

**GCE**

**Mathematics (MEI)**

Unit **4753**: Methods for Advanced Mathematics

Advanced GCE

**Mark Scheme for June 2015**

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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.

OCR will not enter into any discussion or correspondence in connection with this mark scheme.

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## Annotations and abbreviations

<b>Annotation in scoris</b>	<b>Meaning</b>
✓ 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	
<b>Other abbreviations in mark scheme</b>	<b>Meaning</b>
E1	Mark for explaining
U1	Mark for correct units
G1	Mark for a correct feature on a graph
M1 dep*	Method 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

**Subject-specific Marking Instructions for GCE Mathematics (MEI) Pure strand**

- 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, award marks according to the spirit of the basic scheme; if you are in any doubt whatsoever (especially if several marks or candidates are involved) 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, eg 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, eg 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, exactly what is acceptable will be detailed in the mark scheme rationale. If this is not the case please consult your Team Leader.

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 Wrong or missing units in an answer should not lead to the loss of a mark unless the scheme specifically indicates otherwise. Candidates are expected to give numerical answers to an appropriate degree of accuracy, with 3 significant figures often being the norm. Small variations in the degree of accuracy to which an answer is given (e.g. 2 or 4 significant figures where 3 is expected) should not normally be penalised, while answers which are grossly over- or under-specified should normally result in the loss of a mark. The situation regarding any particular cases where the accuracy of the answer may be a marking issue should be detailed in the mark scheme rationale. If in doubt, contact your Team Leader.
  - 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.

Note that a miscopy of the candidate's own working is not a misread but an accuracy error.

Question	Answer	Marks	Guidance	
1	$y = e^{2x} \cos x$ $\Rightarrow \quad dy/dx = 2e^{2x} \cos x - e^{2x} \sin x$ $dy/dx = 0 \Rightarrow e^{2x}(2\cos x - \sin x) = 0$ $\Rightarrow \quad 2\cos x = \sin x$ $\Rightarrow \quad 2 = \sin x / \cos x = \tan x$ $\Rightarrow \quad x = 1.11$  $\Rightarrow \quad y = 4.09$	M1 A1 M1  M1 A1  A1 cao <b>[6]</b>	product rule used cao – mark final ans their derivative = 0  $\sin x / \cos x = \tan x$ used 1.1 or $0.35\pi$ or better, or $\arctan 2$ , not $63.4^\circ$ but condone ans given in both degrees and radians here art 4.1	consistent with their derivs e.g. $2e^{2x} - e^{2x} \tan x$ is A0  or $\sin^2 x + \cos^2 x = 1$ used 1.1071487 ..., 0.352416... $\pi$ , penalise incorrect rounding  no choice
2	let $u = 2x - 1$ , $du = 2 dx$ $\int \sqrt[3]{2x-1} dx = \int \frac{1}{2} u^{\frac{1}{3}} du$  $= \frac{3}{8} u^{\frac{4}{3}} + c$ $= \frac{3}{8} (2x-1)^{\frac{4}{3}} + c$	M1 M1 M1  A1 cao	substituting $u = 2x - 1$ in integral $\times \frac{1}{2}$ o.e. integral of $u^{1/3} = u^{4/3}/(4/3)$ (oe) soi  o.e., but must have $+ c$ and single fraction mark final answer	i.e. $u^{1/3}$ or $\sqrt[3]{u}$ seen in integral condone no $du$ , or $dx$ instead of $du$ not $x^{1/3}$  so $\frac{3}{4} (2x-1)^{\frac{4}{3}} + c$ is M1M0M1A0
	<b>or</b> $\int \sqrt[3]{2x-1} dx = \frac{1}{2} \times (2x-1)^{4/3} \div 4/3$  $= \frac{3}{8} (2x-1)^{\frac{4}{3}} + c$	M1 M1 M1 A1 cao  <b>[4]</b>	$(2x-1)^{4/3}$ seen $\div 4/3$ (oe) soi $\times \frac{1}{2}$ o.e., but must have $+ c$ and single fraction mark final ans	e.g. correct power of $(2x-1)$ e.g. $\frac{3}{4} (2x-1)^{4/3}$ seen  so $\frac{3}{8} (2x-1)^{\frac{4}{3}}$ is M1M1M1A0

