GCE

Mathematics B (MEI)

H640/02: Pure Mathematics and Statistics

Advanced GCE

Mark Scheme for June 2019

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This mark scheme is published as an aid to teachers and students, to indicate the requirements of the examination. It shows the basis on which marks were awarded by examiners. It does not indicate the details of the discussions which took place at an examiners' meeting before marking commenced.

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.

Text Instructions

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
SC	Special case
^	Omission sign
MR	Misread
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 *
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 **In this question you must show detailed reasoning** appears in the question.

Subject-specific Marking Instructions for A Level Mathematics B (MEI)

a Annotations should be used whenever appropriate during your marking. The A, M and B annotations must be used on your standardisation scripts for responses that are not awarded either 0 or full marks. It is vital that you annotate standardisation scripts fully to show how the marks have been awarded. For subsequent marking you must make it clear how you have arrived at the mark you have awarded.

b An element of professional judgement is required in the marking of any written paper. Remember that the mark scheme is designed to assist in marking incorrect solutions. Correct solutions leading to correct answers are awarded full marks but work must not be judged on the answer alone, and answers that are given in the question, especially, must be validly obtained; key steps in the working must always be looked at and anything unfamiliar must be investigated thoroughly. Correct but unfamiliar or unexpected methods are often signalled by a correct result following an apparently incorrect method. Such work must be carefully assessed. When a candidate adopts a method which does not correspond to the mark scheme, escalate the question to your Team Leader who will decide on a course of action with the Principal Examiner.
If you are in any doubt whatsoever you should contact your Team Leader.

c The following types of marks are available.

M
A suitable method has been selected and *applied* in a manner which shows that the method is essentially understood. Method marks are not usually lost for numerical errors, algebraic slips or errors in units. However, it is not usually sufficient for a candidate just to indicate an intention of using some method or just to quote a formula; the formula or idea must be applied to the specific problem in hand, e.g. by substituting the relevant quantities into the formula. In some cases the nature of the errors allowed for the award of an M mark may be specified.

A
Accuracy mark, awarded for a correct answer or intermediate step correctly obtained. Accuracy marks cannot be given unless the associated Method mark is earned (or implied). Therefore M0 A1 cannot ever be awarded.

B
Mark for a correct result or statement independent of Method marks.

E
A given result is to be established or a result has to be explained. This usually requires more working or explanation than the establishment of an unknown result.

Unless otherwise indicated, marks once gained cannot subsequently be lost, e.g. wrong working following a correct form of answer is ignored. Sometimes this is reinforced in the mark scheme by the abbreviation isw. However, this would not apply to a case where a candidate passes through the correct answer as part of a wrong argument.

d When a part of a question has two or more 'method' steps, the M marks are in principle independent unless the scheme specifically says otherwise; and similarly where there are several B marks allocated. (The notation 'dep*' is used to indicate that a particular mark is dependent on an earlier, asterisked, mark in the scheme.) Of course, in practice it may happen that when a candidate has once gone wrong in a part of a question, the work from there on is worthless so that no more marks can sensibly be given. On the other hand, when two or more steps are successfully run together by the candidate, the earlier marks are implied and full credit must be given.

e The abbreviation FT implies that the A or B mark indicated is allowed for work correctly following on from previously incorrect results. Otherwise, A and B marks are given for correct work only – differences in notation are of course permitted. A (accuracy) marks are not given for answers obtained from incorrect working. When A or B marks are awarded for work at an intermediate stage of a solution, there may be various alternatives that are equally acceptable. In such cases, what is acceptable will be detailed in the mark scheme. If this is not the case please, escalate the question to your Team Leader who will decide on a course of action with the Principal Examiner.
Sometimes the answer to one part of a question is used in a later part of the same question. In this case, A marks will often be 'follow through'. In such cases you must ensure that you refer back to the answer of the previous part question even if this is not shown within the image zone. You may find it easier to mark follow through questions candidate-by-candidate rather than question-by-question.

f We are usually quite flexible about the accuracy to which the final answer is expressed; over-specification is usually only penalised where the scheme explicitly says so.

