GCE

Mathematics B (MEI)

H640/03: Pure Mathematics and Comprehension

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.

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 Unless units are specifically requested, there is no penalty for wrong or missing units as long as the answer is numerically correct and expressed either in SI or in the units of the question. (e.g. lengths will be assumed to be in metres unless in a particular question all the lengths are in km, when this would be assumed to be the unspecified unit.) 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. This rule should be applied to each case. 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, except for errors due to premature approximation which should be penalised only once in the examination. There is no penalty for using a wrong value for *g*. E marks will be lost except when results agree to the accuracy required in the question.

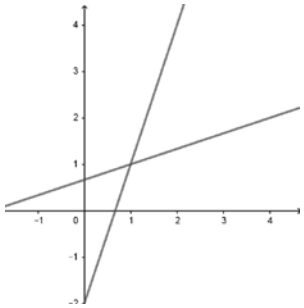
g Rules for replaced work: if a candidate attempts a question more than once, and indicates which attempt he/she wishes to be marked, then examiners should do as the candidate requests; if there are two or more attempts at a question which have not been crossed out, examiners should mark what appears 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 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.

k Anything in the mark scheme which is in square brackets […] is not required for the mark to be earned on this occasion, but shows what a complete solution might look like.

Question			Answer	Marks	AOs	Guidance	
1	(a)		$y = 3x - 2$ so $x = \frac{y+2}{3}$ $f^{-1}(x) = \frac{x+2}{3}$	M1 A1 [2]	1.1a 1.1	Condone '$y =$' but eg '$f(x) =$' does not score	
1	(b)			B1 B1 [2]	1.1 1.1	$y = 3x - 2$ going through (0, –2) Or $y = \frac{x+2}{3}$ going through (0, 2/3) $y = f^{-1}(x)$ a reflection of $y = f(x)$ in $y = x$ Both graphs linear to get B2	Line of symmetry roughly at 45° or implied by coords
1	(c)		$3x - 2 = x$ when $x = 1$ $x > 1$	M1 A1 [2]	3.1a 2.2a	Attempt to find when $f(x) = x$ or attempt to solve $3x - 2 = \frac{x+2}{3}$ or $3x - 2 > \frac{x+2}{3}$ soi by $x = 1$	Using *their* inverse

Question			Answer	Marks	AOs	Guidance	
2	(a)		$x^2+8x-7=(x+4)^2-16-7$	M1	3.1a	For $(x+4)^2$	Or from differentiation
			$(x+4)^2-23$	A1	1.1	Correct completion of square	
			Translation	B1	1.1	More than one transformation loses last two marks	
			$\begin{pmatrix}-4\\-23\end{pmatrix}$	B1	1.1		Must be vector
				[4]			
2	(b)		$(-4,\ -23)$	B1	2.2a	Correct or FT *their* **translation** or vector	
				[1]			
3	(a)		$\frac{1}{(x+2)(x+3)}=\frac{A}{(x+2)}+\frac{B}{(x+3)}$			Method marks are implied by correct answer.	
			$1=A(x+3)+B(x+2)$	M1	1.1a	For clearing the fractions	
			$x=-3 \Rightarrow 1=-B \Rightarrow B=-1$ $x=-2 \Rightarrow 1=A$	M1	1.1	For one appropriate substitution	
			So $\frac{1}{(x+2)(x+3)}=\frac{1}{(x+2)}-\frac{1}{(x+3)}$	A1	1.1	For correct completion	
				[3]			
3	(b)		$\int\left(\frac{1}{(x+2)}-\frac{1}{(x+3)}\right)\mathrm{d}x=\ln\lvert x+2\rvert-\ln\lvert x+3\rvert\ [+c]$	M2	1.1a 1.1	For both terms correct FT their fractions **M1** for one of their terms correct	Need brackets or better (eg single fraction
			$\ln\left\lvert\frac{x+2}{x+3}\right\rvert+c$	A1	2.2a	**A0** if modulus sign missing or if further work eg to try and find c	Ignore ' $f(x)=$ '