Question	Answer	Marks	Guidance	
3	let $u = \ln x$ , $dv/dx = x^3$ , $du/dx = 1/x$ , $v = \frac{1}{4}x^4$ $\int_1^2 x^3 \ln x \, dx = \left[ \frac{1}{4}x^4 \ln x \right]_1^2 - \int_1^2 \frac{1}{4}x^4 \cdot \frac{1}{x} \, dx$ $= \left[ \frac{1}{4}x^4 \ln x \right]_1^2 - \int_1^2 \frac{1}{4}x^3 \, dx$ $= \left[ \frac{1}{4}x^4 \ln x - \frac{1}{16}x^4 \right]_1^2$ $= 4 \ln 2 - 15/16$	M1 A1 M1dep A1cao A1cao  <b>[5]</b>	$u, u', v', v$ all correct $\frac{1}{4}x^4 \ln x - \int \frac{1}{4}x^4 \cdot \frac{1}{x} [dx]$ simplifying $x^4/x = x^3$ in second term (soi) $\frac{1}{4}x^4 \ln x - \frac{1}{16}x^4$ o.e. o.e. must be exact, but can isw	ignore limits  dep 1 <sup>st</sup> M1  must evaluate $\ln 1 = 0$ and combine $-1 + 1/16$
4	$h = r$ so $V = \pi h^3/3$ $dV/dt = 5$  $dV/dh = \pi h^2$ $dV/dt = (dV/dh) \cdot dh/dt$ $\Rightarrow 5 = 100\pi \, dh/dt$ $\Rightarrow dh/dt = 5/100\pi = 0.016 \text{ cm s}^{-1}$  <b>or</b> $V = 5t$ so $\pi h^3/3 = 5t$ $\Rightarrow \pi h^2 dh/dt = 5$ $\Rightarrow dh/dt = 5/\pi h^2 = 5/100\pi = 0.016 \text{ cm s}^{-1}$	B1 B1 B1ft M1 A1  B1 M1 A1  <b>[5]</b>	o.e. e.g. $\pi h^3 \tan 45^\circ / 3$ soi (can be implied from $V = 5t$ ) must be $dV/dh$ soi, ft their $\pi h^3/3$ any correct chain rule in $V, h$ and $t$ (soi)  0.016 or better; accept $1/(20\pi)$ o.e., but mark final answer  or $5 \, dt/dh = \pi h^2$ o.e. 0.016 or better; accept $1/(20\pi)$ o.e., but mark final answer	e.g. from a correct chain rule but must have substituted for $r$ e.g. $dh/dt = dh/dV \times dV/dt$ ,  0.01591549... penalise incorrect rounding  penalise incorrect rounding

