Examiners' Report
Principal Examiner Feedback

Summer 2024

Pearson Edexcel GCE

In A Level Further Mathematics (9FM0)

Paper 02 Core Pure Mathematics 2

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General

This paper provided plenty of opportunity for candidates to demonstrate what they had learnt. All questions provided access at all levels with question 9 perhaps being the most demanding question on the paper.

It is important for candidates to recognise the importance of using the method asked for in a question. This was particularly true for question 4 where some candidates ignored the required use of method of differences and instead used algebra or an alternative method to find the required solution.

There were instances throughout the paper where marks were lost unnecessarily.

Examples are:

- question 1 where candidates failed to complete their proof or write e.g. LHS = RHS
- question 1 where candidates did not have correct use of brackets for their $\ln$ function
- question 2 where candidates did not correctly quote the Maclaurin expansion
- question 6 where the candidate failed to write $x =$
- question 8 where answers were left in the correct form but in a column vector

Question 1

(a) The majority of candidates answered this part well.

Typically, candidates substituted for $\sinh x$ and attempted to cube brackets. Some candidates used the binomial expansion for the cubing of their bracket.

The most common errors were expressing $\sinh x$ as $\left(\frac{e^x + e^{-x}}{2}\right)$ or mistakes in cubing the bracket with sign errors occurring in their expansion.

Other common errors included forgetting to cube the denominator leading to a coefficient of 2 instead of $\frac{1}{2}$.

Some candidates failed to complete their proof and add a conclusion such as LHS = RHS
Also, some candidates concluded by incorrectly stating $= \sinh x$ or $= \sin 3x$ at the end.

Other candidates failed to convert $\sinh x$ to exponentials and used the double angle formulae or other identities resulting in no marks being scored.

(b) This was reasonably well answered.

A minority of candidates cancelled the $\sinh x$ term from both sides, disregarding the possibility that $\sinh x = 0$

Other candidates proceeded from $4\sinh^2 x = 16$ to $\sinh x = \pm 4$

Candidates that used the given logarithmic form formula usually obtained the correct answers, whereas those who used the exponential form to solve $\sinh x = \pm 2$ were less successful, some giving all four solutions from their two quadratics without discarding the incorrect extra values.

There were a significant minority that when taking the square root only wrote $\sinh x = 2$

Most went on to use the correct form of $\text{ar}\sinh x$ in terms of ln. Some opted to solve using the exponential form and this sometimes resulted in sign errors or exact solutions not being found.

A not insignificant number of candidates did not put brackets around their answer leaving it as e.g. $\ln 2 + \sqrt{5}$

Those who substituted the exponential form for each term and proceeded to find a four-term cubic equation in e^{2x} = 0, were much less likely to achieve correct solutions.

Question 2

This question saw the entire range of marks awarded.

(a) Numerous approaches were taken with varying degrees of success.

Candidates were asked to prove a given result. Some candidates failed to realise the requirement for application of the quotient/product and chain rules and scored no marks in this part. Those who used the quotient rule were usually able to score the first two marks, and some would proceed to use the chain rule correctly to score at least the third mark.

A few students used the incorrect identity for $\text{sech}^2 x$ possibly getting confused with $\sec^2 x$
Many candidates accurately simplified their expression to reach the given answer, though some candidates did get lost within their algebraic manipulation.

Alternative methods were seen, the most frequent being removal of the inverse hyperbolic into the form tanh y = …followed by implicit differentiation. This made the requirement for the quotient rule clearer, but several candidates used incorrect identities or struggled with the manipulation stemming from rearranging into $\frac{\mathrm{d}y}{\mathrm{d}x} = ...$ and thus were less likely to score.

Reframing as a logarithm was also seen occasionally, with many candidates again achieving the first two marks for correct rearrangement and simplification of the argument of the logarithm, but once again many failed to appreciate the need for the chain rule and scored no further marks.

(b) This was very straight forward for candidates, even if (a) was not attempted.
However, the most common error was failing to multiply by the "2" when applying the chain rule. There were a few candidates who integrated rather than differentiated.

(c) This was generally well answered. Some candidates did not appear to realise that the Maclaurin expansion is a given formula in their booklets, mis-quoting formulae and thus losing marks, with a significant minority failing to divide their coefficient of x^2 by 2.

A small number of candidates did not process the $\frac{1}{2}\ln 3$ term into the required form.

