Examiners' Report
Principal Examiner Feedback

Summer 2025

Pearson Edexcel International Advanced Level
In Further Pure Mathematics F3 (WFM03)
Paper 01

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Summary

This paper provided a good balance between the application of standard techniques and questions where knowledge had to be applied to unfamiliar situations. Some candidates struggled with technical proficiency in these standard techniques, such as finding eigenvalues, integration by parts or dealing with different forms of the hyperbolic functions. It was rare to see no attempt at most questions, showing that candidates were generally well prepared for this paper.

Questions 7(a)(b), 8(c)(d) and question 9(e) proved to be more challenging for some candidates. There were six "hence" type questions in this paper, and it was pleasing to see that most candidates applied their previous work when attempting these. There were also nine 'show that' type questions in this paper, and a significant number of candidates did not score fully in these questions due to a lack of working shown to convey how they arrived at the given result. It was evident in some of these questions that candidates knew what mathematical technique had to be applied, but the result was not fully shown to justify all marks being awarded. Some candidates' scripts were littered with poor bracketing, unclear notation, careless calculation and a clear lack of exam technique.

Question 1

This question proved to be successful for most, with many fully correct solutions seen. It was clear that candidates were well acquianted with the hyperbolic functions.

Part (a) proved very straightforward to most candidates, with the stipulation that a start with the definition of cosh$x$ in terms of exponentials was required. Some candidates started by combining two steps "in their head" and had e.g.

$2\cosh 5x \cosh x = \mathrm{e}^{5x} + \mathrm{e}^{-5x} \times \dfrac{\mathrm{e}^{x} + \mathrm{e}^{-x}}{2} = \dfrac{\mathrm{e}^{6x} + \mathrm{e}^{4x} + \mathrm{e}^{-4x} + \mathrm{e}^{-6x}}{2}$ as their first line, which

accrued no marks as the question clearly stated to begin with the exponential definitions. Although such simplifications may seem obvious to able candidates, they do not satisfy the demand of the question. Of those who started from the correct exponential definition, most were able to multiply to the correct form and separate to the correct exponential definition of cosh6x and cosh4x. Some attempted a "meet in the middle" type approach, which required the same algebraic manipulations and exponential definitions to score. It was rare to see "arcosh$x$" and "arccos$x$" being conflated.

Part (b) proved more successful, with many candidates scoring at least three marks out of four. Part (a) had to be used as this was a "hence" question, and virtually all candidates were able to use part (a) to arrive at an equation in cosh5x. Those that resorted to replacing with the exponential definition and progressing to a 3TQ in e^{5x} proved more successful than those who used the logarithmic form for arcosh$x$, perhaps due to the $\pm$ being present in the numerator of their expression when applying the quadratic formula- so two solutions were arrived at. Of those who used the logarithmic form for arcosh$x$, it was common to see the second solution missing, with many simply unaware that cosh$x$ is symmetric about the y-axis. Some candidates were penalised for poor/ambiguous bracketing.

Question 2

This question proved to differentiate amongst middle grade candidates, with most making valiant attempts at part (a), but full marks in the remaining parts proving hard to achieve for many. At this level candiates should be fully competent at completing the square, and this proved no trouble for the vast majority, but some candidates exhibited a lack of awareness by continuting with sign errors that cost them valuable marks. Candidates should check when performing a process such as completing the square, that their completed square form does transform back to the original quadratic. Most were able to extract the correct factor and proceed to the arsinh form for the integral. Coefficient errors via incorrect manipulation of the surd, sign errors or incorrect arguments for the arsinh term were common reasons for the final mark being withheld. Some candidates used the alternative version of the standard integral for this type of surd expression, and answers such as $\frac{1}{2}\ln\left[(x+1)+\sqrt{(x+1)^2+\frac{5}{4}}\right]$ or $\frac{1}{2}\ln\left[(2x+2)+\sqrt{4x^2+8x+9}\right]$ etc were also seen, although it was interesting to note that candidates did not opt for the simplest version of standard integral possible involving arsinh. Some poor notation such as "arcsin" or "arsin" or even "arcsinh" was seen.