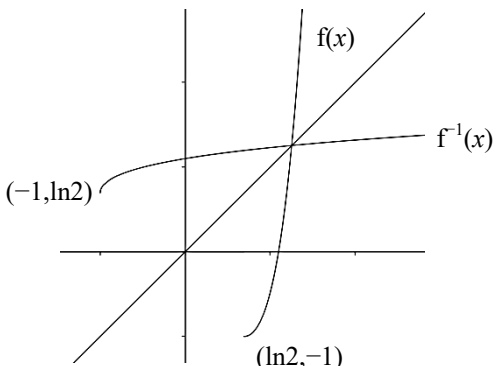


Question	Answer	Marks	Guidance
5	$y^2 + 2x \ln y = x^2$ $1^2 + 2 \times 1 \times \ln 1 = 1^2$ so (1, 1) lies on the curve.  $2y \frac{dy}{dx} + 2 \ln y + 2x \cdot \frac{1}{y} \cdot \frac{dy}{dx} = 2x$  $[\Rightarrow \frac{dy}{dx} = \frac{2x - 2 \ln y}{2y + 2x/y}]$  when $x = 1, y = 1, \frac{dy}{dx} = \frac{2 - 2 \ln 1}{2 + 2}$  $= \frac{1}{2}$	B1  M1 M1 A1 cao   M1  A1 cao  <b>[6]</b>	clear evidence of verification needed  $d/dx (y^2) = 2y dy/dx$ $d/dx (2x \ln y) = 2 \ln y + 2x/y dy/dx$   substituting both $x = 1$ and $y = 1$ into their $dy/dx$ or their equation in $x, y$ and $dy/dx$ not from wrong working
6 (i)	$\arcsin x = \pi/6 \Rightarrow x = \sin \pi/6$  $= \frac{1}{2}$	M1 A1  <b>[2]</b>	allow unsupported answers
6 (ii)	$\sin \pi/4 = \cos \pi/4 = 1/\sqrt{2}$ $\Rightarrow \arcsin (1/\sqrt{2}) = \arccos (1/\sqrt{2})$ $\Rightarrow x = 1/\sqrt{2}$	B2  <b>[2]</b>	o.e. e.g. $\sqrt{2}/2$ , must be exact; SCB1 0.707...
7 (i)	$ff(x) = f\left(\frac{1-x}{1+x}\right) = \frac{1 - \frac{1-x}{1+x}}{1 + \frac{1-x}{1+x}}$ $= \frac{1+x-1+x}{1+x+1-x} = \frac{2x}{2} = x^*$ $f^{-1}(x) = f(x) = (1-x)/(1+x)$	M1  A1  B1	substituting $(1-x)/(1+x)$ for $x$ in $f(x)$  correctly simplified to $x$ <b>NB AG</b>  or just $f^{-1}(x) = f(x)$

Question		Answer	Marks	Guidance	
			[3]		
7	(ii)	$g(-x) = \frac{1 - (-x)^2}{1 + (-x)^2}$ $= \frac{1 - x^2}{1 + x^2} = g(x)$ <p>Graph is symmetrical about the <math>y</math>-axis.</p>	M1 A1 B1 [3]	<p>substituting <math>-x</math> for <math>x</math> in <math>g(x)</math> condone use of 'f' for g</p> <p>must indicate that <math>g(-x) = g(x)</math> somewhere</p> <p>allow 'reflected', 'reflection' for symmetrical</p>	<p>if brackets are omitted or misplaced allow M1A0</p> <p>condone use of 'f' for g</p> <p>must state axis (<math>y</math>-axis or <math>x = 0</math>)</p>
8	(i)	$f(x) = \frac{x \cdot 2(x-2) - (x-2)^2}{x^2}$ $= \frac{2x^2 - 4x - x^2 + 4x - 4}{x^2}$ $= (x^2 - 4)/x^2 = 1 - 4/x^2 *$	M1 A1 A1	<p>quotient (or product) rule, condone sign errors only</p> <p>correct exp, condone missing brackets here</p> <p>simplified correctly <b>NB AG</b></p>	<p>e.g. <math>\frac{\pm x \cdot 2(x-2) \pm (x-2)^2}{x^2}</math></p> <p>PR: <math>(x-2)^2 \cdot (-x^{-2}) + (1/x) \cdot 2(x-2)</math></p> <p>with correct use of brackets</p>
		<p><b>or</b> <math>f(x) = (x^2 - 4x + 4)/x</math></p> $= x - 4 + 4/x$ $\Rightarrow f'(x) = 1 - 4/x^2 *$	M1 A1 A1	<p>expanding bracket and dividing each term by <math>x</math> correctly</p> <p>not from wrong working <b>NB AG</b></p>	<p>must be 3 terms: <math>(x^2 - 4)/x</math> is M0</p> <p>e.g. <math>x - 4 + 2/x</math> is M1A0</p>
		$f''(x) = 8/x^3$ <p><math>f'(x) = 0</math> when <math>x^2 = 4</math>, <math>x = \pm 2</math></p> <p>so at Q, <math>x = -2</math>, <math>y = -8</math>.</p> <p><math>f''(-2) = [-1] &lt; 0</math> so maximum</p>	B1 M1 A1 B1 dep [7]	<p>o.e. e.g. <math>8x^{-3}</math> or <math>8x/x^4</math></p> <p><math>x = \pm 2</math> found from <math>1 - 4/x^2 = 0</math></p> <p><math>(-2, -8)</math></p> <p>dep first B1. Can omit <math>-1</math>, but if shown must be correct. Must state <math>&lt; 0</math> or negative.</p>	<p>allow for <math>x = -2</math> unsupported</p> <p>must use 2<sup>nd</sup> derivative test</p>

