



**General Certificate of Education
June 2010**

Mathematics

MFP3

Further Pure 3

Mark Scheme

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Key to mark scheme and abbreviations used in marking

M	mark is for method		
m or dM	mark is dependent on one or more M marks and is for method		
A	mark is dependent on M or m marks and is for accuracy		
B	mark is independent of M or m marks and is for method and accuracy		
E	mark is for explanation		
✓ or ft or F	follow through from previous incorrect result	MC	mis-copy
CAO	correct answer only	MR	mis-read
CSO	correct solution only	RA	required accuracy
AWFW	anything which falls within	FW	further work
AWRT	anything which rounds to	ISW	ignore subsequent work
ACF	any correct form	FIW	from incorrect work
AG	answer given	BOD	given benefit of doubt
SC	special case	WR	work replaced by candidate
OE	or equivalent	FB	formulae book
A2,1	2 or 1 (or 0) accuracy marks	NOS	not on scheme
-x EE	deduct x marks for each error	G	graph
NMS	no method shown	c	candidate
PI	possibly implied	sf	significant figure(s)
SCA	substantially correct approach	dp	decimal place(s)

No Method Shown

Where the question specifically requires a particular method to be used, we must usually see evidence of use of this method for any marks to be awarded. However, there are situations in some units where part marks would be appropriate, particularly when similar techniques are involved. Your Principal Examiner will alert you to these and details will be provided on the mark scheme.

Where the answer can be reasonably obtained without showing working and it is very unlikely that the correct answer can be obtained by using an incorrect method, we must award **full marks**. However, the obvious penalty to candidates showing no working is that incorrect answers, however close, earn **no marks**.

Where a question asks the candidate to state or write down a result, no method need be shown for full marks.

Where the permitted calculator has functions which reasonably allow the solution of the question directly, the correct answer without working earns **full marks**, unless it is given to less than the degree of accuracy accepted in the mark scheme, when it gains **no marks**.

Otherwise we require evidence of a correct method for any marks to be awarded.

Q	Solution	Marks	Total	Comments
1(a)	$y(1.1) = y(1) + 0.1[1 + 3 + \sin 1]$	M1A1	3	Condone > 4dp
	$= 1 + 0.1 \times 4.84147 = 1.4841(47..)$ $= 1.4841$ to 4dp	A1		
(b)	$y(1.2) = y(1) + 2(0.1)\{f[1.1, y(1.1)]\}$	M1	3	Ft on cand's answer to (a) CAO Must be 2.019 Note: If using degrees max mark is 4/6 ie M1A1A0;M1A1FA0
	$\dots = 1 + 2(0.1)\{1.1+3+\sin[1.4841(47..)]\}$ $= 2.019$ to 3dp	A1F A1		
Total			6	
2(a)	$-4k \sin 2x + k \sin 2x = \sin 2x$	M1 A1	3	Substituting into the differential equation Accept correct PI
	$k = -\frac{1}{3}$	A1		
(b)	(Aux. eqn $m^2 + 1 = 0$) $m = \pm i$ CF: $A \cos x + B \sin x$	B1 M1 A1F	4	PI M0 if m is real OE Ft on incorrect complex values for m For the A1F do not accept if left in the form $Ae^{ix} + Be^{-ix}$ c's CF +c's PI but must have 2 constants
	(GS: $y =$) $A \cos x + B \sin x - \frac{1}{3} \sin 2x$	B1F		
Total			7	
3(a)	The interval of integration is infinite	E1	1	OE
(b)	$\int 4xe^{-4x} dx = -xe^{-4x} - \int -e^{-4x} dx$	M1 A1	3	$kxe^{-4x} - \int ke^{-4x} dx$ for non-zero k Condone absence of $+c$
	$= -xe^{-4x} - \frac{1}{4}e^{-4x} \{+c\}$	A1F		
(c)	$I = \int_1^{\infty} 4xe^{-4x} dx = \lim_{a \rightarrow \infty} \int_1^a 4xe^{-4x} dx$	M1	3	F(a) – F(1) with an indication of limit ' $a \rightarrow \infty$ ' For statement with limit/ limiting process shown CSO
	$\lim_{a \rightarrow \infty} \left\{ -ae^{-4a} - \frac{1}{4}e^{-4a} \right\} - \left[-\frac{5}{4}e^{-4} \right]$			
	$\lim_{a \rightarrow \infty} ae^{-4a} = 0$	M1		
	$I = \frac{5}{4}e^{-4}$	A1		
Total			7	

MFP3 (cont)

