



**GCE**

**Further Mathematics B (MEI)**

**Y422/01: Statistics major**

Advanced GCE

**Mark Scheme for Autumn 2021**

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All examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes should be read in conjunction with the published question papers and the report on the examination.

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## Annotations and abbreviations

Annotation in scoris	Meaning
✓ and ✖	
BOD	Benefit of doubt
FT	Follow through
ISW	Ignore subsequent working
M0, M1	Method mark awarded 0, 1
A0, A1	Accuracy mark awarded 0, 1
B0, B1	Independent mark awarded 0, 1
E	Explanation mark 1
SC	Special case
^	Omission sign
MR	Misread
BP	Blank page
Highlighting	
Other abbreviations in mark scheme	Meaning
E1	Mark for explaining a result or establishing a given result
dep*	Mark dependent on a previous mark, indicated by *. The * may be omitted if only previous M mark.
cao	Correct answer only
oe	Or equivalent
rot	Rounded or truncated
soi	Seen or implied
www	Without wrong working
AG	Answer given
awrt	Anything which rounds to
BC	By Calculator
DR	This indicates that the instruction <b>In this question you must show detailed reasoning</b> appears in the question.

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Question		Answer	Marks	AOs	Guidance	
<b>1</b>	<b>(a)</b>	$34.711$ $\pm 1.96$ $\times \frac{1.53}{\sqrt{50}}$ $= 34.711 \pm 0.424 \text{ or } (34.287, 35.135)$	<b>B1</b> <b>M1</b> <b>M1</b> <b>A1</b> <b>[4]</b>	<b>1.1</b> <b>3.3</b> <b>1.1</b> <b>3.4</b>	Allow 34.29 to 35.13 or 35.14	
<b>1</b>	<b>(b)</b>	50 is a sufficiently large sample to apply the CLT which states that for large samples the distribution of the sample mean is approximately Normal	<b>B1*</b> <b>*B1</b> <b>[2]</b>	<b>2.2b</b> <b>2.4</b>	For mention of central limit theorem For full statement (including CLT)	No credit if CLT not mentioned

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Question		Answer	Marks	AOs	Guidance	
2	(a)	$P(X=0) = \frac{6}{6} \times \frac{1}{6} \times \frac{1}{6}$ $= \frac{1}{36}$	<b>M1</b> <b>A1</b> <b>[2]</b>	<b>3.1a</b> <b>1.1</b>	<b>AG</b>	Allow M1 for $\frac{1}{6} \times \frac{1}{6} = \frac{1}{36}$
2	(b)		<b>B1</b> <b>B1</b> <b>[2]</b>	<b>1.1</b> <b>1.1</b>	For heights For axes and labels	Roughly correct but must have linear scale Do not allow just P on vertical axis
2	(c)	The distribution has (slight) negative skew	<b>B1</b> <b>[1]</b>	<b>1.1</b>	Allow 'roughly symmetrical' or 'unimodal'	Not 'Normal distribution'
2	(d)	<b>DR</b> $E(X) = 0 \times \frac{1}{36} + 1 \times \frac{5}{36} + 2 \times \frac{2}{9} + 3 \times \frac{1}{4} + 4 \times \frac{2}{9} + 5 \times \frac{5}{36}$ $= \frac{105}{36} = \frac{35}{12} = 2.9166\dots$ $E(X^2) = 0^2 \times \frac{1}{36} + 1^2 \times \frac{5}{36} + 2^2 \times \frac{2}{9} + 3^2 \times \frac{1}{4} + 4^2 \times \frac{2}{9} + 5^2 \times \frac{5}{36}$ $= \frac{371}{36} = 10.3055\dots$ $\text{Var}(X) = 10.3055\dots - (2.9166\dots)^2$ $= \frac{259}{144} = 1.80 \quad (1.7986\dots)$	<b>M1</b> <b>A1</b> <b>M1</b> <b>M1</b> <b>A1</b> <b>[5]</b>	<b>1.1a</b> <b>1.1</b> <b>1.1</b> <b>1.2</b> <b>1.1</b>	Allow fraction or decimal form	
2	(e)	Variance = $30^2 \times 1.7986\dots = 1619$ (pence <sup>2</sup> )	<b>B1</b> <b>[1]</b>	<b>1.1</b>		
2	(f)	Average amount received = $30 \times 2.916\dots = 87.5$ $k - 87.5 = 12.5 \Rightarrow k = 100$	<b>B1</b> <b>B1</b> <b>[2]</b>	<b>3.1a</b> <b>1.1</b>		