Question		Answer	Marks	Guidance	
8	(ii)	$f(1) = (-1)^2/1 = 1$ $f(4) = (2)^2/4 = 1$	B1	verifying $f(1) = 1$ and $f(4) = 1$	or $(x-2)^2 = x \Rightarrow x^2 - 5x + 4 = 0$ $\Rightarrow (x-1)(x-4) = 0, x = 1, 4$
		$\int_1^4 \frac{(x-2)^2}{x} dx = \int_1^4 (x-4+4/x) dx$ $= [x^2/2 - 4x + 4 \ln x]_1^4$ $= (8 - 16 + 4 \ln 4) - (1/2 - 4 + 4 \ln 1)$ $= 4 \ln 4 - 4 1/2$ Area enclosed = rectangle - curve $= 3 \times 1 - (4 \ln 4 - 4 1/2) = 7 1/2 - 4 \ln 4$	M1  A1  A1cao M1 A1cao	expanding bracket and dividing each term by $x$ 3 terms: $x - 4/x$ is M0  $x^2/2 - 4x + 4 \ln x$  soi o.e. but must combine numerical terms and evaluate $\ln 1$ - mark final ans	if $u = x - 2$ $\int \frac{u^2}{u+2} du = \int (u-2 + \frac{4}{u+2}) du$ $u^2/2 - 2u + 4 \ln(u+2)$
		<b>or</b> $\text{Area} = \int_1^4 [1 - \frac{(x-2)^2}{x}] dx$ $= \int_1^4 (5-x-4/x) dx$ $= [5x - x^2/2 - 4 \ln x]_1^4$ $= 20 - 8 - 4 \ln 4 - (5 - 1/2 - 4 \ln 1)$ $= 7 1/2 - 4 \ln 4$	M1  M1 A1 A1  A1cao [6]	no need to have limits  expanding bracket and dividing each term by $x$ $5 - x - 4/x$ $5x - x^2/2 - 4 \ln x$  o.e. but must combine numerical terms and evaluate $\ln 1$ - mark final ans	must be 3 terms in $(x-2)^2$ expansion
8	(iii)	$[g(x) =] f(x+1) - 1$ $= \frac{(x+1-2)^2}{x+1} - 1$ $= \frac{x^2 - 2x + 1 - x - 1}{x+1} = \frac{x^2 - 3x}{x+1} *$	M1  A1  A1  [3]	soi [may not be stated]  correctly simplified - not from wrong working <b>NB AG</b>	

Question		Answer	Marks	Guidance	
8	(iv)	Area is the same as that found in part (ii)	M1	award M1 for $\pm$ ans to 8(ii) (unless zero)	
		$4\ln 4 - 7\frac{1}{2}$	A1 cao [2]	need not justify the change of sign	
9	(i)	At P, $(e^x - 2)^2 - 1 = 0$ $\Rightarrow e^x - 2 = [\pm]1,$ $e^x = [1 \text{ or } 3]$	M1	square rooting – condone no $\pm$	
		<b>or</b> $(e^x)^2 - 4e^x + 3 = 0$ $\Rightarrow (e^x - 1)(e^x - 3) = 0, e^x = 1 \text{ or } 3$	M1	expanding to correct quadratic and solve by factorising or using quadratic formula	condone $e^{x^2}$
		$\Rightarrow x = [0 \text{ or } \ln 3]$	A1 [2]	$x$ -coordinate of P is $\ln 3$ ; must be exact	condone $P = \ln 3$ , but not $y = \ln 3$
9	(ii)	$f'(x) = 2(e^x - 2)e^x$ $= 0$ when $e^x = 2, x = \ln 2$ *	M1 A1 A1	chain rule correct derivative not from wrong working <b>NB AG</b>	e.g. $2u \times$ their deriv of $e^x$ $2(e^x - 2)x$ is M0 or verified by substitution
		<b>or</b> $f(x) = e^{2x} - 4e^x + 3$ $\Rightarrow f'(x) = 2e^{2x} - 4e^x$ $= 0$ when $2e^{2x} = 4e^x, e^x = 2, x = \ln 2$ *	M1 A1 A1	expanding to 3 term quadratic with $(e^x)^2$ or $e^{2x}$ correct derivative, not from wrong working or $2e^x(e^x - 2) = 0 \Rightarrow e^x = 2, x = \ln 2$ not from wrong working <b>NB AG</b>	condone $e^{x^2}$ or verified by substitution
		$y = f(\ln(2)) = -1$	B1 [4]		