Q	Solution	Marks	Total	Comments
4	$\text{IF is } \exp\left(\int \frac{3}{x} dx\right)$ $= e^{3\ln x}$ $= x^3$ $\frac{d}{dx} [yx^3] = x^3(x^4 + 3)^{\frac{3}{2}}$ $\Rightarrow yx^3 = \frac{1}{10}(x^4 + 3)^{\frac{5}{2}} + A$ $\Rightarrow \frac{1}{5} = \frac{1}{10}(4)^{\frac{5}{2}} + A$ $\Rightarrow A = -3; \quad (*)$ $\Rightarrow yx^3 = \frac{1}{10}(x^4 + 3)^{\frac{5}{2}} - 3$	<p>M1</p> <p>A1</p> <p>A1</p> <p>M1</p> <p>A1</p> <p>m1</p> <p>A1</p> <p>m1</p> <p>A1</p>	<p>9</p>	<p>and with integration attempted</p> <p>PI</p> <p>LHS. Use of c's IF. PI</p> <p>$k(x^4 + 3)^{\frac{5}{2}}$</p> <p>Condone missing 'A'</p> <p>Use of boundary conditions in attempt to find constant after intgr. Dep on two M marks, not dep on m</p> <p>ACF. The A1 can be awarded at line (*) provided a correct earlier eqn in y, x and 'A' is seen immediately before boundary conditions are substituted.</p>
	Total		9	

MFP3 (cont)

Q	Solution	Marks	Total	Comments
5(a)	$\cos 4x \approx 1 - \frac{(4x)^2}{2} + \frac{(4x)^4}{4!} \dots$	M1	2	Clear attempt to replace x by $4x$ in expansion of $\cos x \dots$ condone missing brackets for the M mark
	$\approx 1 - 8x^2 + \frac{32}{3}x^4 \dots$	A1		
(b)(i)	$\frac{dy}{dx} = \frac{1}{2 - e^x} \times (-e^x)$	M1	6	Chain rule Quotient rule OE ACF All necessary rules attempted (dep on previous 2 M marks) ACF
	$\frac{d^2y}{dx^2} = \frac{(2 - e^x)(-e^x) - (-e^x)(-e^x)}{(2 - e^x)^2}$	M1		
	$= \frac{-2e^x}{(2 - e^x)^2}$	A1		
	$\frac{d^3y}{dx^3} = \frac{(2 - e^x)^2(-2e^x) - (-2e^x)2(2 - e^x)(-e^x)}{(2 - e^x)^4}$	m1		
(ii)	$y(0) = 0; y'(0) = -1; y''(0) = -2; y'''(0) = -6$	M1	2	At least three attempted CSO AG (The previous 7 marks must have been awarded and no double errors seen)
	$\ln(2 - e^x) \approx y(0) + xy'(0) + \frac{x^2}{2}y''(0) + \frac{x^3}{6}y'''(0) \dots$ $\dots \approx -x - x^2 - x^3 \dots$	A1		
(c)	$\left[\frac{x \ln(2 - e^x)}{1 - \cos 4x} \right] \approx \frac{-x^2 - x^3 - x^4 \dots}{8x^2 - \frac{32}{3}x^4}$	M1	3	Using the expansions The notation $o(x^n)$ can be replaced by a term of the form kx^n Division by x^2 stage before taking the limit CSO
	Limit = $\lim_{x \rightarrow 0} \frac{-x^2 - o(x^3)}{8x^2 - o(x^4)}$	m1		
	$\dots = \lim_{x \rightarrow 0} \frac{-1 - o(x)}{8 - o(x^2)}$			
	$\dots = -\frac{1}{8}$	A1		
Total			13	

MFP3 (cont)