Question			Answer	Marks	AOs	Guidance	
				[3]			

4			**DR** $\frac{\sqrt{11}-\sqrt{10}}{11-10}+\frac{\sqrt{12}-\sqrt{11}}{12-11}+\frac{\sqrt{13}-\sqrt{12}}{13-12}$ $\sqrt{13}-\sqrt{10}$ $\frac{3}{\sqrt{10}+\sqrt{13}}=\frac{3\left(\sqrt{13}-\sqrt{10}\right)}{13-10}=\sqrt{13}-\sqrt{10}$ [hence the two expressions are equal]	**M1** **A1** **E1** **[3]**	**3.1a** **1.1** **2.4**	Rationalising denominators, allow one error Convincing completion	

Question			Answer	Marks	AOs	Guidance	
5			Suppose there is a largest prime, [p]	**M1**	**2.1**	Allow 'If there is …' oe	
			Multiply all the primes up to and including [p] and add 1 This number is not divisible by any of the primes				
			Therefore it is prime (and larger than p)	**A1**	**2.3**		
			This is a contradiction (so there is no largest prime)	**A1**	**2.4**	Must mention 'contradiction'	
				[3]			

6	**(a)**		Radius = 4 $(x-10)^2+(y-4)^2=16$	**B1** **B1** **[2]**	**3.1a** **1.1**	soi by 16 o.e.	
6	**(b)**		Where $y=x$ meets the circle $(x-10)^2+(x-4)^2=16$ $2x^2-28x+116=16$ or $x^2-14x+50=0$ or $2x^2-28x+100=0$ $b^2-4ac=-4$ or -16 so no meeting points i.e. not a tangent	**M1** **M1** **M1** **E1**	**3.1a** **1.1** **1.1** **2.4**	For sub'n of $y=x$ into their circle equation For expanding and collecting like terms Rearranging to 3 term quadratic =0 Or $(x-7)^2+1=0$ no meeting points hence not a tangent	'No real roots' not enough for E1 Allow E1 for correct reasoning following omission of '=0'
			Alternative method Angle between $y=x$ and x-axis = 45º Let θ be the angle between the x-axis and the line joining (0, 0) and (10, 4). tan θ =0.4 θ= 21.80(2 d.p.) If $y=x$ was a tangent θ would be 22.5º hence not a tangent	 **M1** **M1** **M1** **E1**		**Alternative method 2** gradient of normal is -1 Line joining point of contact (k, k) to centre (10, 4) must have gradient -1 $k=7$ (7, 7) does not lie on circle	
				[4]			
6	**(c)**		$5\mathbf{i}+2\mathbf{j}$ or $\begin{pmatrix}5\\2\end{pmatrix}$	**B1** **[1]**	**2.5**	Must be correct vector notation; not (5, 2)	
7	**(a)**		**DR** $\ln 3^2$, $\ln 3^3$ seen	**B1**	**1.1a**		

			$\ln 3 \times 2\ln 3 \times 3\ln 3 = 6(\ln 3)^3$	**B1** **[2]**	**2.2a**		
7	**(b)**		**DR** $3 > e$ so $\ln 3 > 1$ $(\ln 3)^3 > 1$ so $6(\ln 3)^3 > 6$	**M1** **E1** **[2]**	**2.2a** **2.4**	Convincing completion (answer given)	Must mention e

8	**(a)**		**DR** $\frac{dy}{dx} = 3x^2$	**M1**	**3.1a**		
			Gradient at (1, 1) is 3	**M1**	**1.1**		
			Tangent is $(y-1) = 3(x-1)$	**A1**	**1.1**	($y = 3x - 2$; simplified form not essential)	**or** $\frac{AB}{AD} = 3$
			OE = 2 and OD = $\frac{2}{3}$	**M1**	**3.1a**	Finding either of these lengths soi by E (0, -2) or D ($\left(\frac{2}{3}, 0\right)$	**or** $AD = \frac{1}{3}$
				A1	**1.1**	Bothe OE and OD correct	**Or** Triangle ODE is similar to ABD [with scale factor 2]
			Area triangle ODE = $\frac{1}{2} \times \frac{2}{3} \times 2 = \frac{2}{3}$	**A1**	**1.1**		
				[6]			

