OCR
Oxford Cambridge and RSA

GCE

Mathematics B MEI

H640/03: Pure Mathematics and Comprehension

A Level

Mark Scheme for June 2022

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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

1. 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 **In this question you must show detailed reasoning** appears in the question.

2. Subject-specific Marking Instructions for AS Level Mathematics B (MEI)

a Annotations must be used during your marking. For a response awarded zero (or full) marks a single appropriate annotation (cross, tick, M0 or ^) is sufficient, but not required.

For responses that are not awarded either 0 or full marks, you must make it clear how you have arrived at the mark you have awarded and all responses must have enough annotation for a reviewer to decide if the mark awarded is correct without having to mark it independently.

It is vital that you annotate standardisation scripts fully to show how the marks have been awarded.

Award NR (No Response)

- if there is nothing written at all in the answer space and no attempt elsewhere in the script
- OR if there is a comment which does not in any way relate to the question (e.g. 'can't do', 'don't know')
- OR if there is a mark (e.g. a dash, a question mark, a picture) which isn't an attempt at the question.

Note: Award 0 marks only for an attempt that earns no credit (including copying out the question).

If a candidate uses the answer space for one question to answer another, for example using the space for 8(b) to answer 8(a), then give benefit of doubt unless it is ambiguous for which part it is intended.

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 always 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 method mark may usually be implied by a correct answer unless the question includes the DR statement, the command words "Determine" or "Show that", or some other indication that the method must be given explicitly.

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.
- When a value is **not given** in the paper accept any answer that agrees with the correct value to **2 s.f.** unless a different level of accuracy has been asked for in the question, or the mark scheme specifies an acceptable range.
  NB for Specification A the rubric specifies 3 s.f. as standard, so this statement reads "3 s.f"

Follow through should be used so that only one mark in any question is lost for each distinct accuracy error.
Candidates using a value of 9.80, 9.81 or 10 for *g* should usually be penalised for any final accuracy marks which do not agree to the value found with 9.8 which is given in the rubric.

g Rules for replaced work and multiple attempts:

- If one attempt is clearly indicated as the one to mark, or only one is left uncrossed out, then mark that attempt and ignore the others.
- If more than one attempt is left not crossed out, then mark the last attempt unless it only repeats part of the first attempt or is substantially less complete.
- if a candidate crosses out all of their attempts, the assessor should attempt to mark the crossed out answer(s) as above and award marks appropriately.

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 or B mark in the question. Marks designated as cao may be awarded as long as there are no other errors. If a candidate corrects the misread in a later part, do not continue to follow through. E marks are lost unless, by chance, the given results are established by equivalent working. 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 that there is nothing in the wording of the question specifying that analytical methods are required such as the bold "In this question you must show detailed reasoning", or the command words "Show" and "Determine. 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	AO	Guidance
1			Equation of form $y = \frac{k}{x}$ $y = \frac{2}{x}$ oe	M1 A1 [2]	1.1a 2.2a	Can be implied later by an equation of the correct form

2	(a)		$\sqrt{25-x^2}$	B1 [1]	1.1	Isw
2	(b)	(i)	$25-x^2 \geq 0$ $-5 \leq x \leq 5$ o.e.	M1 B1 B1 [3]	1.1a 2.2a 2.5	Implied by **B2** At least one part of the domain correct, condone missing = for this mark, e.g. $x < 5$ Can score **M0 B1** Domain completely correct and correctly expressed Eg allow $x \geq -5$ and $x \leq -5$ but not $x \geq -5$ or $x \leq -5$ or other ambiguous notation eg a comma Condone $x \leq \pm 5$ seen in working if final answer is correct
2	(b)	(ii)	$0 \leq \text{fg}(x) \leq 5$ or $0 \leq y \leq 5$	B1 B1 [2]	2.2a 2.5	At least one part of the range correct, condone missing = for this mark, e.g. $y < 5$, allow use of f(x) or g(x) notation here but not x Range completely correct and correctly expressed See notes in 2(b)(i)

3	**(a)**		1	**B1** **[1]**	**2.2a**	Cao Must be clear that the limit is **equal to 1**. Therefore tending to or approaching 1 or 0.999 or → 1 etc do not score
3	**(b)**		$a_n = 1 - \frac{1}{n+1}$ $n+1$ increases as n increases so $\frac{1}{n+1}$ decreases Less is being taken away from 1 each time so $a_n = 1 - \frac{1}{n+1}$ increases	**M1** **M1** **E1**	**3.1a** **2.4** **2.1**	 Convincing explanation that $\frac{1}{n+1}$ decreases Convincing completion (A.G.) **Special Case (**Max 2 for this method) Correct differentiation and states > 0 to demonstrate increasing **SC B1** Goes on to consider [positive] integers as a subset of reals to complete their argument **SC B1** dep on first **B1**.
				[3]		