Q	Solution	Marks	Total	Comments
6(a)(i)	$x^2 + y^2 = r^2, x = r \cos \theta, y = r \sin \theta$	B2,1,0		B1 for one stated or used
	$r^2 = 2r(\cos \theta - \sin \theta)$ $x^2 + y^2 = 2(x - y)$	M1 A1	4	ACF
(ii)	$(x - 1)^2 + (y + 1)^2 = 2$	M1 A1F		
	Centre (1, -1); radius $\sqrt{2}$	A1F	3	
(b)(i)	Area = $\frac{1}{2} \int (4 + \sin \theta)^2 d\theta$	M1		Use of $\frac{1}{2} \int r^2 d\theta$.
	$= \frac{1}{2} \int_0^{2\pi} (16 + 8 \sin \theta + \sin^2 \theta) d\theta$	B1 B1		Correct expn of $[4 + \sin \theta]^2$ Correct limits
	$= \int_0^{2\pi} (8 + 4 \sin \theta + 0.25(1 - \cos 2\theta)) d\theta$	M1		Attempt to write $\sin^2 \theta$ in terms of $\cos 2\theta$
	$= \left[8\theta - 4 \cos \theta + \frac{1}{4} \theta - \frac{1}{8} \sin 2\theta \right]_0^{2\pi}$	A1F		Correct integration ft wrong coefficients
	$= 16.5\pi$	A1	6	CSO
(ii)	For the curves to intersect, the eqn $2(\cos \theta - \sin \theta) = 4 + \sin \theta$ must have a solution.	M1		Equating rs and simplifying to a suitable form
	$2 \cos \theta - 3 \sin \theta = 4$ $R \cos(\theta + \alpha) = 4,$	M1		OE. Forming a relevant eqn from which valid explanation can be stated directly
	where $R = \sqrt{2^2 + 3^2}$ and $\cos \alpha = \frac{2}{R}$ $\cos(\theta + \alpha) = \frac{4}{\sqrt{13}} > 1$. Since must have $-1 \leq \cos X \leq 1$ there are no solutions of the equation $2(\cos \theta - \sin \theta) = 4 + \sin \theta$ so the two curves do not intersect.	A1 E1	4	OE. Correct relevant equation Accept other valid explanations.
(iii)	Required area = answer (b)(i) - $\pi(\text{radius of } C_1)^2$ $= 16.5\pi - 2\pi = 14.5\pi$	M1 A1F	2	Ft on (a)(ii) and (b)(i)
Total			19	

MFP3 (cont)

Q	Solution	Marks	Total	Comments
7(a)(i)	$\frac{dx}{dt} \frac{dy}{dx} = \frac{dy}{dt}$ $\frac{1}{2} t^{-\frac{1}{2}} \frac{dy}{dx} = \frac{dy}{dt} \quad \text{so} \quad \frac{dy}{dx} = 2t^{\frac{1}{2}} \frac{dy}{dt}$	M1 A1	2	OE Chain rule CSO A.G.
(a)(ii)	$\frac{d^2 y}{dx^2} = \frac{d}{dx} \left(2t^{\frac{1}{2}} \frac{dy}{dt} \right) = \frac{dt}{dx} \frac{d}{dt} \left(2t^{\frac{1}{2}} \frac{dy}{dt} \right)$ $\frac{d^2 y}{dx^2} = 2t^{\frac{1}{2}} \left[2t^{\frac{1}{2}} \frac{d^2 y}{dt^2} + t^{-\frac{1}{2}} \frac{dy}{dt} \right]$ $\frac{d^2 y}{dx^2} = 4t \frac{d^2 y}{dt^2} + 2 \frac{dy}{dt}$	M1 m1 A1	3	$\frac{d}{dx}(f(t)) = \frac{dt}{dx} \frac{d}{dt}(f(t))$ O.E. eg $\frac{d}{dt}(g(x)) = \frac{dx}{dt} \frac{d}{dx}(g(x))$ Product rule O.E. used dep on previous M1 being awarded at some stage CSO A.G.
(b)	$t^{\frac{1}{2}} \left[4t \frac{d^2 y}{dt^2} + 2 \frac{dy}{dt} \right] - (8t+1)2t^{\frac{1}{2}} \frac{dy}{dt}$ $+ 12t^{\frac{3}{2}} y = 12t^{\frac{5}{2}}$ $4t^{\frac{3}{2}} \frac{d^2 y}{dt^2} - 16t^{\frac{3}{2}} \frac{dy}{dt} + 12t^{\frac{3}{2}} y = 12t^{\frac{5}{2}}$ Divide by $4t^{\frac{3}{2}}$ gives $\frac{d^2 y}{dt^2} - 4 \frac{dy}{dt} + 3y = 3t$	M1 A1	2	Subst. using (a)(i), (a)(ii) into given DE to eliminate all x CSO A.G.
(c)	Solving $\frac{d^2 y}{dt^2} - 4 \frac{dy}{dt} + 3y = 3t$ (*) Auxl. Eqn. $m^2 - 4m + 3 = 0$ $(m-1)(m-3) = 0$ $m = 1$ and 3 CF $Ae^t + Be^{3t}$ For PI try $y = pt + q$ $-4p + 3pt + 3q = 3t \Rightarrow p = 1, q = \frac{4}{3}$ GS of (*) is $y = Ae^t + Be^{3t} + t + \frac{4}{3}$ GS of $x \frac{d^2 y}{dx^2} - (8x^2 + 1) \frac{dy}{dx} + 12x^3 y = 12x^5$ is $y = Ae^{x^2} + Be^{3x^2} + x^2 + \frac{4}{3}$	M1 A1 M1 M1 A1 B1F A1	7	PI Condone x for t here; ft c's 2 real values for ' m ' OE CF + PI with 2 arb. constants and both CF and PI functions of t only
	Total		14	
	TOTAL		75	