Question	Answer	Marks	Guidance
9 (iii)	$\int_0^{\ln 3} [(e^x - 2)^2 - 1] dx = \int_0^{\ln 3} [(e^x)^2 - 4e^x + 4 - 1] dx$ $= \int_0^{\ln 3} [e^{2x} - 4e^x + 3] dx$ $= \left[ \frac{1}{2} e^{2x} - 4e^x + 3x \right]_0^{\ln 3}$ $= (4.5 - 12 + 3 \ln 3) - (0.5 - 4)$ $= 3 \ln 3 - 4 \text{ [so area} = 4 - 3 \ln 3]$	M1 A1 B1 A1ft A1 <b>[5]</b>	expanding brackets must have 3 terms: $(e^x)^2 - 4$ is M0, condone $e^{x^2}$ $\int e^{2x} - 4e^x + 3 [dx]$ (condone no dx) $\int e^{2x} = \frac{1}{2} e^{2x}$ $[\frac{1}{2} e^{2x} - 4e^x + 3x]$ condone $3 \ln 3 - 4$ as final ans; mark final ans
9 (iv)	$y = (e^x - 2)^2 - 1 \quad x \leftrightarrow y$ $x = (e^y - 2)^2 - 1$ $\Rightarrow x + 1 = (e^y - 2)^2$ $\Rightarrow \pm \sqrt{x + 1} = e^y - 2 \text{ (+ for } y \geq \ln 2)$ $\Rightarrow 2 + \sqrt{x + 1} = e^y$ $\Rightarrow y = \ln(2 + \sqrt{x + 1}) = f^{-1}(x)$ <p>Domain is <math>x \geq -1</math>  Range is <math>y \geq \ln 2</math></p> 	M1 A1 A1 B1 B1 M1 A1 <b>[7]</b>	attempt to solve for $y$ (might be indicated by expanding and then taking lns) condone no $\pm$ must have interchanged $x$ and $y$ in final ans must be $\geq$ and $x$ (not $y$ ) or $f^{-1}(x) \geq \ln 2$ , must be $\geq$ (not $x$ or $f(x)$ ) if $x > -1$ and $y > \ln 2$ SCB1 recognisable attempt to reflect curve, or any part of curve, in $y = x$ good shape, cross on $y = x$ (if shown), correct domain and range indicated. [see extra sheet for examples]

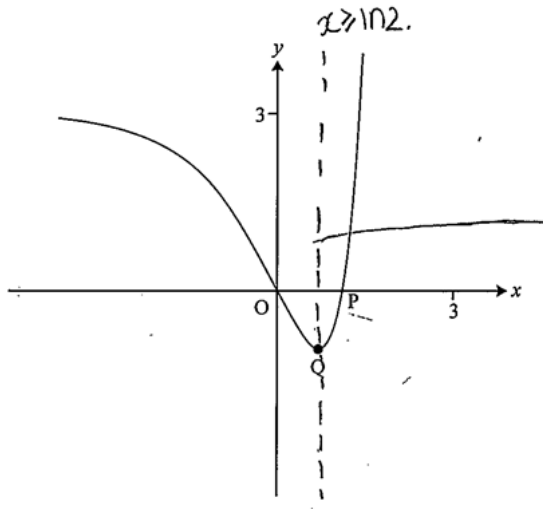
**Appendix 1 Annotation notes**

1. All questions on practice and standardisation scripts should be fully annotated, unless they are all correct or worth no credit.
2. For all other scripts, each part question should be annotated according to the following guidelines:
  - if part marks awarded, annotate fully or:
  - If fully correct, one tick; if worth no credit, one cross, or a yellow line
  - if one mark only is lost, you can indicate this by A0 or B0 in the appropriate place
  - if 1 mark only is earned, you can indicate this by M1 or B1 in the appropriate place
  - if M0, then you need not annotate dependent A marks
3. The following questions can be divided into sub-parts, which can be treated as above:
  - 8(i) First 3 marks, last 4 marks
  - 8(ii) First 4 marks, last 2 marks
  - 9(iv) first 3 marks, next 2 marks, last 2 marks