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Question		Answer	Marks	AOs	Guidance	
3	(a)	Using B(50, 0.04) $P(X = 2) = 0.276$	M1 A1 [2]	3.3 1.1	BC	
3	(b)	$0.96^9 \times 0.04 = 0.0277$	B1 [1]	1.1		Allow 0.028
3	(c)	$0.96^{20} = 0.442$	B1 [1]	1.1		
3	(d)	Expected value for one misunderstood = $\frac{1}{0.04} = 25$  Because geometric For 3 misunderstood expected number = $25 + 25 + 25 = 75$	B1  E1 E1 [3]	2.1  2.4 1.1		Must quote probabilities to get full marks
3	(e)	Require $P(2 \text{ misunderstood in first } 59) \times 0.04$ so using B(59, 0.04) gives $P(X = 2) = 0.267$ $0.267 \times 0.04 = 0.0107$	B1 M1 A1 [3]	3.1a 2.2a 1.1	For identifying required probability Use of correct binomial BC	
4	(a)	Nuclei decay randomly and decays are independent with constant probability $\frac{1}{200000}$  The number of decays out of 1 000 000 is being counted, so a binomial distribution is appropriate  Because $n = 1\,000\,000$ is large and $p = \frac{1}{200000}$ is small a Poisson distribution is also appropriate	E1  E1  E1 [3]	2.4  2.4  2.4	For partial explanation of binomial  For full explanation  For explanation of Poisson	
4	(b)	Po(5) $P(X = 6) = 0.146$ $P(X > 6) = 1 - 0.762 = 0.238$	M1 A1 A1 [3]	3.3 1.1 1.1	BC BC	
4	(c)	Mean = $10 \times 5 = 50$ $P(\text{at least } 60 \text{ decays}) = 1 - 0.9077 = 0.0923$	B1 B1 [2]	3.3 1.1	BC	Allow 0.092

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Question		Answer	Marks	AOs	Guidance	
5	(a)	Two A and one B $\sim N(2 \times 3.9 + 7.8, 2 \times 0.32^2 + 0.41^2)$  N(15.6, 0.3729) P( $\geq 16$ ) = 0.256 (0.25622...)	<b>B1</b>  <b>M1</b> <b>A1</b> <b>[3]</b>	<b>3.3</b>  <b>1.1</b> <b>3.4</b>	For N and mean  For variance <b>BC</b>	Allow if N stated anywhere in answer SOI
5	(b)	Four B – one C $\sim N(4 \times 7.8 - 30.2, 4 \times 0.41^2 + 0.64^2)$ N(1, 1.082) P(within 1 unit) = 0.473 (0.47274...)	<b>B1</b> <b>M1</b> <b>A1</b>  <b>[3]</b>	<b>3.3</b> <b>1.1</b> <b>3.4</b>	For N and mean For variance <b>BC</b>	Allow -1 for mean Allow if N stated anywhere in answer SOI
5	(c)	<b>DR</b> $H_0: \mu = 30.2$ $H_1: \mu \neq 30.2$  where $\mu$ is the population mean capacitance Sample mean = 29.96  Est. population variance = $\frac{1}{9} \left( 8981.0 - \frac{299.6^2}{10} \right)$ = 0.5538  Test statistic = $\frac{29.96 - 30.2}{\sqrt{\frac{0.5538}{10}}}$ = -1.020  Refer to $t_9$ Critical value (2-tailed) at 5% level is 2.262  -1.020 > -2.262 so not significant (do not reject $H_0$ ) Insufficient evidence to suggest that the capacitance of the batch is different from 30.2	<b>B1</b>  <b>B1</b> <b>B1</b>  <b>M1</b>  <b>A1</b>  <b>M1</b>  <b>A1</b> <b>M1</b> <b>A1</b>  <b>M1</b> <b>E1</b>  <b>[11]</b>	<b>3.3</b>  <b>1.2</b> <b>1.1</b>  <b>1.1</b>  <b>1.1</b>  <b>3.3</b>  <b>1.1</b> <b>3.4</b> <b>1.1</b>  <b>2.2b</b> <b>3.5a</b>	Hypotheses in words only must include “population” For definition in context    FT their mean and/or sd  BC No FT if not $t_9$  Or 1.020 < 2.262	Or sd = 0.7442       Or P( $t < -1.020$ ) = 0.1672 Or 0.1672 > 0.025 Answer must be in context

