Examiners' Report
Principal Examiner Feedback

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In Further Pure Mathematics F1 (WFM01)
Paper 01

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Introduction

This paper proved to be a fair test of student knowledge and understanding. There were many accessible marks available to all students as well as some more challenging question parts for higher ability students.

Question 1

The opening question on inverting a matrix was a very good source of marks for nearly all students.

The method for obtaining the determinant in part (a) was recalled by almost all and it was very rare to see any algebraic slips producing the simplified form.

A range of approaches were possible in part (b), although the overwhelming majority opted for calculating the discriminant or completing the square. The required mathematics was almost always performed successfully although some lost a mark for omitting to explicitly conclude that the matrix was non-singular.

The method for the inverse in part (c) was also well-known. The overwhelming majority were able to reach $\frac{1}{\det \mathbf{P}} \times$ a matrix but there were occasional slips obtaining Adj(**P**). On a small number of occasions **P** rather than Adj(**P**) was used.

Question 2

This question on numerical methods also saw very good scoring.

In part (a), evaluations of f(0.3) and f(0.4) were rarely incorrect. As usual, the evaluations needed to be followed by "sign change, continuous, root" and mentioning the continuity of the curve was omitted by some.

The differentiation required in part (b) was often correct, with most students correctly simplifying the fraction. The minus sign that preceded the fraction caused a significant number to have the wrong sign with their last term. The method of differentiation was applied with few issues in the main. A very small number neglected to differentiate after simplifying. There were a few students who used the quotient rule or product rule on the fraction - this was not a good choice here and errors were far more common with this approach.

Part (c) required application of the Newton-Raphson process and was a good source of marks for most. Students are advised that they should clearly show their method here - a few attempts just gave a value and if this was incorrect then no marks could be scored.

Part (d) required linear interpolation and correct equations were formed by many. Useful sketches were often seen. The common error of not correcting the sign of f(1.3) was not perhaps as common as in other series. There were a few mistakes solving the equation to find the approximate root - sometimes the result of premature rounding. The interval [1.3, 1.4] instead of [1.3, 1.5] was used occasionally. A very small number attempted interval bisection.

Question 3

There was excellent scoring with this question on roots of quadratics although a small number of the usual errors were seen. It was pleasing to see hardly any responses which solved the equation first.

The mark in part (a) was rarely lost although a very small number made sign errors, the most common one being the use of $+\frac{b}{a}$ instead of $-\frac{b}{a}$ for $\alpha+\beta$.

It was very rare to see an incorrect identity used in part (b) although arithmetical errors were seen on occasion.

Part (c) was answered better than similar questions in past series. Identities for the new sum and product were often correct although $\alpha\beta+\frac{\alpha+\beta}{\alpha\beta}$ was sometimes used for the new sum instead of $\alpha+\beta+\frac{\alpha+\beta}{\alpha\beta}$. Some students had the correct expressions but made substitution errors. Most were able to form a quadratic expression with their new sum and product although occasionally the sign of the new sum was not changed. Some answers were seen without the required integer coefficients and/or without the "=0".

Question 4

Although there were many fully correct responses to this question on the complex roots of a cubic equation, there was a fairly varied range of mark profiles awarded.

In part (a), almost all students were able to identify the conjugate root.

Those who went on to form the quadratic factor in part (b) were almost always correct and they invariably proceeded to multiply by an appropriate linear factor. Some did not multiply their answer to match the given first term of $6z^3$ and so did not obtain the integer coefficients as required. There was a range of possible alternative approaches but the awkward form of the complex roots tended to make these methods inefficient and students using them had mixed degrees of success. A small number used knowledge of the roots of cubic equations and tended to proceed correctly. Those who tried to substitute the roots to form simultaneous equations were often not able to equate real and imaginary parts with the complex roots to obtain enough equations. There were also some attempts which tried to bring together a mixture of strategies but these usually ended prematurely in confusion.

In part (c), most students were able to plot the roots in the correct quadrants of the Argand diagram although $z = -\frac{3}{2}$ was sometimes placed on the imaginary axis. A significant number lost a mark here since it was required that the conjugate pair needed to be closer to the y-axis than the real root. Occasionally none of the roots were labelled.

Question 5

This question on series summation saw good scoring in part (a) but marks were often lost in part (b) for not explicitly showing substitution.

In part (a) almost all were able to expand $r(r+1)(r+5)$ correctly and apply at least one of the summation formulae to their expression. A somewhat common error was to replace $\sum r$ with n instead of $\frac{1}{2}n(n+1)$. Those who went on to extract the factor of $\frac{1}{4}n(n+1)$ were almost always correct. Some chose to multiply out to obtain a cubic and were not always successful recovering the required factorised form.

Part (b) proved slightly more discriminating than anticipated. This was a "hence" question and therefore the working had to indicate that the expression in part (a) was being used. Some were not able to identify the correct values of n to use. Sometimes f(45) was used instead of f(40) and f(20) was sometimes used instead of f(19).

Question 6

This question on a rectangular hyperbola saw good scoring with the "bookwork" required in part (a) but part (b) proved to be quite challenging.

A good number of completely correct responses were seen with part (a). The full range of differentiation methods were seen (explicit, implicit and parametric) and it was rare to see errors applying the perpendicular gradient rule. Most went on to form an appropriate straight line equation although it remains the case that a sizeable number of students use $y = mx + c$ when $y - y_1 = m(x - x_1)$ is almost always a more efficient method. An intermediate step was required before the given answer which was omitted by a few. There were a small number of cases where a gradient in terms of x or x and y was used when forming the line equation. Recovery was only allowed if immediate substitution of $\left(10t, \frac{10}{t}\right)$ was seen and this did not always happen.