			Alternative method 1 $\frac{n+1}{n+2}$ $n(n+2) < (n+1)^2$ $n(n+2) = n^2 + 2n$ and $(n+1)^2 = n^2 + 2n + 1$ Expanding brackets to give convincing completion (A.G.)	**M1** **M1** **E1**		This method is testing $\frac{n}{n+1} < \frac{n+1}{n+2}$ Formulating expression for (n+1)th or (n-1)th term For formulating inequality and cross multiplying Probably see $\frac{n+1}{n+2} > \frac{n}{n+1}$ [i.e. increasing]
			Alternative method 2 $\frac{n+1}{n+2}$ Difference is $\frac{n+1}{n+2} - \frac{n}{n+1} = \frac{(n+1)^2 - n(n+2)}{(n+1)(n+2)}$ $\frac{(n+1)^2 - n(n+2)}{(n+1)(n+2)} = \frac{1}{(n+1)(n+2)} > 0$ So sequence is increasing	**M1** **M1** **E1**		Formulating expression for (n+1)th term Finding difference and attempts to form a single fraction eg may be $a_n - a_{n+1}$ Convincing completion (A.G.)
				[3]		

4			**DR** $2\left(1-\sin^2 x\right)=3\sin x$	**M1**	**3.1a**	
			$2\sin^2 x+3\sin x-2\ [=0]$	**M1**	**1.1**	For getting a 3-term quadratic on the same side in a single trig ratio (not dep on M1)
			$\sin x=\frac{1}{2}$	**A1**	**1.1**	BC, ignore second value if presented
			$\frac{\pi}{6}$	**A1**	**1.1**	First angle correct and in radians
			$\frac{5\pi}{6}$	**B1**	**2.2a**	FT ($\pi-$ *their* first angle) OR (180 - *their* first angle) (dep on first M1) If further solutions in range **B0**
					[5]	

5	**(a)**		$4x+3x\frac{dy}{dx}+3y+2y\frac{dy}{dx}=0$	**M1** **A1**	**1.1a** **1.1**	Attempt at implicit differentiation. Either $3x\frac{dy}{dx}+3y$ or $2y\frac{dy}{dx}$ correct. Condone $\frac{dy}{dx}=$ for M1 All correct
			$3x\frac{dy}{dx}+2y\frac{dy}{dx}=-4x-3y$ $\frac{dy}{dx}=-\frac{4x+3y}{3x+2y}$	**E1** **[3]**	**2.1**	AG At least one step of working needed to achieve convincing completion.
5	**(b)**		**DR** $\frac{dy}{dx}=0\Rightarrow y=-\frac{4x}{3}$ or $x=-\frac{3y}{4}$ $2x^2-4x^2+\frac{16x^2}{9}+2=0$ Or $\frac{9}{8}y^2-\frac{9}{4}y^2+y^2+2=0$ $\frac{2x^2}{9}=2\Rightarrow x=\pm 3$ Or $-\frac{1}{8}y^2=-2\Rightarrow y=\pm 4$ (3, –4) and (–3, 4)	**M1** **M1** **A1** **A1** **[4]**	**3.1a** **1.1** **1.1** **1.1**	Finding y in terms of x (or vice versa) Condone sign errors for **M1** Substitution into equation of curve to get equation in x (or y) Both values – some working needed nfww (eg sign error in first line) Both points as coordinates. Dep on **M2A1**. A0 if extra values

6	**(a)**		$\frac{dT}{dt} = k(T-20)$ [where k is a constant]	**B2** **[2]**	**3.3** **1.1**	May be $-k$ and/or $(20-T)$	B1 if no constant If additional terms seen **B0**
6	**(b)**		k = + 0.07 OR -0.07 oe	**B1**	**1.1**		
			$\int \frac{1}{(T-20)}\, dT = \int k\ dt$	**M1**	**3.1a**	Appropriate separation of variables for *their* DE soi by correct integration or answer Condone missing dt and/or dT	
			$\ln(T-20) = kt\ [+c]$	**M1**	**1.1**	o.e. For correct integration to include a ln term	Or $T-20 = e^{kt\ [+c]}$
			$\ln 70 = c$	**M1**	**1.1**	To find c from their equation using t = 0, T = 90	Or $e^c = 70$
			$\ln(T-20) = -0.07t + \ln 70$				
			$\ln(20) = -0.07t + \ln 70$	**M1**	**3.4**	Clear substitution of $T = 40$ into their equation in T and t coming from integration	$-\frac{2}{7} = -0.07t$
			$t \approx 17.9$ [minutes]	**A1** **[6]**	**3.2a**	17.8966… If there is any doubt about the rigour of an otherwise correct solution withhold the A1.	Any accuracy ≥ 2sf 17.9 nfww gets 6

