Mark Scheme (Results)

Summer 2022

Pearson Edexcel GCE
In Further Mathematics (8FM0)
Paper 23 Further Statistics 1

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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 GCE MATHEMATICS
General Instructions for Marking

1. The total number of marks for the paper is 40.

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
- ⌐ The second mark is dependent on gaining the first mark

4. 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.

5. Where a candidate has made multiple responses and indicates which response they wish to submit, examiners should mark this response.
   If there are several attempts at a question which have not been crossed out, examiners should mark the final answer which is the answer that is the most complete.

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

7. Mark schemes will firstly show the solution judged to be the most common response expected from candidates. Where appropriate, alternatives answers are provided in the notes. If examiners are not sure if an answer is acceptable, they will check the mark scheme to see if an alternative answer is given for the method used.

Question	Scheme	Marks	AOs
1.(a)	(i) $\frac{40\times174}{400}$ (ii) $\frac{96\times226}{400}$	M1	1.1b
	= 17.4 = 54.24	A1	1.1b
		(2)	
(b)	H_0: There is no association between the **application** of the **treatment** and the number of **years** that a fruit tree remains free from this disease. H_1: There is an association between the application of the treatment and the number of years that a fruit tree remains free from this disease.	B1	3.4
	$\sum\frac{(O-E)^2}{E}=\frac{(15-"17.4")^2}{"17.4"}+\frac{(61-"54.24")^2}{"54.24"}+2.642$	M1	1.1b
	= 3.815… awrt 3.82	A1	1.1b
	[3.82 <] $\chi^2_{2,(0.05)}=5.991$	B1	3.1b
	There is no evidence of association between the **application** of the **treatment** and the number of **years** that a fruit tree remains free from this disease.	A1ft	2.2b
		(5)	
			(7 marks)

Notes:		
(a)	**M1**	A correct method to work out either expected frequencies – or 1 correct
	A1	17.4 and 54.24 (accept 54.2)
(b)	**B1:**	For both hypotheses in terms of "association" or independence" Must mention application/treatment and years in at least one and be connected correctly to H_0 and H_1 [Use of link, relationship or connection. is B0 but allow for last A1ft]
	M1:	A correct method to find the total χ^2 value. ft their values from (a) If no method shown at least 1 of the two missing χ^2 contributions must be correct (0.331… $\left(\frac{48}{145}\right)$ and 0.8425… allow 2sf). Implied by awrt 3.82
	A1:	awrt 3.82 or awrt 3.83
	B1:	Using the degrees of freedom to find the χ^2 CV for the appropriate model. awrt 5.991 allow 5.9915
	A1ft:	Ft "their 3.82" and their CV or *p*-value. Correct conclusion in context. (application or treatment and years) This is independent of hypotheses ie if they should accept H_0 then they need eg there is no association between …. If they should reject H_0 then they need there is an association"… Allow relationship, link, connection for association BUT do not accept correlation or contradictory statements
		NB If *p*-value [0.148388] given instead of CV could get B1M1A1B0A1 unless they give the CV as well

Question	Scheme		Marks	AOs
2(a)	$X \sim \text{Po}(3)$		M1	3.3
	$\text{P}(X = 4) = 0.1680...$		A1	1.1b
			(2)	
(b)	$e^{-0.6\times t} < 0.16$ oe		M1	3.1b
	$-0.6\times t < \ln 0.16$		dM1	1.1b
	$[t > 3.054...]$ $t = 3.1$		A1	1.1b
			(3)	
(c)	$H_0: \lambda = 1.4$ $H_1: \lambda > 1.4$		B1	2.5
	$J \sim \text{Po}(5.6)$		B1	3.3
	Method 1 $P(J \geqslant 12) = 1 - P(J \leqslant 11)$	Method 2 $P(J \geqslant 11) =$ awrt 0.0282 and $P(J \geqslant 10) =$ awrt 0.0591...	M1	1.1b
	$= 1 - 0.9875\ldots$			
	$= 0.01(248\ldots)$	$J \geqslant 11$	A1	1.1b
	0.01(24) < 0.05 or $12 > 11$ or 12 is in the critical region or 12 is significant or Reject H_0. There is evidence at the 5% level of significance that the **rate** of fish caught may have **increased**.		A1	2.2b
			(5)	
				(10 marks)