Part (b) generated more errors due to incorrect coefficients when using integration by parts, or choosing overly obtuse methods to integrate the standard integral once integration by parts had been applied. Some candidates were clearly less prepared for single mathematics material involving WMA13 integration for example (which is a pre-requisite for WFM03) with the integration $b\int \frac{x}{\sqrt{\pm(cx^2-1)}} \to k\sqrt{\pm(cx^2-1)}$ proving troublesome. Some candidates conflated "arcosh3x" with "cosh3x" and proceeded to replace the latter with the exponential form, while others attempted to use the logarithmic form for arcosh3x, scoring zero as the complexity of the resulting integral rendered the question undoable for most, with a horrendous integration by parts yielding an even more complex integrand. Candidates who applied a substitution:

$$u = \operatorname{ar}\cosh 3x \Rightarrow x = \frac{1}{3}\cosh u \Rightarrow \frac{\mathrm{d}x}{\mathrm{d}u} = \frac{1}{3}\sinh u$$

$$\int \operatorname{arcosh}3x\,\mathrm{d}x = \int \frac{1}{3}u\sinh u\,\mathrm{du} = \frac{u}{3}\cosh u - \int \frac{1}{3}\cosh u\,\mathrm{du}$$

were generally more successful due to the simplicity of the resulting integration. Accuracy errors when re-writing in terms of x were seen but not common.

Question 3

This question had lots of accessible marks for routine work at this level, and the majority of candidates were able to use correct processing to obtain the eigenvalues and associated eigenvectors. Some candidates made the algebra more complex than it needed to be, and basic errors with collecting terms and solving the resulting cubic were seen.

In part (a) the first two marks were almost universally scored for a correct eigenvalue. There were relatively few errors in multiplying the first row of matrix **M** with the given eigenvector, but sign errors were the most common cause of the incorrect value being found.

Part (b) was similarly successful, with very few incorrect attempts seen. It was evident that candidates were very well versed in multiplying matrices and comparing elements. There were very few errors when solving the resulting equations for their eigenvalue calculated in part (a).

Part (c) proved more challenging for some candidates, but this was mainly down to processing rather than a lack of awareness of the underlying method needed to obtain the other eigenvalues. The formulation of the correct unsimplified characteristic polynomial was almost universally seen, with most expanding via the first row, but the simplification and solving of the resulting cubic seemed to perturb many candidates, with numerous re-starts observed. The expression obtained did not factorise, and terms had to be collected after multiplication. There were many elaborate and sometimes time-consuming attempts seen, when the best approach was to count coefficients from each term and combine together. Of those who proceeded to the correct cubic equation, most were able to solve successfully (using a calculator or otherwise) to obtain the other eigenvalues. Although candidates were permitted to use a calculator to solve their resulting characteristic cubic polynomial, this mark was not permitted unless sufficient method had been shown to obtain the equation being solved.

Part (c)(ii) was only attempted by those who had found other eigenvalues from part (c)(i) and most were able to obtain at least one correct corresponding eigenvector. Candidates would have been rewarded for applying the correct process using any eigenvalue, however found, to score the first M mark in this part of the question. It would be prudent to remind candidates that using a specific value to demonstrate a correct process can sometimes result in a method mark being awarded, even if the underlying value used is incorrect. Some candidates did not appear to understand what an eigenvector was, with $x = 0$, $y = 0$, $z = 0$ seen. Others listed non-zero values but did not give the answer as a vector. It was rare to see an approach involving the cross product of any two rows of their $\mathbf{M} - \lambda\mathbf{I}$.

Question 4

This question proved to be very straightforward for most candidates, and it was the most successful on the paper. Lack of clarity and/or poor technical accuracy resulted in some losing marks unnecessarily.