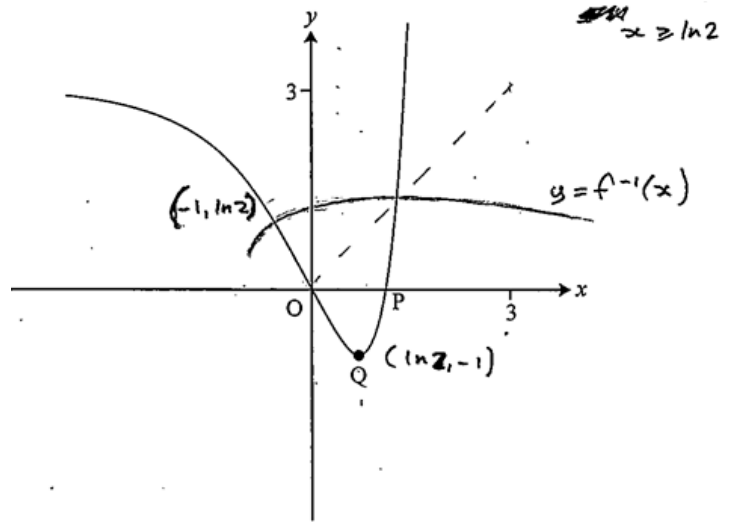
**NB Please annotate all blank pages with a ‘BP’ mark (especially AOs), and blank answer spaces with a mark to show they have been seen (e.g. with a tick, a carat or yellow line) . Don’t forget to scroll down to the bottom of each page, and annotate this if necessary to show this. Also, please indicate you have seen the spare copy of the graph in 9(iv)**

Please put the annotations close to where they apply, rather than using the margins.

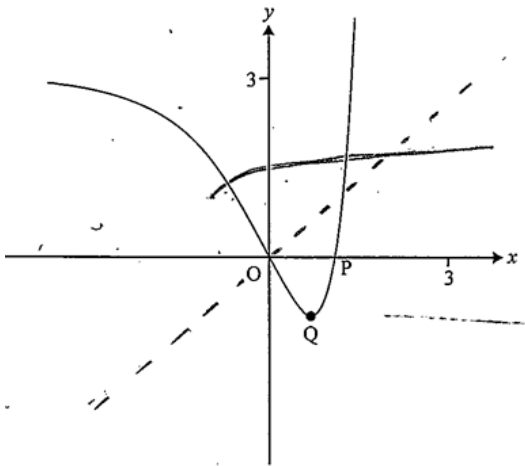
Appendix 2: Marked examples of 9(iv)



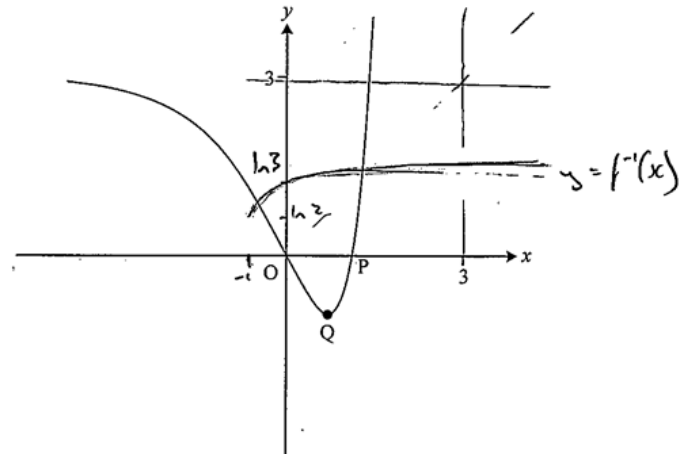
M1A0 (incorrect domain)