Notes:

(a)	**M1:**	Writing or using Po(3)
	A1:	awrt 0.168
(b)	**M1:**	Forming a correct equation from the information given. Condone $e^{-0.6\times t} = 0.16$ or finding $P(X = 0)$ for $[t = 3.1]$ 0.155… and $[t = 3]$ 0.165… or $P(X = 0)$ for $[\lambda = 1.84]$ 0.158… and $[\lambda = 1.83]$ 0.1604…
	dM1:	Dependent on the 1st method mark. A correct method to solve their inequality/equation. Or $[t = 3.05]$ 0.1604 or $[\lambda = 1.835]$ 0.159…
	A1:	3.1
	NB	An answer of 3.1 gains 3/3
(c)	**B1:**	Both hypotheses in terms of λ or μ. Allow 5.6 instead of 1.4
	B1:	Writing or using Po(5.6)
	M1:	For writing or using $1 - P(J \leqslant 11)$ Implied by a correct probability or CR Allow $P(J \leqslant 10) =$ awrt 0.972 and $P(J \leqslant 9) =$ awrt 0.941
	A1:	0.01 or better (allow truncation eg 0.0124)
		NB Allow M1 A1 if $P(J \leqslant 11) = 0.9875...$ is written on its own
	A1:	Independent of hypotheses. A correct conclusion based on their probability with 0.05 conclusion in context (bold words) Do not accept contradicting statements.

Question	Scheme	Marks	AOs
3(a)	Not all the expected frequencies are likely to be over 5 Or the sample size is too small.	B1	3.5b
		(1)	
(b)	**5** degrees of freedom since the parameter is not estimated from the data [and the totals agree]	B1	2.4
		(1)	
(c)	H_0: B(5,0.6) is a suitable model H_1: B(5,0.6) is not a suitable model	B1	3.4
	$\sum\frac{(O-E)^2}{E}=\frac{(2-5.12)^2}{5.12}+...+\frac{(51-38.88)^2}{38.88}$	M1	2.1
	= 15.8063… awrt 16	A1	1.1b
	[15.8 >] $\chi^2_{5,(0.05)}=11.070$	B1ft	1.1b
	B(5,0.6) is not a suitable model [for the number of heads spun **]**	A1ft	3.5a
		(5)	
(d)	$\frac{[0\times2]+(1\times27)+(2\times93)+(3\times181)+(4\times146)+(5\times51)}{500}$ [= 3.19]	M1	3.3
	B([5], $p=\frac{3.19}{5}=0.638$)	A1	1.1b
		(2)	

Notes: **(9 marks)**

(a)	**B1:**	For recognising the limitations of using a chi squared model on small sample sizes eg 20 is not large, not enough data, sample needs to be larger, you may need to combine cells.
(b)	**B1 :**	For 5 [dof] and a correct reason indicating parameter(probability) is not estimated. Condone missing comment about totals
(c)	**B1:**	Both hypotheses correct Must have B(5,0.6) or binomial with number (n) = 5 and probability(p) = 0.6 (in at least 1) and be attached to H_0 and H_1 the right way round.
	M1:	Attempting to find the test statistic $\sum\frac{(O-E)^2}{E}$ (at least two correct expressions, fractions or decimals) or $\chi^2=\sum\frac{O^2}{E}=\frac{(2)^2}{"5.12"}+...+\frac{51^2}{38.88}-500$ (at least two correct expressions, fractions or decimals plus the − 500) Implied by awrt 15.8
	A1:	Awrt16
	B1ft:	Allow 11.07 or awrt 11.070 For correct CV, ft their answer to (b) **NB** dof 3 is 7.815 dof 4 is 9.488
	A1ft:	Ft "their 11.070" and their CV or p value. A correct conclusion independent of the hypotheses ie [If they should reject H_0 then they need "is not a suitable model.If they should accept H_0 then they need "is suitable"…] Allow Binomial is not a suitable model eg condone B(500, 0.6) is not a suitable model. Do not accept contradictory statements
		NB If p value [0.007419] given instead of CV they could get B1M1A1B0A1unless they give the CV as well
(d)	**M1:**	For a correct method using the data to improve the model. Implied by 3.19
	A1:	Correct model. Condone use of any value of n Accept Binomial with p = 0.638