- When a value is given in the paper only accept an answer correct to at least as many significant figures as the given value.
- When a value is not given in the paper accept any answer that agrees with the correct value to **2 s.f.**

Follow through should be used so that only one mark is lost for each distinct accuracy error.

g Rules for replaced work: if a candidate attempts a question more than once, and indicates which attempt he/she wishes to be marked, then examiners should do as the candidate requests; if there are two or more attempts at a question which have not been crossed out, examiners should mark what appears to be the last (complete) attempt and ignore the others. NB Follow these maths-specific instructions rather than those in the assessor handbook.

h For a genuine misreading (of numbers or symbols) which is such that the object and the difficulty of the question remain unaltered, mark according to the scheme but following through from the candidate's data. A penalty is then applied; 1 mark is generally appropriate, though this may differ for some units. This is achieved by withholding one A mark in the question. Marks designated as cao may be awarded as long as there are no other errors. E marks are lost unless, by chance, the given results are established by equivalent working. 'Fresh starts' will not affect an earlier decision about a misread. Note that a miscopy of the candidate's own working is not a misread but an accuracy error.

i If a graphical calculator is used, some answers may be obtained with little or no working visible. Allow full marks for correct answers (provided, of course, that there is nothing in the wording of the question specifying that analytical methods are required). Where an answer is wrong but there is some evidence of method, allow appropriate method marks. Wrong answers with no supporting method score zero. If in doubt, consult your Team Leader.

j If in any case the scheme operates with considerable unfairness consult your Team Leader.

Question			Answer	Marks	AOs		Guidance
1	(a)		$0.2 + 0.1 + k + 2k + 4k$ [= 1] **soi** [k =] 0.1	**M1** **A1** **[2]**	**1.1a** **1.1**		
1	(b)		1 – 2×their k 0.8 or $\frac{4}{5}$ cao	**M1** **A1** **[2]**	**1.1** **1.1**	1 – their P(X = 4) oe	
2	(a)		$k(x^2+5)^{11}$ seen $24x(x^2+5)^{11}$	**M1** **A1** **[2]**	**1.1a** **1.1**		
2	(b)		$a(x^2+5)^{12}$ $2(x^2+5)^{12}(+c)$	**M1** **A1** **[2]**	**1.1** **1.1**	condone omission of + c	**A1** FT their $kx(x^2 + 5)^{11}$ from part **(a)**
3	(a)		2.8 to 2.81 BC	**B1** **[1]**	**1.1**		NB 2.8063583815029..

Question			Answer	Marks	AOs		Guidance
3	(b)		eg the data is already grouped oe eg we do not have the original raw data oe eg we are using the mid-point of the intervals eg we are assuming the data are uniformly distributed across each interval oe	**B1** **[1]**	**2.4**		
3	(c)		eg using upper class limit in each case gives mean is 3.4…so it is possible that mean is more than 3	**B1** **[1]**	**2.3**	or eg need 520 or more and using the upper limits gives 590	simply stating eg the mean could be 3.4 is insufficient
4	(a)		$\frac{0.5}{2}\left[\sqrt{1+(-1)^3}+2\sqrt{1+(-0.5)^3}+\sqrt{1+0^3}\right]$ oe $\sqrt{1+(-0.5)^3}$ soi 0.717707 cao	**M1** **B1** **A1** **[3]**	**1.1** **1.1** **1.1**	condone omission of brackets NB $\frac{\sqrt{14}}{4}$ = 0.9(35414346693) NB $\frac{2+\sqrt{14}}{8}$ unsupported implies **M1B1**	must be three terms in the bracket if unsupported allow **SC3** for 0.717707 and **SC2** for 0.717707173347 unsupported to 7 or more dp
4	(b)		under-estimate since curve is concave down /convex up oe	**B1** **[1]**	**2.4**	or eg the slant lines of both trapezia are entirely below the curve allow annotated diagram with at least one trapezium	condone eg trapezium below curve allow integral is 0.841309 BC so my answer is an underestimate