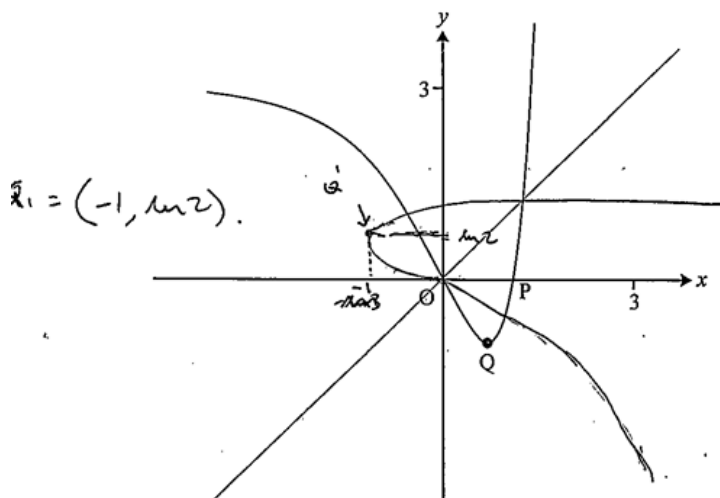
M1A1 (condone -ve gradient for  $x > 3$ )



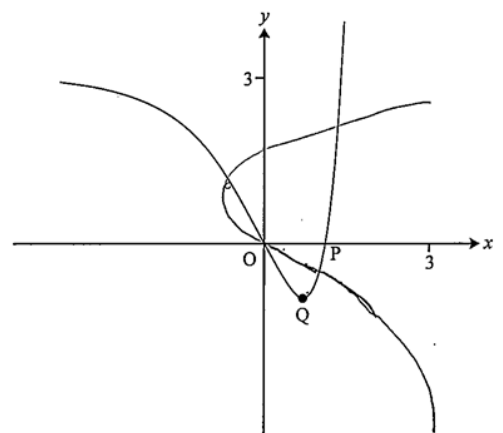
M1A0 (domain not indicated)