Question	Scheme	Marks	AOs
4(a)(i)	$\mathrm{E}(X)=[0\times p]+(2\times 0.25)+3q+(6\times 0.4)\,[=2.9+3q]$	B1	1.1b
(ii)	$\mathrm{E}(X^2)=[0\times p]+(2^2\times 0.25)+3^2q+(6^2\times 0.4)\,[=15.4+9q]$	B1	1.1b
		(2)	
(b)	$("15.4+9q")-("2.9+3q")^2=3.66$	M1	1.1b
	$9q^2+8.4q-3.33=0 \Rightarrow q=0.3$ and $-37/30$	M1	1.1b
	$q=0.3$* since q cannot be negative	A1cso*	2.4
	SC $("15.4+9\times 0.3")-("2.9+3\times 0.3")^2$ can get M1M0A0		
		(3)	
(c)	$\mathrm{P}(x_1+x_2+x_3+x_4=20)$ = P(6,6,6,2 or 6,6,2,6 or 6,2,6,6 or 2,6,6,6)	M1	1.1b
	$=4\times 0.4^3\times 0.25$	M1	1.1b
	$=0.064$ oe	A1	1.1b
		(3)	
(d)	$\mathrm{P}(x_5+x_6\geqslant 7)$ = P(6,6 or 6,3 or 6,2)	M1	3.1a
	$=(0.4^2)+2\times(0.4\times 0.3)+2\times 0.4\times 0.25$ [= 0.6]	M1	1.1b
	$\mathrm{P}(\text{score}\geqslant 27)$ = "0.064" × "0.6" [= 24/625 = 0.0384]	M1	1.1b
	$Y\sim$ B(3, "0.0384")	dM1	3.3
	$\mathrm{P}(Y\geqslant 1)=1-\mathrm{P}(Y=0)$	M1	1.1b
	= 0.1108…	A1cso	1.1b
		(6)	

Notes **(14 marks)**

(a)(i)	**B1:**	Correct expression for E(X) need not be simplified
(ii)	**B1:**	Correct expression for E(X^2) need not be simplified
(b)	**M1:**	Using "their E(X^2)" – "their (E(X))^2" = 3.66
	M1:	Rearranging to get a correct 3 term quadratic (condone missing = 0) leading to 0.3 and – 37/30(awrt –1.23) or $(10q-3)(30q+37)$
	A1cso:*	cso with a comment why –37/30 is eliminated. Minimum required is $q > 0$ or they say it is impossible.
(c)	**M1:**	Realising that combination is 6662. Any order. Implied by $0.4^3\times 0.25$
	M1:	Correct calculation
	A1:	0.064 oe only eg 8/125
(d)	**M1:**	Realising all the different combinations 7 or more can be scored from 2 games. (no need for arrangements) Implied by (0.4^2) and (0.4×0.3) and (0.4×0.25)
	M1:	Fully correct method.
	M1:	For multiplying "their (c)" with "their $\mathrm{P}(x_5+x_6\geqslant 7)$" providing at least 2 combinations are used to find $\mathrm{P}(x_5+x_6\geqslant 7)$"
	dM1:	Dependent on 3rd M1 being awarded for using or writing B(3, "their $\mathrm{P}(x_1+x_2+x_3+x_4+x_5+x_6\geqslant 27)$") $(1-"0.0384")^3$ or
	M1:	For writing or using $1-\mathrm{P}(Y=0)$ **eg** $1-(1-"0.0384")^3$
	A1cso:	awrt 0.111 from correct working

NB (b)	**1st 3 marks**
Fully correct method	"0.064"$\times(0.4^2)+0.064\times 2\times(0.4\times 0.3)+0.064\times 2\times(0.4\times 0.25)$ is M1M1M1
All 3 but no arrangements	ie "0.064"$\times(0.4^2)+0.064\times(0.4\times 0.3)+0.064\times(0.4\times 0.25)$ M1M0M1
At least 2 combinations used for	>7 eg $0.064\times(0.4\times 0.3)+0.064\times(0.4^2)$ or $2\times(0.4\times 0.3)$ M0M0M1

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