Question			Answer	Marks	AOs		Guidance
5	(a)		2.5	**B1** **[1]**	**1.1**		
5	(b)		positive skew cao	**B1** **[1]**	**1.1**		
5	(c)		1	**B1** **[1]**	**1.1**		
6			$k\frac{x^{-4}}{-4}\ln x - \int k\frac{x^{-4}}{-4}\times\frac{1}{x}\mathrm{d}x$ oe $[32]\frac{x^{-4}}{-4}\ln x - \int [32]\frac{x^{-4}}{-4}\times\frac{1}{x}\mathrm{d}x$ oe $-8x^{-4}\ln x - 2x^{-4} + c$ oe isw	**M1** **A1** **A1** **A1** **[4]**	**3.1a** **1.1** **1.1** **1.1**	allow sign errors only all correct two of three elements correct all three elements correct	
7	(a)		$\theta = \frac{72.576}{r^2}$ or $72.576\ r^{-2}$ isw	**B1** **[1]**	**1.1**	eg $\frac{9072}{125r^2}$ or $\frac{9072r^{-2}}{125}$	
7	(b)		$r\theta + 2r$ or $r(\theta + 2) = 24.48$ seen **and** $\theta = \frac{24.48 - 2r}{r}$ or equivalent constructive step to give $\frac{24.48}{r} - 2$ **AG**	**B1** **[1]**	**1.1**	or $2\pi r\frac{\theta}{2\pi} + 2r = 24.48$	

Question			Answer	Marks	AOs		Guidance
7	(c)		$their\ \frac{2\times36.288}{r^2} = \frac{24.48}{r} - 2$ oe	M1	3.1a	NB 72.576	
			$r^2 - 12.24r + 36.288$ [= 0]	M1	2.1	quadratic obtained in form f(r) [= 0]	allow **B3** for 5.04 **and** 7.2 unsupported **or** allow **SC3** for obtaining and solving an equation for θ and then finding both values of r
			[r =] 5.04 or 7.2 oe	A1 [3]	1.1		
8	(a)		0.4×0.4 or 0.6×0.2 seen	M1	3.1a	or tree diagram with correct outcomes and probabilities shown	allow 0.4×0.4×0.4 or 0.4×0.6×0.2
			0.4×0.4 + 0.6×0.2	A1	1.1		
			0.28	A1 [3]	1.1		mark the final answer
8	(b)		$\frac{1}{120}$ or $\frac{5}{120}$ seen	M1	3.1a		
			$\frac{1}{24}$ or 0.0416666…to 2 or more sf	A1 [2]	1.1	**B2** for 0.0416666…unsupported **B0** for 0.042 unsupported	mark the final answer

Question			Answer	Marks	AOs		Guidance
8	**(c)**		1 – their $\frac{1}{24}$ evaluated	**M1**	**3.1a**		
			$1 - \left(\frac{23}{24}\right)^n > 0.95$ FT	**M1**	**2.1**	allow use of =, $\geqslant$ or $\leqslant$	
			$\left(\frac{23}{24}\right)^n < 0.05$ FT	**M1**	**1.1**	allow use of = or $\leqslant$	
			$n = 71$ cao	**A1** **[4]**	**2.2a**	70.3890…unsupported but rounded to 1 or more dp implies **M1M1M1**	award full marks for 71 unsupported or from trial and improvement
9	**(a)**		$(2x + 3 – 1)^2$ or $(2x + 3)^2 – 2(2x + 3) + 1$ seen	**M1**	**1.1**	substitution	
			simplified to eg $4(x + 1)^2$ or $4x^2 + 8x + 4$ or $(2x + 2)^2$	**A1**	**1.1**	mark the final answer	ignore superfluous work on eg finding roots
			domain is $– 1 < x < 0$	**B1** **[3]**	**1.1**	from $2x + 3 > 1$	
9	**(b)**		$0 < \text{gf}(x) < 4$	**B1** **[1]**	**1.1**		