8	**(b)**		**DR** Area = $\int_0^1 \left(x^3 - (3x-2)\right)\,\mathrm{d}x$	**M1** **M1**	**3.1a** **1.1**	Integrand. FT their tangent Limits (may be seen later)	
			$\left[\frac{x^4}{4} - \frac{3x^2}{2} + 2x\right]_0^1$	**M1**	**1.1**	Allow one error	
			$\frac{3}{4}$	**A1**	**2.2a**		
			Alternative method Area between curve and x-axis = $\int_0^1 x^3\,\mathrm{d}x = \left[\frac{x^4}{4}\right]_0^1 = \left[\frac{1}{4}\right]$	**M1**			
			Area triangle ABD = $\frac{1}{2}\times\frac{1}{3}\times 1 = \frac{1}{6}$	**M1**			
			Area = area between curve and x-axis + triangle ODE – triangle ABD	**M1**		Using *their* values	
			$\frac{3}{4}$	**A1**			
				[4]			

9			**DR** Gradient of normal = 2 $\Rightarrow$ gradient of tangent = -0.5 $2y\frac{dy}{dx}+y+x\frac{dy}{dx}=0$ eg $-y+y-0.5x=0 \Rightarrow x=0$ $y^2=8$ $\left(0,\ \sqrt{8}\right)$ and $\left(0,\ -\sqrt{8}\right)$	**M1** **M1** **A1** **A1** **M1** **A1**	**3.1a** **1.1** **1.1** **2.2a** **1.1** **1.1**	$\frac{-y}{x+2y}=-\frac{1}{2}$ Attempt at implicit differentiation with one algebraic term differentiated correctly Correct implicit expression Implied by at least one y-value	**Or M1** for correct expression for x in terms of y and attempt to differentiate For one step solving their equation in x and/or y with original equation

			Alternative method $\frac{dx}{dy} = \frac{-8-y^2}{y^2}$ oe $\frac{8+y^2}{y^2} = 2$ oe $y^2 = 8$ $\left(0,\ \sqrt{8}\right)$ and $\left(0,\ -\sqrt{8}\right)$	**M1** **M1** **A1** **M1** **M1** **A1** **[6]**		Rearranging to $x = \frac{8-y^2}{y}$ and attempting differentiation Differentiation by dividing first or quotient rule – allow one error Correct differentiation Using negative reciprocal Implied by at least one y-value	

10			$f'(x) = \frac{(1+e^x)e^x - e^x e^x}{(1+e^x)^2}$ or $f'(x) = \frac{e^x}{1+e^x} - \frac{e^{2x}}{(1+e^x)^2}$ from product rule $f'(x) = \frac{e^x}{(1+e^x)^2}$ $f'(x) > 0 \Rightarrow$ f(x) is an increasing function for all x	**M1** **A1** **M1** **E1** **[4]**	**1.1a** **1.1** **2.1** **2.4**	Use of quotient rule or product rule (allow one error) Correct derivative Simplifying derivative to a form which shows it is positive All correct and clear completion	

11			Let $u = 1+\sqrt{x}$ $\Rightarrow \mathrm{d}x = 2(u-1)\mathrm{d}u$ or $dx = \frac{du}{\frac{1}{2}x^{-\frac{1}{2}}}$ oe or $2\sqrt{x}du$	**M1**	**1.1**		
			$\int \frac{x}{1+\sqrt{x}}\mathrm{d}x = \int \frac{2(u-1)^3}{u}\mathrm{d}u$ oe	**A1**	**1.1**	In terms of u	
			$\int \frac{2(u^3-3u^2+3u-1)}{u}\mathrm{d}u$	**M1**	**1.1**	For expanding cubic (allow one error)	
			$\int 2\left(u^2-3u+3-\frac{1}{u}\right)\mathrm{d}u$	**M1**	**3.1a**	Dividing by u	
			$\frac{2u^3}{3}-3u^2+6u-2\ln\lvert u\rvert+c$	**M1**	**1.1**	3 of *their* terms correctly integrated to inc ln$u$. Constant term may be missing at this stage	Condone omission of modulus (since $1+\sqrt{x}$, and hence u, must be positive)
			$\frac{2\left(1+\sqrt{x}\right)^3}{3}-3\left(1+\sqrt{x}\right)^2+6\left(1+\sqrt{x}\right)-2\ln\left\lvert 1+\sqrt{x}\right\rvert+c$ oe	**A1** **[6]**	**2.5**	Correct answer in terms of x with constant term	