7	(a)		$\frac{x^6}{8} \geq 0$ or $x^6 \geq 0$	B1 [1]	2.4	Do not accept $\frac{x^6}{8}$ is always positive (ie > 0)
7	(b)		The expansion with two terms is a better approximation than the one with three terms but it should be the other way round.	E1 [1]	2.3	O.E. See exemplars
7	(c)		$1+\frac{1}{2}\left(-x^3\right)+\frac{1}{2}\left(-\frac{1}{2}\right)\frac{\left(-x^3\right)^2}{2!}+\frac{1}{2}\left(-\frac{1}{2}\right)\left(-\frac{3}{2}\right)\frac{\left(-x^3\right)^3}{3!}+...$ $1-\frac{x^3}{2}-\frac{x^6}{8}-\frac{x^9}{16}...$	M1 A2 [3]	1.1a 1.1 1.1	Working for 3rd or 4th term correct Must see the negative x^3 A2 all terms correct or A1 for three terms correct
7	(d)		$\lvert x\rvert < 1$ oe	B1 [1]	1.1	
7	(e)		Goes through 2.5 on *y*-axis and (1,0) Right shape for values of *x* from –1 to 1	B1 B1 [2]	2.2a 1.1	Curve reaches between (-1, 3) to (-1, 4.5)
7	(f)		**DR** $2.5\int_{-0.75}^{0.75}\left(1-\frac{x^3}{2}-\frac{x^6}{8}-\frac{x^9}{16}\right)\mathrm{d}x$ $\left[2.5\right]\left[x-\frac{x^4}{8}-\frac{x^7}{56}-\frac{x^{10}}{160}\right]_{-0.75}^{0.75}$	M1 M1	3.1b 1.1	For their expression from 7(c) in an integration. Condone d*x* missing. 2.5 and limits needed but may be seen later For integrating their expression (3 terms or more) allow one error Limits could be wrong or missing here

			$[2.5]\left[\left(0.75-\frac{0.75^4}{8}-\frac{0.75^7}{56}-\frac{0.75^{10}}{160}\right)-\left(-0.75-\frac{(-0.75)^4}{8}-\frac{(-0.75)^7}{56}-\frac{(-0.75)^{10}}{160}\right)\right]$	**M1**	**1.1**	For attempt at their limits substituted into their integrand. Substitution *must* be seen.
			$3.74\ m^2$	**A1**	**3.2a**	AWRT 3.74 from correct working. Must include units. 1.495 will probably get either **M2** or **M3** Annotate final page
			Special Case If trapezium rule used on original function allow **M1 A1** maximum			Likely answers If 2 strips used: $3.71m^2$ If 3 strips used: $3.72\ m^2$ If 6 strips used: $3.73\ m^2$
				[4]		

8	**(a)**		$y = x^3 - 8$ $x^3 = y + 8$ $\sqrt[3]{(x+8)}$ oe isw	**M1** **A1** **[2]**	**1.1a** **2.2a**	Attempt to re-arrange Ignore labelling of this expression eg fh(x) = $\sqrt[3]{(x+8)}$ scores 2
8	**(b)**		A (0, –8) B (2, 0) C (0, 2) D (–8, 0)	**B1** **B2** **B1** **B1** **[5]**	**1.1** **2.2a** **1.1** **1.1**	Condone lack of brackets if meaning is clear FT their B FT their A
8	**(c)**		Midpoint is (1, –4) and Gradient of AB is 4 Gradient of perpendicular bisector is $-\frac{1}{4}$ Equation $y + 4 = -\frac{1}{4}(x-1)$ $y = -\frac{1}{4}x - 3\frac{3}{4}$	**B1** **B1** **M1** **A1** **[4]**	**1.1** **3.1a** **2.2a** **1.1**	FT their A and B. May be implied by later work FT -ve reciprocal of their 4 Or using $y = mx + c$ and attempting to evaluate c Must be using their midpoint and their $-\frac{1}{4}$ Final answer