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Question		Answer	Marks	AOs	Guidance	
6	(a)	Mean = 1.725 Variance = 1.768 The variance is reasonably close to the mean so this does support the suitability of a Poisson model	<b>B1</b> <b>B1</b> <b>E1</b> <b>[3]</b>	<b>1.1</b> <b>1.1</b> <b>2.2b</b>	Condone 1.759 (using divisor $n$ )	Or $\frac{345}{200}$  Dep on mean and variance correct
6	(b)	Cell C3 = 0.3106 Cell D3 = 62.1124 Cell E3 = $\frac{(65 - 62.1224)^2}{62.1224}$ = 0.1342	<b>B1</b> <b>B1FT</b> <b>M1FT</b> <b>A1</b> <b>[4]</b>	<b>3.4</b> <b>2.2a</b> <b>1.1a</b> <b>1.1</b>	200 × their C3 (62.12 if use 0.3106)	Do not allow 0.311 Allow 62.2 from 0.311 Must show working to get M1 Allow 0.126 from 62.2
6	(c)	Because otherwise some expected frequencies would be less than 5 so too small for the test to be valid	<b>E1</b> <b>[1]</b>	<b>3.5b</b>	For 'less than 5 so invalid'	
6	(d)	H <sub>0</sub> : Poisson model is a good fit H <sub>1</sub> : Poisson model is not a good fit $X^2 = 2.43$ Refer to $\chi_5^2$ Critical value at 5% level = 11.07  2.43 < 11.07 so result is not significant  There is insufficient evidence to suggest that the Po(1.7) model is not a good fit.	<b>B1</b> <b>B1FT</b> <b>B1</b> <b>B1</b>  <b>M1</b>  <b>A1</b> <b>[6]</b>	<b>2.5</b> <b>1.1</b> <b>3.4</b> <b>1.1</b>  <b>1.1</b>  <b>2.2b</b>	FT Their value of E3 For degrees of freedom = 5 soi  For comparison with critical value  Conclusion in context	Allow M1 (not A1) for comparison with any chi squared critical value eg 1.145 or 5.991



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Question			Answer	Marks	AOs	Guidance
7	(a)		The pairing will eliminate any differences in grip strengths between different people and so will only compare the grip strengths of the dominant and non-dominant hands	<b>E1</b> <b>E1</b> [2]	<b>2.2b</b> <b>2.2b</b>	Give 1 mark for any valid comment For 2 marks must include pairing
7	(b)		The parent population of differences must be Normally distributed	<b>E1</b> <b>E1</b> [2]	<b>1.1</b> <b>1.2</b>	For Normally distributed For full answer including 'differences'
7	(c)		It does because the confidence interval contains 2	<b>E1</b> [1]	<b>3.5a</b>	
7	(d)	(i)	Sample mean difference = 2.39 $0.45 = 1.96 \times \frac{SD}{\sqrt{100}}$ Sample SD = 2.30 (2.2959...)	<b>B1</b>  <b>M1</b>  <b>A1</b> [3]	<b>1.1</b>  <b>3.1b</b>  <b>1.1</b>	
7	(d)	(ii)	The sample must be random since only a random sample enables proper inference about the population to be undertaken	<b>B1</b> <b>B1</b> [2]	<b>3.2b</b> <b>2.4</b>	Do not allow eg a random sample is less likely to be biased

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8	(a)	(i)	Predicted = 50.5	B1 [1]	1.1	Do not allow answer to more than 2dp	
8	(a)	(ii)	Although this point lies within the data (interpolation), the points do not lie too close to the line and the value of $r^2$ is not too close to 1 so the estimate is only moderately reliable	B1 B1 [2]	2.2a 3.5b	Mention of 1 of the three points Mention of at least 2 points with correct conclusion	
8	(a)	(iii)	Coordinates (47.3, 48.7)	B1 [1]	1.1		
8	(a)	(iv)	This is the point with coordinates which are the means of the $x$ - and $y$ -values respectively	B1 [1]	1.1	Allow 'This is the centroid'	
8	(b)	(i)	The scatter diagram is very roughly elliptical and so the distribution may be bivariate Normal	E1 E1 [2]	3.5a 2.4		
8	(b)	(ii)	$S_{vt} = 3886.53 - \frac{1}{20} \times 80.37 \times 970.86 \quad (= -14.87\dots)$ $S_{tt} = 324.71 - \frac{1}{20} \times 80.37^2 \quad (= 1.743\dots)$ $S_{vv} = 47829.24 - \frac{1}{20} \times 970.86^2 \quad (= 700.78\dots)$ $r = \frac{S_{tv}}{\sqrt{S_{tt}S_{vv}}} = \frac{-14.87}{\sqrt{1.743 \times 700.78}}$ $= -0.4255$	M1  M1  M1 A1 [4]	1.1a  1.1  3.3  1.1	Numerical evaluations are not required at this stage For either $S_{tt}$ or $S_{vv}$  For general form including sq. root  BC	
8	(b)	(iii)	$H_0: \rho = 0, H_1: \rho < 0$ where $\rho$ is the population pmcc between $t$ and $v$ For $n = 20$ , the 5% critical value is 0.3783 Since $ -0.4255  > 0.3783$ the result is significant, so there is sufficient evidence to reject $H_0$ There is sufficient evidence at the 5% level to suggest that there is negative correlation between marathon time and $VO_{2\max}$	B1 B1 B1  M1  A1FT [5]	3.3 2.5 3.4  1.1  2.2b	For both hypotheses For defining $\rho$ For correct critical value For comparison and conclusion Allow $-0.4255 < -0.3783$  FT for conclusion in words	Do not allow $r$ in place of $\rho$ Hypotheses in words only get B1 unless population mentioned  Answer must be in context