Question			Answer	Marks	AOs		Guidance
9	**(c)**		factorise their gf(x) to obtain perfect square or complete the square	**M1**	**3.1a**	allow eg $2(x + 1)(2x + 2)$; may follow slip eg dividing by 4	or $g^{-1}(x) = \sqrt{x} + 1$ or $f^{-1}(x) = ½(x – 3)$ for **M1**
			$y = 4(x + 1)^2$ or $(2x + 2)^2$ oe	**A1**	**2.1**	FT	**A1** for both correct
			$(x + 1) = (\pm)\sqrt{\frac{y}{4}}$ oe	**M1**	**1.1**		**M1** for their f^{-1}(their $\sqrt{x} + 1$)
			$[(gf)^{-1}(x) =] \sqrt{\frac{x}{4}} – 1$ or $\frac{\sqrt{x}}{2} – 1$ oe	**A1**	**1.1**		**A1** for $(gf)^{-1}(x) = \sqrt{\frac{x}{4}} – 1$ or $\frac{\sqrt{x}}{2} – 1$ oe
			domain is $0 < x < 4$	**B1** **[5]**	**1.1**	FT their **(b)**	x and y may be interchanged for the first 3 marks but not for the final **A1**
10	**(a)**		[=]153	**B1** **[1]**	**1.1**		
10	**(b)**		$z = \pm 1.645$ used	**B1**	**1.1**	or ±1.644(85…)	
			their positive 1.645 = $\frac{183 – their\ 153}{\sigma}$ oe (= 18.237…to 18.248…)	**M1**	**2.1**		**M0** if continuity correction used
			$\sigma = 18.2$ cao	**A1** **[3]**	**1.1**		

Question			Answer	Marks	AOs		Guidance
10	(c)		$\left[\frac{16}{452} =\right] 0.035(398 \ldots)$ their P(X < 120) from N(their 153, their 18.2^2) probability of 0.0349 to 0.0352 which agrees to 2 sf	**B1** **M1** **A1** **[3]**	**3.1b** **1.1** **2.2b**	allow percentage **M0** if continuity correction used allow percentage …… **or B1** for their P(X < 120) then **M1** for 452 × their 0.03490.. then **A1** for 15.77 to 15.91 which is close to 16 oe …… **or B1** as main scheme then **M1** for $\sigma = \frac{120 - 153}{their\ -1.809}$ and 18.3 ≈ 18.2 for **A1**	or **B1** as main scheme then Invnorm(0.0353, their 153, their 18.2) for **M1** **NB** 119.95 to 120.15 which is close to 120 oe for **A1** **or B1** as main scheme then $z = \frac{120 - their\ 153}{their\ 18.2}$ for **M1** **NB** –1.809 to –1.813 and Invnorm(0.0353, 0, 1) to obtain –1.806 to – 1.812 which is close to –1.809 to –1.813) for **A1**

Question			Answer	Marks	AOs		Guidance
10	(d)		H_0: μ = their 153 H_1: μ < their 153	**B1**	**1.1**	for both hypotheses; may be stated in words, but need to see 153 for **B1** and **population** mean for 2nd **B1**	**B0** if other parameter used unless clearly defined as population mean
			μ is the **population mean** flight time from **Magaluf to Liverpool**	**B1**	**2.5**		
			use of N(their153, $\frac{their18.2^2}{24}$) to find $P(\bar{X} < 143.6)$	**M1***	**3.3**	or inv Norm(0.01, their 153, $\frac{their\ 18.2^2}{24}$)	or $z = \frac{143.6-their153}{their\frac{18.2}{\sqrt{24}}}$
			awrt 0.0057 to 0.0058… to 2 or more sf oe **isw**	**A1**	**1.1**	$\bar{X} < 144$ to 144.4 is critical region	z = – 2.5248.. to –2.5302… to 2 or more dp
			their 0.0057 correctly compared with 0.01 oe	**M1dep***	**3.4**	143.6 correctly compared with their 144.36 FT their comparison	their z compared with – 2.326 or – 2.33
			result is significant or reject H_0 or accept H_1	**A1**	**1.1**	FT their comparison	
			there is sufficient evidence to **suggest** at the 1% level that the **mean** flight time from **Magaluf to Liverpool** is less than **153** / mean flight time from Liverpool to Magaluf	**A1**	**2.2b**		do not allow eg conclude / prove / indicate or other assertive statement instead of suggest
				[7]			