			Either			
8	**(d)**		$(0 - a)^2 + (2 – b)^2 = r^2$ using C $(0 - a)^2 + (-8 – b)^2 = r^2$ using A $(2 - a)^2 + (0 – b)^2 = r^2$ using B $(-8 - a)^2 + (0 – b)^2 = r^2$ using D Setting up any 2 of the above equations Attempting to solve to find *a* or *b* Centre (-3, -3) oe Using their centre and another point (A, B, C or D) to find the radius $(x+3)^2+(y+3)^2=34$ cao	**M1** **M1** **A1** **M1** **A1** **[5]**	**3.1a** **3.1a** **1.1** **2.1** **2.2a**	May solve all 4 which also earns 3rd method mark
			Or			
			Intersection of any 2 of $y=x$, $x=-3$, $y=-3$, $y=-\frac{1}{4}x-3\frac{3}{4}$, $y=-4x-15$ Attempting to solve to find intersection point $(-3,\ -3)$ Using their centre and another point (A, B, C or D) to find the radius $(x+3)^2+(y+3)^2=34$	**M1** **M1** **A1** **M1** **A1** **[5]**	**3.1a** **3.1a** **1.1** **2.1** **2.2a**	Identifying 2 perp bisectors of 2 chords eg BD and AC, or AB and CD

9			$\frac{dy}{dx} = \cos x$ cos 0 =1 and this is the same as the gradient of $y = x$ (AG)	**M1** **E1** **[2]**	**1.1** **2.2a**	Attempt to use small angle approximations scores **M0** Convincing completion not necessarily in words
10			**DR** $\frac{dy}{dx} = \frac{4}{\pi} - \frac{8x}{\pi^2} - \cos x$ $x = 2.6$, $\frac{dy}{dx} = 0.0226...$ $x = 2.7$, $\frac{dy}{dx} = -0.0112...$ Gradient zero for a value between 2.6 and 2.7 Gradient positive, zero, negative so max	**M1** **M1** **A1** **E1** **B1** **[5]**	**3.1a** **3.1a** **1.1** **2.2a** **2.4**	Attempt to differentiate. Both an *x* term and a cos term needed condone other errors. If π^2 is treated as a variable and incorrectly differentiated eg to 2π then M0. Similarly with π . At least one substitution into their expression Both correct (at least 2d.p., rounded or truncated) Can be implied by 'sign change' or sketch Dependent on M2 but can be earned following **M2A0** Allow 2nd derivative used at turning point found BC (x= 2.67, 2nd deriv = -0.356) or 2 relevant values eg -0.295 and -0.383 seen and stated as < 0 therefore max

11			$\frac{4\times45(180-45)}{40500-45(180-45)}=\frac{12}{17}$	**B1**	**1.1**	Substitution seen or implied by partial working Condone 0.70588…
			$45°=\frac{\pi}{4}$	**B1**	**1.2**	Soi maybe in substitution
			$\frac{16\times\frac{\pi}{4}\left(\pi-\frac{\pi}{4}\right)}{5\pi^2-4\times\frac{\pi}{4}\left(\pi-\frac{\pi}{4}\right)}=\frac{12}{17}$	**B1**	**2.2a**	Substitution seen or implied by partial working Both answers must be $\frac{12}{17}$
				[3]		

12	**(a)**		$y=\sin\left(x+\frac{\pi}{2}\right)$ is a translation of $y=\sin x$ $\frac{\pi}{2}$ to left and so is the same as $y=\cos x$	**M1** **E1** **[2]**	**3.1a** **2.2a**	OR $\sin\left(x+\frac{\pi}{2}\right)=\sin x\cos\frac{\pi}{2}+\sin\frac{\pi}{2}\cos x$ OR $\sin\left(x+\frac{\pi}{2}\right)=\sin x\times 0+1\times\cos x=\cos x$ Convincing completion (AG)
12	**(b)**		$[\cos x\approx]\frac{16\left(x+\frac{\pi}{2}\right)\left(\frac{\pi}{2}-x\right)}{5\pi^2-4\left(x+\frac{\pi}{2}\right)\left(\frac{\pi}{2}-x\right)}$ $[\cos x\approx]\frac{16\left(\frac{\pi^2}{4}-x^2\right)}{5\pi^2-4\left(\frac{\pi^2}{4}-x^2\right)}$ $[\cos x\approx]\frac{4\pi^2-16x^2}{4\pi^2+4x^2}=\frac{\pi^2-4x^2}{\pi^2+x^2}$	**M1*** **DM1** **A1** **[3]**	**2.1** **1.1** **1.1**	Substitute $x+\frac{\pi}{2}$ Multiplying out brackets (dep on first M1) Convincing completion (AG) Check continuation page

Exemplars for 7b

Accept (eg)

The 3-term expansion is further away than the one with 2 terms

The 3-term expansion moves away from the 2-term expansion

The 3-term expansion is on the wrong side of the graph of the 2-term expansion

The 3-term expansion goes up at the end

The 3-term expansion should be more accurate than a 2-term expansion [and it isn't]

The 3-term expansion moves away from the other 2

Do not accept (eg)

They don't follow the same shape

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