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Question		Answer	Marks	AOs	Guidance
9	(a)	$P\left(X > \frac{1}{2}n\right) = \frac{\frac{1}{2}(n+1)}{2n+1}$ $= \frac{n+1}{2(2n+1)}$	<b>M1</b> <b>M1</b> <b>A1</b> <b>[3]</b>	<b>3.1a</b> <b>1.1</b> <b>1.1</b>	For correct denominator For correct numerator
9	(b)	$(2n+1)$ values so $\text{Var}(X) = \frac{1}{12}[(2n+1)^2 - 1]$ Var of sum of 10 values $= 10 \times \frac{1}{12}[(2n+1)^2 - 1]$ $= \frac{10}{3}n^2 + \frac{10}{3}n$	<b>M1</b> <b>M1</b> <b>A1</b> <b>[3]</b>	<b>3.1a</b> <b>1.1</b> <b>1.1</b>	Allow M1 for 10× any attempt at variance
10	(a)	$P(T \leq 56) = \frac{104}{500} = 0.208$ $P(T > 61) = 1 - \frac{253}{500} = 0.494$	<b>B1</b> <b>B1</b> <b>[2]</b>	<b>1.1</b> <b>1.1</b>	
10	(b)	$E(T) = 25 + 28 + 5 + 3 = 61$ $\text{Var}(T) = \frac{1}{12} \times 10^2 + \frac{1}{12} \times 6^2 + 4 + 16$ $= \frac{94}{3} \quad (= 31.333)$ $W \sim N(61, 31.333)$ so $P(W \leq 56) = 0.186$ $P(W > 61) = 0.5$	<b>B1</b> <b>M1</b> <b>A1</b> <b>B1</b> <b>B1</b> <b>[5]</b>	<b>3.1a</b> <b>1.1</b> <b>1.1</b> <b>3.3</b> <b>1.1</b>	<b>BC</b>
10	(c)	Because the mean is 61 and both the uniform and Normal distributions are symmetrical so you would expect the simulated probability to be very close to 0.5	<b>E1</b> <b>E1</b> <b>[2]</b>	<b>2.2b</b> <b>2.4</b>	For second mark must mention symmetrical

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Question		Answer	Marks	AOs	Guidance
11	(a)	$F(3) = 1 \Rightarrow \int_0^2 ax^2 dx + \int_2^3 b(3-x)^2 dx = 1$ $\Rightarrow \frac{8}{3}a + \frac{1}{3}b = 1$ $E(X) = 2 \Rightarrow \int_0^2 ax^3 dx + \int_2^3 bx(3-x)^2 dx = 2$ $\Rightarrow 4a + \frac{3}{4}b = 2$ $a = \frac{1}{8}, b = 2$	<b>M1</b> <b>A1</b> <b>M1</b> <b>A1</b> <b>A1</b> <b>[5]</b>	<b>3.1a</b> <b>1.1</b> <b>3.1a</b> <b>1.1</b> <b>1.1</b>	
11	(b)	$F(2) = \int_0^2 \frac{1}{8}x^2 dx = \frac{1}{3}$ $\Rightarrow \int_2^m 2(3-x)^2 dx = \frac{1}{6}$ $\Rightarrow -\frac{2}{3}(3-m)^3 + \frac{2}{3} = \frac{1}{6}$ $\Rightarrow (3-m)^3 = \frac{3}{4} \Rightarrow m = 2.09 \quad (2.0914\dots)$	<b>B1</b> <b>M1</b>  <b>A1</b> <b>[3]</b>	<b>3.1a</b> <b>2.2a</b>  <b>1.1</b>	Or $m = 3 - \sqrt[3]{\frac{3}{4}}$
11	(c)	Using $N(2, \frac{0.2}{50})$ $N(2, 0.004)$ Estimate $P(\text{Mean} < 1.9) = 0.0569$	<b>M1</b> <b>M1</b> <b>A1</b> <b>[3]</b>	<b>3.1a</b> <b>1.1a</b> <b>1.1</b>	For use of Normal distribution For correct values

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