ a.
(b)	B1ft	bias $= \pm\left(\frac{1}{2}a + 6\right)$ or $\pm\left(\frac{a+12}{2}\right)$ or ft their μ provided $\mu \neq \alpha$
(c)	M1	Sets $\frac{2}{3}\left(\text{their } \mathrm{E}(\bar{X})\right) + k = a$. This mark can be implied.
	A1	$k = -4$. **Note** that $k = -4$ with no working is M1 (implied) A1.
(d)	1st M1	An attempt to use the sample data given to find $\frac{2}{3}\bar{x}$ + "their k".
		Allow full expression for $\bar{x}$ or $\frac{\sum x}{n}$. (**Note** that from the data $\bar{x} = 7.8$)
	2nd M1	2´ "their a" + 9 where their a is a function of the sample mean – which has been found by applying
		$\frac{\sum x}{n}$ from the data values given in the question.
	A1	11.4 cao
	Note	$2(10.6) + 9 = 30.2$ is M0M0A0

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