12			Gradient = $-\frac{h}{r}$	**M1**	**1.1a**		
			$y = -\frac{h}{r}x+h$ so $ry+hx=hr$	**A1** **[2]**	**3.3**	Convincing completion (answer given). May start with different standard form of equation of straight line	

13	**(a)**	**(i)**	[Area =] $2xl + \pi x^2$ $l = \pi(r - x)$ so Area = $2x\pi(r-x) + \pi x^2 = 2\pi rx - \pi x^2 = \pi x(2r - x)$	**M1** **A1** **[2]**	**1.1a** **2.4**	Convincing completion (answer given)	Use of $l = \pi(r - x)$ to get formula in terms of x
13	**(a)**	**(ii)**	$ry + hx = hr$ so $x = \frac{hr - ry}{h}$ and $\pi x(2r - x) = \pi\left(\frac{hr - ry}{h}\right)\left(\frac{2rh - hr + ry}{h}\right)$ $\pi\left(\frac{hr - ry}{h}\right)\left(\frac{hr + ry}{h}\right) = \frac{\pi}{h^2}(h^2r^2 - r^2y^2)$ $= \frac{\pi r^2}{h^2}(h^2 - y^2)$	**M1** **A1** **[2]**	**3.1a** **2.2a**	Finding x in terms of y correctly and using it Convincing completion (answer given)	
13	**(b)**	**(i)**	$y = 0$ so area = $\frac{\pi r^2}{h^2}(h^2) = \pi r^2$	**B1** **[1]**	**3.5a**		
13	**(b)**	**(ii)**	$y = h$ so area = $\frac{\pi r^2}{h^2}(h^2 - h^2) = 0$	**B1** **[1]**	**3.5a**		

14	**(a)**		$\int_0^h (h^2 - y^2)\,\mathrm{d}y$	**B1** **[1]**	**1.1**	Condone dy missing or as δy but nothing else	Condone integration started provided seen or used in 14(b)
14	**(b)**		$V = \frac{\pi r^2}{h^2}\int_0^h (h^2 - y^2)\,\mathrm{d}y$ $\frac{\pi r^2}{h^2}\left[h^2 y - \frac{y^3}{3}\right]_0^h$ $\frac{\pi r^2}{h^2}\left(h^3 - \frac{h^3}{3}\right)$ $= \frac{2}{3}\pi r^2 h$	**M1** **M1** **A1** **[3]**	**2.2a** **1.1a** **2.1**	Multiplying their integral from 14a by $\frac{\pi r^2}{h^2}$ May be at a later stage Integration (one term correct condone omission of $\frac{\pi r^2}{h^2}$) Convincing completion (answer given)	

15			$r = \frac{5.4}{\pi}$ V =74.2 to 74.3 or r = 1.727 or 1.73 Suitable comment consistent with working E.g. • Not exactly right but the measurements may not be exact • The volume/radius is too small but it's close • Allowing for approximation the formula seems accurate **[3]**	**B1** **B1** **E1**	**3.1a** **1.1** **3.5b**	soi by 1.71[88], 1.72 If r from V=75 and h = 12 Dependent on both B marks	

OCR (Oxford Cambridge and RSA Examinations)
The Triangle Building
Shaftesbury Road
Cambridge
CB2 8EA

OCR Customer Contact Centre

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Telephone: 01223 553998
Facsimile: 01223 552627
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Facsimile: 01223 552553