Question			Answer	Marks	AOs		Guidance
10	(e)		**reduce** the value of μ **increase** the value of σ or σ^2	**B1** **B1** **[2]**	**3.5c** **3.5c**	 allow **B1** for eg use new sample data to calculate new estimate for σ or σ^2	eg take a bigger sample is insufficient
11	(a)		differentiate to obtain $2x - 4$ $+ 1 \times \ln x + x \times \frac{1}{x}$ oe derivative = 0 oe seen and terms combined $2x - 3 + \ln x = 0$ www **isw AG**	**B1** **M1** **A1** **A1** **[4]**	**3.1a** **2.1** **1.1** **2.4**	 use of Product Rule all correct	 allow one error

Question			Answer	Marks	AOs		Guidance
11	**(b)**		any rearrangement to obtain $x = g(x)$ from given derivative = 0	**M1***	**2.1**	allow sign error	eg $x = e^{2x-3}$
			$x = \frac{3 - \ln x}{2}$	**A1**	**1.1**	any correct rearrangement	need not see subscripts in iterative formula
			use of their $g(x_n) = \frac{3 - \ln x_n}{2}$ to obtain at least two iterates eg 2, 1.1534, 1.4286…	**M1dep***	**1.1**	must see iterates	
			1.3500 cao	**A1**	**2.2a**		**0** for 1.3500 unsupported
			……	**[4]**			trial and improvement does not score
			Alternatively, $x_{n+1} = x_n - \frac{2x_n - 3 + \ln x_n}{\text{their}\left(2 + \frac{1}{x_n}\right)}$	**M1***	**2.1**	Newton-Rapshon iterative formula seen (not for solving $f(x) = 0$)	need not see subscripts in iterative formula
			use of their N-R formula to obtain $x_1, x_{2,...}$	**A1**	**1.1**	formula all correct	
			eg 1.5, 1.34795, 1.34996,….1.349962	**M1dep***	**1.1**	must see iterates	
			1.3500 cao	**A1**	**2.2a**		
				[4]			

Question			Answer	Marks	AOs		Guidance
12	**(a)**		$0.94^n < k$ or $0.06^n < k$ seen	**M1**	**3.4**		allow = instead of <
			$k = 0.025$ used in inequality as above	**B1**	**1.1**		
			60	**A1**	**2.2a**	NB 59.617.. or 1.311…to 1 or more dp if unsupported implies **M1B1**	60 unsupported or from trial and improvement scores 3
				[3]			

Question			Answer	Marks	AOs		Guidance
12	(b)		$H_0 : p = 0.06$ allow equivalent in words $H_1 : p \neq 0.06$	**B1**	**1.1**		
			p is the probability that a **jaguar** chosen at random is a **black** panther / has **black** coat	**B1**	**2.5**	**or** p is the proportion of **jaguars** that are **black** panthers / have a **black** coat	
			use of B(83, 0.06) to obtain P($X \leq K$) oe	**M1***	**3.3**	not P($X = K$)	NB P($X \leq 10$) = .98927…
			cdfBinomial(83, 0.06, 9) = 0.973 to 0.97321… or 1 – cdfBinomial(83, 0.06, 9) = 0.02679 to 0.027	**A1**	**1.1**	or critical region is $X \geq 11$ (ignore lower tail)	for comparison of their P($X > K$) with 0.025 or their P($X \leq K$) with 0.975 or stating whether 10 is in their critical region
			1 – their P($X \leq K$) compared with 0.025 or their P($X \leq K$) compared with 0.975 oe	**M1dep***	**3.4**	eg 10 compared with their critical region oe	
			result is not significant or do not reject H_0 or reject H_1	**A1**	**1.1**	must have the correct probability or correct critical region for the last two **A** marks	allow accept H_0
			there is insufficient evidence at the 5% level to **suggest** that the probability that a **jaguar** selected at random from this population is a **black panther** is not 0.06	**A1** **[7]**	**2.2b**		do not allow eg conclude / prove / indicate or other assertive statement instead of suggest
13	**(a)**		3	**B1** **[1]**	**3.3**		