In part (a) the standard derivative for arsinh$x$ was applied to both parts of the given expression, with the chain rule needed on the second term of the expression. Only a minority of candidates failed to score this first mark, with a success rate of over 70%. Most were then able to handle the resulting algebra required to show that the differentiated expression had the form given in the question. The most common approach to combine both parts of the differentiated expression was to use a common denominator inside the surd, and then extract the x to the numerator of the second fraction. Attempts involving the common denominator of the two initial terms obtained after correct differentiation were rare, and often less successful.

In part (b) proved to be a very easy question for almost all candidates. The 'hence' meant that part (a) was used to find x and substitute into the expression for y to find the correct value. Some resorted to substituting their value of x into the given equation then using the exponential form for sinh to form and solve a quadratic in $e^{\frac{y}{2}}$. Poor bracketing was rare, and most were able to obtain one of the three acceptable exact forms for y.

Question 5

This question was similar to previous iterations of reduction formulae, and it was evident that most candidates were well practised on using the integration by parts technique to begin. Technical inaccuracies were the main source of marks being deducted, while some weaker candidates attempted integration by parts in the wrong direction and/or attempted to 'jump' between steps in their working, failing to satisfy the demand of the question.

Part (a) was a 'show that' question and as such candidates need to be reminded that all stages of working are required in order to satisfy the demands of the question. Most were able to apply integration by parts in the correct direction, and obtain an expression of the correct form to warrant at least the first method mark. Splitting the $(3x-2)^{\frac{1}{2}}$ term was needed to score the next M mark, and some candidates combined the integration by parts with the splitting of this expression into the form $(3x-2)(3x-2)^{-\frac{1}{2}}$, scoring three marks on their first line of working. Others resorted to writing the $(3x-2)^{\frac{1}{2}}$ term as a surd, but separated in the same way. Some made errors by writing this as $(3x-2)I_{n-1}$. The dependency of the method marks here meant that candidates would likely lose marks for any 'jumps' in working, as the given result had to be fully shown. Of those who scored the second method mark, most were able to then also score the third method mark for separating the integral and involving both I_n and I_{n-1} terms. Sign errors, coefficient errors, missing 'dx' on either or both integrals and/or the misapplication of limits caused some to lose the final A1* mark. Some candidates used summary notation when performing integration by parts, so things like $\int_1^6 x^n (3x-2)^{-\frac{1}{2}}\,dx = \left[\frac{2}{3}x^n(3x-2)^{\frac{1}{2}}\right]_{(1)}^{(6)} - \frac{2}{3}\int_{(1)}^{(6)} d\left(x^n\right)(3x-2)^{\frac{1}{2}}\,dx$ were observed. While this may be a useful shorthand notation, method marks were not awarded until the full expression was seen, given that this was a 'show that' question which required full working with no ambiguity, even if the result seems obvious to the candidate.

Part (b) was pleasingly successful, with more than 50% of candidates proceeding to the correct exact value of the given integral. Most were able to score at least the first method mark for one correct application of the reduction formula, with some resorting to using this twice then substituting for I_1 while others used the reduction formula three times then substituted for I_0. Processing errors were less common than seen previously, as candidates seemed very well accustomed to using this type of reduction formula to obtain the exact answer. Candidates who worked upwards from I_0 or I_1 to I_3 were generally more successful than those who started from I_3 and worked downwards.

Question 6

This question was another that examined a standard technique were most candidates were able to score highly. Technical inaccuracies were the main source of marks being deducted, but many were able to score full marks, with approximately 50% of candidates achieving this.

Part (a) was standard work at this level and provided very few difficulties for most candidates. Expansion via the first row for the 3 x 3 determinant was almost universally seen, as was progression to a linear expression which was then solved successfully to find a value for k. Unusually it was the first term in the determinant expression that generated the most sign errors, perhaps due to the negative signs here. A high proportion of candidates miscopied the given matrix, but demonstrated the correct method to obtain the first two method marks.