Question 3

(a) Overall, this was answered well, although some candidates lost marks by stating that the integral was undefined, without referring to the infinite limit, A few candidates incorrectly referred to the function rather than the limit with others stating that the function was not defined at $\frac{4}{3}$, also losing the mark.

(b) Most candidates identified the correct form for the integral, $\alpha \arctan(\beta x)$

The most common error was to have $\alpha = \frac{1}{4}$. The most successful candidates took out a factor of $\frac{1}{9}$ before integrating. A few candidates made a substitution, in general, successfully. Very few candidates lost marks because they did not refer to $\lim_{t \to \infty}$ and a pleasing number realised that this was $\frac{\pi}{2}$. The most common incorrect values were 0 and ∞.

Question 4

This question was well answered.

Most candidates realised that they needed to use partial fractions and apply the method of differences. A few made errors in their partial fractions, but this was extremely rare. Nearly all candidates had the correct cancelling terms. The most common mistakes were simple errors with the algebraic manipulation into the final algebraic fraction. Sometimes confusion arose with negatives or a very occasional arithmetic slip costing some the final accuracy mark.

The most common incorrect answer seen was $\frac{n(11n-61)}{30(n+5)(n+6)}$

Question 5

(a) There were many very good, correct diagrams and almost all students identified that the two loci were a circle and a half line. A small number of candidates drew their circle centred on the imaginary axis, but the significant majority drew the correct circle in place and drew a suitable half line. By far the most common error was the angle at which the half line was drawn, with many students drawing a line with shallow gradient that intersected the circle to the right of centre, losing this mark and potentially giving a misleading diagram from which to work from in part c).

(b) The majority of candidates shaded the appropriate region for their diagram with only a very small proportion shading above their half line, or below the real axis.

(c) There was increased challenge here, with several potential routes to finding the required area. Most candidates attempted this part, though success was notably mixed.

Candidates with the correct diagram generally went on to score well. Some got confused by which parts to subtract/add to each other. Many started to work with a semicircle and then switched to a full circle when attempting to find the areas of the relevant sectors or segments. Some successfully found both coordinates of the point of intersection, gaining the first two marks, but had no overall strategy for the required area. Those who used the geometrical approach had less work to do, especially if they realised the triangle formed by the intersection point, the origin and the circle centre was equilateral.

A successful approach was to use polar coordinates, where candidates with an incorrect diagram in part (a) often scored full marks. When marks were dropped using polar co-ordinates it was usually due to arithmetic errors when squaring their value for r or omitting the $\frac{1}{2}$ from their integral or using sin instead of cos. Occasional attempts at integration of the Cartesian form were seen; however, this method was significantly more demanding and rarely scored any marks.

Question 6

Most candidates made a good attempt at this question, although a significant number were unable to access the marks for part (c)

(a) Almost all the candidates solved the auxiliary equation successfully, and most of those wrote down the correct Complementary Function. Only a minority did not find a Particular Integral. Of those who did find the PI most had the correct equation of $2t + 1$. Only a few made an error by finding PI as $2t + 2$, the most common incorrect expression. When writing down the general solution only a handful did not use the correct variables with $x = \mathrm{f}(t)$.

(b) Most candidates used $x = 3$ and $\frac{\mathrm{d}x}{\mathrm{d}t} = -2$ with $t = 0$ correctly and differentiated their general solution. The particular solution caused some candidates problems, typically with slips in solving the simultaneous equations they had formed, with a few using $\frac{dx}{dt} = 0$ instead of the given value. This would prove to be a costly error as it gave the candidates a particular solution with two exponential terms and led them to lose almost all the remaining marks for question 6.

(c)(i) Candidates who had found correct values for *A* and *B* mostly went on to find the value for *t* when $\frac{dx}{dt} = 0$. A few errors were seen in applying the logarithm rules. A correct value of *t* usually led to a correct minimum value.

(c)(ii) Candidates were expected to take the second derivative of the function correctly and justify that this is a minimum by stating their second derivative is greater than 0 (and often also finding its value of 4). This had mixed responses usually from incorrect earlier work. Some candidates incorrectly substituted for *x* instead of *t*.