In part (b), the first two marks were widely scored. Most found the y-axis intercept of the normal although there were a few cases when the x-axis intercept was found instead. The next mark for forming an appropriate equation using the given triangle area was usually obtained although the "$\frac{1}{2}$" was occasionally missing. A significant number were working with the wrong triangle. Sketches were not commonly seen but where present they were usually found to be useful. A considerable number could not deal with the issue of the line PQ crossing the x-axis so that one of the terms in the product for the triangle area needed to have its sign corrected. As a result it was common to see the equation $t^4 = -14$ reached, which often brought the attempt to an end. Some realised what they now needed to do whilst others proceeded to "fudge" a positive value for t^4. Only the very best were able to find a correct value of t from a correct equation. A very small number only produced one point but the majority of those who reached the correct $t^2 = 16$ went on to secure full marks.

Question 7

This question on matrix transformations saw a lot of success although the rotation in (i)(a) was not widely identified.

Although "rotation" was widely seen in part (a), the correct angle was not. Many clearly just wrote down the value of $\arccos\left(-\frac{1}{2}\right)$ but did not check for consistency with the matrix $\begin{pmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{pmatrix}$ that is given on the formula sheet. A small number failed to refer to the origin as the centre of rotation.

There were a lot of correct answers for the matrix **B** although it is clear that the forms of matrices for stretches remain not as well-known as those for translations, rotations and enlargements.

In part (c) most realised the need to find **C** = **AB** rather than **BA** and those who had achieved the correct **B** usually evaluated the elements of **C** correctly.

Part (ii)(a) was a good source of marks for most. Most applied **M** to the point (k, k) correctly although the multiplication was occasionally seen the wrong way round. The mark scheme required there to be no evidence that students had only solved one of the resulting equations and a few fell foul of this requirement. Most solved both and chose the common root. Some solved simultaneously which was fine if they eliminated k^2 but those who eliminated k ended up with the inconclusive $k = \pm 7$. Some solved one equation and verified it in the second equation which was an acceptable alternative.

It was widely known that the determinant of the matrix was needed in part (b) and it was rare to see the given area multiplied by its value instead of divided by it. The most common error was to see $2\times 7^2 - (-1)(-2)$ miscalculated as 100 instead of 96.

Question 8

This question on proof by induction had the usual mixed response. Progress in part (i) was slightly more evident than in part (ii).

In part (i), the first mark as usual required the base case to be verified. Minimal substitution needed to be seen and this wasn't always the case. The general method however was widely known and recalled, and it was common to see a correct matrix obtained for $n = k + 1$. However, not all went on to write the elements explicitly in terms of $k + 1$. Some tried "meet in the middle" approaches which were only condoned if they were convincing. Although the mark scheme for the final mark was quite generous, some students were not able to provide a sufficient narrative/conclusion. A common mistake was to just say "true for $n = 1$, true for $n = k$, true for $n = k + 1$ so true for n" with no indication of assuming the statement being true for $n = k$ implies it is true for $n = k + 1$. There were numerous responses where it was quite clear that the student was not sufficiently well-practised at the overall method of induction proofs.

Part (ii) featured a recurrence relation and this proof by induction task always leads to some confused responses. Since these questions feature a recurrence relation and a general formula, some students do not seem to know which they should be using at the appropriate time. The base case needed to be verified by calculating u_1 and u_2 via the formula. There is no requirement to calculate u_3, although this was often also seen. Many only calculated u_3 via the recurrence relation and verified this by the formula. As in part (i), sometimes substitution into the formula was not explicitly evident. A few only assumed the result was true for $n = k + 1$ and then had nowhere to go. Those that clearly knew the method, usually made progress although the result for $n = k + 2$ was not always explicitly given in terms of $k + 2$. As with part (i), some conclusions were insufficient with the omission of assuming true for both $n = k$ and $n = k + 1$ a common error.

Question 9

The final question on a parabola saw good scoring with finding the tangent in part (a). The last two marks of the locus problem of part (b) proved quite elusive although some fully correct and clearly argued responses were seen.

In part (a) the full range of differentiation methods was again seen as with question 6. Those using explicit differentiation were slightly more prone to error, making slips with the fractional powers and surds involved. There were a few cases where the normal gradient instead of the tangent gradient was found. As with question 6, a number of those who worked with a gradient in terms of x or y ended up multiplying this by the x and y in their straight line equation. The required intermediate step before the given answer was again occasionally omitted.

Most students were able to find the y-axis intercept of the tangent. Some were clearly unaware of what a "perpendicular bisector" is but those who did usually realised the need to find a midpoint of AP. Some attempted perpendiculars through point P or point A. Most midpoint attempts were correct although occasionally $\left(\frac{x_1 - x_2}{2}, \frac{y_1 - y_2}{2}\right)$ rather than $\left(\frac{x_1 + x_2}{2}, \frac{y_1 + y_2}{2}\right)$ was used. Some did not know where to go from here but many did proceed to form the equation of line AP. The gradient of $-t$ was sometimes needlessly calculated - occasionally incorrectly - when it could have been deduced immediately. There were not many diagrams seen in part (b) although as always, students who made a reasonable sketch of the situation tended to find it useful. Only those who formulated a structured, organised approach were able to access the final 2 marks. The elimination of t was achieved in many different ways although those who were working with the line AP in $y = mx + c$ form were more vulnerable to algebraic errors. A small number assumed the given result to determine α and β but often ended up just stating the values for these constants instead of giving the required equation.