Part (b) proved to be similarly successful, with many fully correct attempts seen. Sign errors when obtaining the matrix of cofactors was the most common error, and/or miscopying previous work or the given matrix in the question. Some resorted to stating the inverse after the matrix of minors was obtained, or applying the transpose first and then the sign convention, but candidates should be encouraged to show all stages of the process in case errors are made, resulting in minimal marks if it is not clear that a correct approach has been followed. Most divided correctly by their determinant, but a few divided by its modulus. Very few candidates substituted a value of k into the given matrix, which would have demonstrated a complete misunderstanding of what was required.

Question 7

This question proved to be a challenge for many candidates, with marks lost through lack of justification, poor notation, and/or a failure to fully utilise the substitution given to simplify the integral. Part (a) was bipartisan, with just under half of candidates scoring full marks, with others, despite clear understanding, failing to show sufficient work to gain the marks. Candidates should be reminded that printed answers need to be justified fully with correct intermediate work shown.

Part (a) was a standard 'show that' question which was given a generous two marks. To demonstrate a correct method, candidates were expected to not only differentiate the simple trigonometric function, but also to show it utilised in the correct surface area formula. This could be shown with a correct substitution, clearly evidenced via $S = 2\pi\int_{(0)}^{\left(\frac{\pi}{4}\right)} \cos 2x\sqrt{1+\left(-2\sin 2x\right)^2}\,(\mathrm{d}x) \Rightarrow S = \cdots$ but as the formula for the surface area was given in the formula booklet, and the printed result was also given, candidates who simply wrote down the result after a simple differentiation scored zero marks as the result was not fully shown. The other alternative was for candidates to quote the correct surface area formula, their derivative and the expression for $\left(\frac{\mathrm{d}y}{\mathrm{d}x}\right)^2$ for their derivative via

$$S = 2\pi\int_{(0)}^{\left(\frac{\pi}{4}\right)} y\sqrt{1+\left(\frac{\mathrm{d}y}{\mathrm{d}x}\right)^2}\,(\mathrm{d}x) \text{ and } \left(\frac{\mathrm{d}y}{\mathrm{d}x}\right)^2 = \ldots \Rightarrow S = \cdots$$

Part (b) proved to be a very good discriminator amongst all candidates, with many varied attempts seen. The most common approach was to differentiate the given substitution with respect to theta and then replace all x terms in the original integral to obtain an integral in theta. Candidates who did not differentiate the given substitution had integrals with two variables and/or did not show a complete substitution, which conveyed an incorrect method. Other equally valid, and equally successful approaches were to make either theta or x the subject of the substitution expression, differentiate and then substitute. Once a correct form for the integrand was seen, double angle formulae were often used to obtain an integrable form for the resulting expression, with a less common approach to replace cosh with its exponential form, and use algebra to proceed to an integrable form. Once an integrable form was seen, over half of the candidates who achieved this inegrable form went on to achieve full marks. Errors with the application of limits were seen with many solutions, with just over a quarter of all students able to progress to the correct exact answer.

Question 8

This was a routine vectors question, similar in nature to previous questions on this topic, and proved accessible to all candidates, with virtually all able to score at least some of the marks available for routine work. Overly complex methods were observed when finding the line of intersection between the two planes, but it was pleasing to see good notation and a high level of accuracy when calculating vector products.

Part (a) over 85% of candidates were able to produce the correct cross product, with a minority going on to divide the elements by a common factor of 2. However, ISW allowed these candidates to score this mark.

Part (b) was not quite as successful, but approximately two thirds of candidates were able to find the correct dot product to obtain the value of p. Only a handful of candidates over complicated the question by using a point on the plane other than the one given.