Question			Answer	Marks	AOs		Guidance
13	**(b)**		$[8\times3^4 =]$ 648	**B1** **[1]**	**1.1**		
13	**(c)**		$\frac{8(3^n-1)}{3-1}$ $= 4(3^n-1)$ or $-4(1-3^n)$	 **B1** **[1]**	 **3.4**	use of formula for sum of gp mark the final answer	 or $4\times3^n - 4$
13	**(d)**		their $4(3^n - 1) = 185\ 207$ or $3^n = 46303(.75)$ awrt 9.8 cao [=] 9	**M1** **A1** **A1** **[3]**	**3.1a** **1.1** **3.2a**	**M0** for eg $8\times3^{n-1}$ no FT available here not from wrong working	allow use of < or $\leqslant$ for up to 3 marks allow **M1** only for use of > or $\geq$ or $3^9 = 19683$ **and** $3^{10} = 59049$ seen for **M1** then **A1** (comparison with 46 303)
13	**(e)**		unlikely because eg some of the population will be immune to the virus eg some of the population will not be exposed to the virus eg medical intervention eg extrapolation eg movement of people in and out of town	**B1** **[1]**	**3.5b**	any sensible reason	it's unlikely that everyone will be affected oe is insufficient

Question			Answer	Marks	AOs		Guidance
14	**(a)**		the data was not available for all countries oe	**B1** **[1]**	**2.4**		
14	**(b)**		use of $Q_1 - 1.5\times(Q_3 - Q_1)$ and $Q_3 + 1.5\times(Q_3 - Q_1)$ seen for either set 4.135 < 6.28 and 15.775 > 14.46 0.38 < 3.58 and 18.86 > 14.89	**M1** **A1** **A1** **[3]**	**3.1b** **1.1** **1.1**	if **A0A0** allow **SC1** for 4.135, 15.775, 0.38 and 18.86 all seen	
14	**(c)**		22 954 isw	**B1** **[1]**	**3.1b**	allow 22 955, 22 950 or 23 000	**NB** $6411776 \times \frac{3.58}{1000}$
14	**(d)**		there are almost certainly more "old" people in the population oe	**B1** **[1]**	**2.4**		

Question			Answer	Marks	AOs		Guidance
14	(e)		in African countries there is a negative association / relationship between (or negative correlation between the ranks of) median age and crude death rate, but in Europe there seems to be a positive association / relationship between (or positive correlation between the ranks of) median age and crude death rate	**B1**	**2.4**	do not allow "negative correlation" and / or "positive correlation"	comment comparing and contrasting type of relationship in both continents for **B1**, **and** one comment comparing and contrasting strength of relationship in both continents for **B1**
			the "association" / "relationship between" or "correlation between the ranks of" median age and crude death rate (appears to be) stronger in Europe	**B1** **[2]**	**2.4**	allow **B1** both relationships are weak oe	allow equivalent explanations in words eg as median age increases crude death rates decrease in Africa and similar for Europe

Question			Answer	Marks	AOs		Guidance
15			$\mu = 35$ **soi**	**B1**	**1.2**	by symmetry	
			$\sigma = 4$ seen	**B1**	**3.1b**	$35 - 31 = 4$	may be embedded in $N(35,4^2)$ or $N(35,16)$
			use of $N(35, 4^2)$ to obtain a value for $P(30 < X < 40)$	**M1**	**2.1**		**M0** if continuity corrections used
			[cdfNormal(30, 40, 35, 4) =] 0.788700… BC to 2 or more dp	**A1**	**1.1**		
			use of $Y \sim B(50,$ their 0.7887$)$ to find $P(Y \leq K)$ or $P(Y \geq K)$	**M1**	**3.1b**	eg cdfBinomial(50,0.7887,45,50)	their 0.7887 must be from use of $N(35, 4^2)$
			$[1 - P(Y \leq 44)] = 0.032$ to 0.034 BC	**A1**	**1.1**		
				[6]			

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