(d) The final part of the question was perhaps not well answered with most not establishing that the speed becomes constant as e^{-2t} tends to zero or failing to draw an appropriate conclusion. Some just assumed that as *t* increased, the speed must also continue increasing. Some realised the speed approached a constant value 2 but failed to state the model was suitable.

Question 7

(a) This was generally answered. Care should be taken to read the given domain as several candidates were using intervals such as $(-\pi, \pi]$ or even $(0, 2\pi)$ with $e^{2\pi i}$ being the most common incorrect answer. Some candidates missed i out of their solutions and some had the denominator as 6. Almost all candidates listed each of solutions rather than using *k* notation which was completely acceptable.

(b) Most candidates realised the six points form a hexagon of some description. However, there was a lack of care in the drawing of a regular hexagon with two vertices needed to be correctly plotted on the coordinate axis. There was often a lack of symmetry in the diagram.

(c) There were various allowable approaches. Writing the complex number in polar and/or exponential form was the most straight forward and most successful, and many candidates gave clear concise solutions. Another approach was to expand the brackets which was time consuming and sometimes resulted in algebraic errors. Those who used a binomial expansion were slightly quicker and made less errors. However, many fully correct solutions were provided using both of these methods.

(d) Most candidates either were successful and scored full marks or did not know where to start. Many achieved the first two marks in this part for $r = 2$ and one correct answer: usually $2e^{\frac{\pi}{6}i}$. Errors here were generally from an incorrect angle; using $\frac{1}{3}$ was often seen. A common error was missing i on at least one of their solutions.

Question 8

(a) Many candidates managed to invert the matrix accurately and there were pleasingly few slips in the involved calculations. Where marks where dropped this was overwhelmingly due to arithmetic errors when calculating either their determinant or matrix of minors that then led to an incorrect answer. Some students struggled to negate the correct terms at the end of the process. Unfortunately, those with an incorrect determinant would lose several marks on this question.

(b) Most candidates solved the equation by multiplying the vector $\begin{pmatrix} 3 \\ 1 \\ 6 \end{pmatrix}$ by their inverse. Those who used the matrix approach often did not achieve all the marks. This was due to an incorrect answer in part (a) or basic arithmetic errors in their matrix multiplication and subsequent algebraic simplification. Several candidates lost the final mark because they didn't give their answer as coordinates. A smaller number gave un-simplified answers. Leaving the determinant outside the vector was another cause of marks lost.

A few candidates opted instead for the elimination method for solving their three equations simultaneously, sometimes abandoning halfway through. Those who were successful with this approach had the advantage of writing their answers automatically in the correct form. Also, they had the opportunity to gain full marks even if their answer to part (a) was wrong.

Question 9

This question proved challenging for most candidates with many failing to make any progress at all in part (b).

(a) This was generally well-answered with the majority reaching correct values for a and b, though it was noted that many candidates performed significant unnecessary working to achieve these values. Some candidates reached $a = 0$ and thus restricted their available marks for (b)

(b) This was by some margin the most technically demanding section of the paper, and many candidates only managed to score 1 or 2 marks here. However, many candidates did identify the need to rotate around the y axis leading to the requirement to apply $(\pi)\int x^2 \frac{dy}{dt}\,dt$

This is where candidates generally ceased scoring marks (other than scoring the later mark for the volume of the cylinder). Few candidates progressed to an integrable form via the use of $\sin 2t$ identities (some instead attempting identities moving towards terms in $\cos 4t$ but stopping short of an attempt at integration by parts or another correct method). Those who did use the correct identity were often still unable to perform any integration correctly. Where correct integration was seen it was generally on their $\sin t$ and $\sin^2 t \cos t$ terms, but very few candidates progressed to a fully correct integral and often their attempts at part (b) ended prematurely.

The correct value of $\frac{588\pi}{5}$ sometimes appeared with no working, candidates having used their calculator, and they gained no credit for this.

Some candidates did attempt alternate methods of integration such as parts or conversion to a cartesian form. However, these routes were equally technically demanding and did not generally lead to better outcomes, with fully correct responses via either of these methods rarely seen.

(c) This was generally well-answered by those who attempted it, with a mixture of correct responses regarding smoothness/symmetry, failure to consider the thickness of the vase or the curve not accurately modelling the shape of the vase. However, several candidates misunderstood the relevant limitations of the model and commented on things such as the vase being solid, the cylinder not being vertical (or equivalent) or even the cross section being wrong, all of which scored no marks.

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