Part (c) proved to be a differentiator amongst all candidates, with many, varied solutions seen. The most successful approach (and the simplest) was to find the direction of the line of intersection by evaluating the cross product between the two normal vectors. Some candidates attempted this but showed no method. A simple 3 x 3 determinant approach would convey the method here, although candidates were allowed a slip with two correct components sufficient to gain the method mark if no method was shown. Candidates who used this method to find the direction of the line were usually also then able to formulate the cartesian equations of the planes and substitute values for x, y or z to find a point on the line of intersection. Candidates should be reminded that 0 is the simplest value to use here. Other candidates attempted to combine the cartesian equations together to find one variable in terms of the other two and find the line of intersection in cartesian form. However, there are many potential places where candidates can lose accuracy marks for numerical slips or incorrect processing, so this method is best avoided for these questions if possible. Some candidates did all the hard work in finding the correct line direction, and a valid point, but then stated the line equation in the wrong form, or displayed poor bracketing to lose the final mark here. It was pleasing to see that it was less common than has been seen previously for candidates to find a valid point on the line of intersection, and then spoil their method by multiplying their point by a scalar. This would result in the method mark being lost here, as multiples of points on a 3D line are not also necessarily on the line. (This is only true if the line goes through the origin).

Full marks in part (d) proved elusive for many, with less than 20% of candidates going on to achieve the correct shortest distance between the lines. However most were able to score at least the first method mark for achieving the correct direction of the second line, while the direction of the shortest distance was less successfully attempted via the cross product of their direction vectors. It was clear that some candidates had remembered the formula for the shortest distance between skew lines, while others made valiant attempts to resolve the general vector between two points on the lines in the perpendicular direction. It was rare to see a scalar triple product used to find the numerator in the shortest distance formula, but those who progressed to this point usually carried an accuracy error that was only penalised at the end. The most successful approaches were those who calculated each constituent part of the shortest distance formula separately, and then substituted in at the end. It was extremely rare to see a decimal answer given, and it was even more unusual to see the alternative method on the mark scheme being applied, perhaps due to the complexity and volume of calculation work required.

Question 9

This question proved to be a good source of marks for most candidates, with multiple parts involving standard work and more complex mathematical reasoning. Parts (a) ,(b), (c) and (d) were very well answered with around 80% of candidates scoring both marks in part (a) and two thirds scoring all the marks in part (b). The scoring was equally impressive in parts (c) and (d) with around 75% of candidates scoring in these parts. Part (e) was one of the most challenging in the paper, but it allowed very capable mathematicians to demonstrate their capabilities. Some responses were rushed or unfinished, indicating that some ran out of time.

Part (a) was another 'show that' question, and it was pleasing to see that most candidates offered at least one line of working between their correct equation with values substituted and the given answer. Some rearranged the correct eccentricity formula before substituting values, and this was acceptable as long as the undelying method was clear. Candidates are advised to start with the given formula before attempting to use re-arranged versions in 'show that' questions, as the underlying method may be spoiled if there is any ambiguity.

Part (b) was standard 'bookwork' at this level, and many fully correct equations of the tangent were seen. Careless work in rearranging and sign errors were the most common cause of marks being deducted here. Once again it was pleasing to see at least one further line of working before the printed answer was seen. Some candidates did not find the gradient in terms of theta, which was needed for the given equation to be formed.

Parts (c) and (d) proved very easy marks to obtain for most, given that both equations were stated in the question, although some simply stated the y values and not the coordinates as requested.

Part (e) was challenging for many, but the first two marks were easily obtained by finding the centre and radius of the circle with QR as a diameter. The most successful candidates here had a clear diagram to visualise the situation described, and were able to formulate the equation of the circle. Some seemed perturbed by the resulting algebra to show that the equation was satisfied when it passed through the foci, when all that was needed was a full attempt to find x when $y = 0$ recognising that common terms would cancel on both sides of the circle equation, or to show that the expressions were equal on both sides of the circle equation when the foci were substituted. Some candidates appeared to want to show that numerical values were equal on both sides when substituting the foci into the circle equation, but a simple listing of terms and simplifying coefficients was sufficient. It was rare to see any of the alternative methods on the mark scheme being applied to this question, but other novel approaches involved finding the distance between the foci and the centre, and showing that this was equal to the radius of the described circle.

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