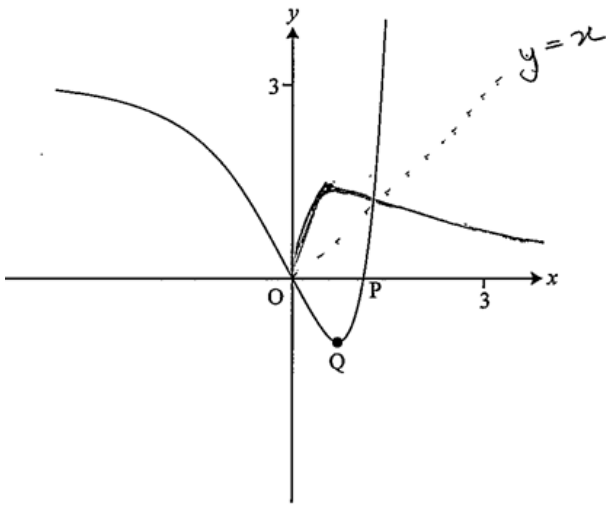
M1A0



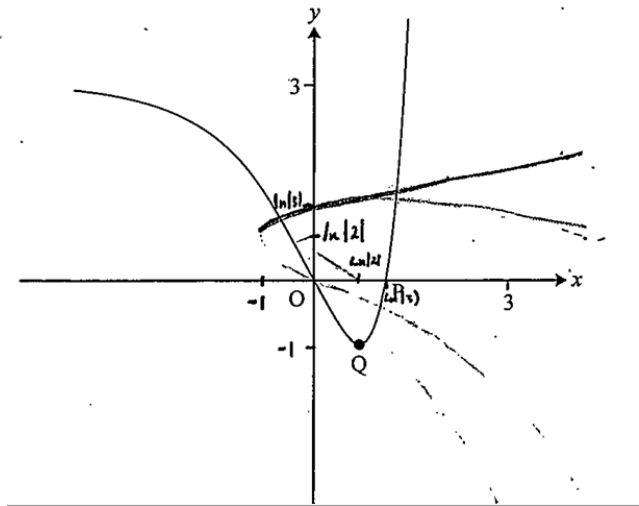
M1A1



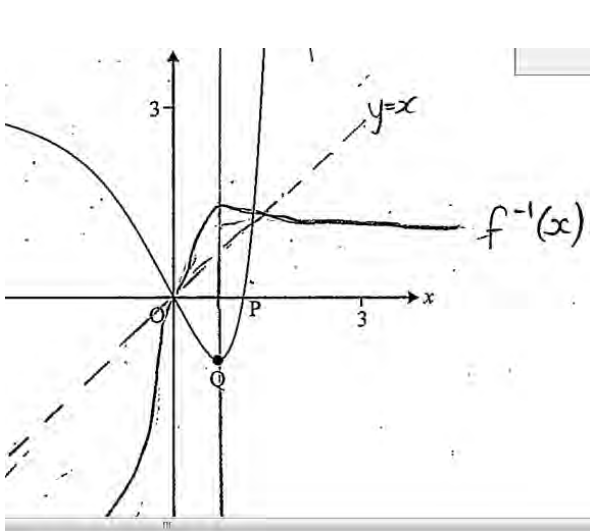
M1A0



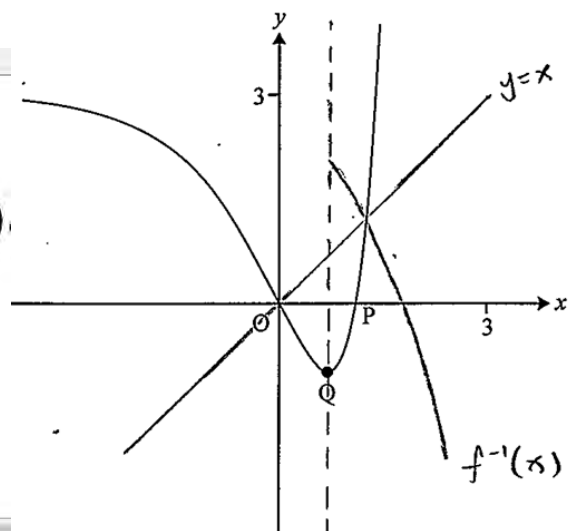
M1A0



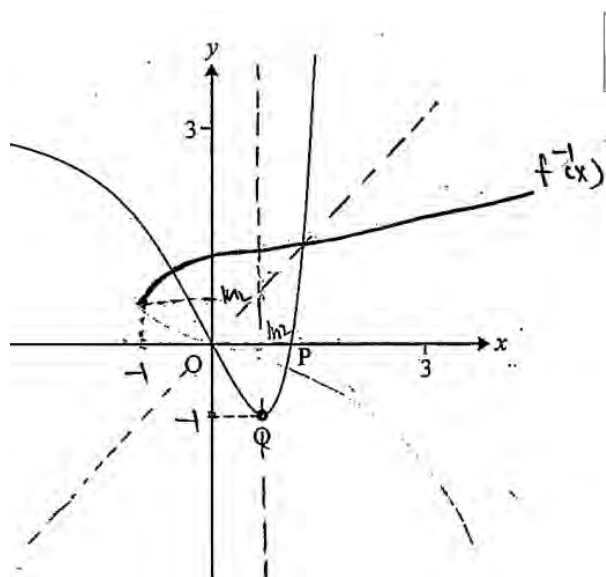
M1bodA1 (condone gradient at  $(-1, \ln 2)$ )



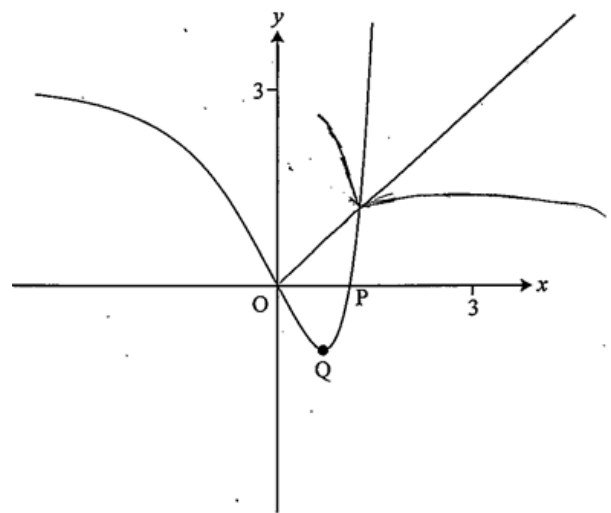
M1 A0



M1 A0



M1 A1



bod M1 A0 (evidence of reflection of part of curve here)



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