Pearson Edexcel

Examiners' Report

Principal Examiner Feedback

Summer 2025

Pearson Edexcel GCE

In A Level Further Mathematics (9FM0)

Paper 02 Core Pure Mathematics 2

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Overview

Question 1 proved to be more challenging than anticipated, however, the majority of learners approached the rest of the paper confidently, with many strong responses seen.

The overall standard of work was good with improved handwriting and clarity in responses than in previous series.

Individual Question reports

Question 1

This should have been a very straightforward opening question for candidates, but a lot of the responses lacked a rigorous structure with many not stating what they had just proved or giving a minimal (but not satisfactory) conclusion. Many learners lost the final mark in each part due to not giving any an acceptable conclusion.

Work was sometimes laid out well, with signposting as to what was being calculated but many learners lost marks with incorrect work and no explicit indication of what was being attempted. There was a tendency to essentially use a circular reasoning that assumed the general results to prove the specific example rather than to simply work out the two sides for each part from the given Cartesian forms and verify the result held.

Part (a) was more leniently marked in terms of the "circular" reasoning and consequently was generally well done. Most learners could find the moduli of *z* and *w* without difficulty to secure the first mark, sometimes being the only mark scored. Proceeding from this point was patchy. Many used their calculators to find $\frac{z}{w}$ before finding its modulus, while a few did show the correct method of multiplying through by the conjugate of the denominator to get it. Others essentially used the result by simply putting moduli around the earlier division of moduli, $\left|\frac{z}{w}\right| = \left|\frac{4}{2}\right| = 2$, with no evidence of finding $\frac{z}{w}$ at all, while a significant proportion of learners opted to use modulus-argument forms (polar or exponential) and essentially used the ratio of moduli to find the new modulus These cases were permitted credit in part (a) for demonstrating the correct overall process but should be made aware of the circular reasoning of their work.

Very few candidates identified that $z = -2w$ as in the alternative approach in the mark scheme, while some had i's present in their moduli, e.g. $|z| = 4\text{i}$

It was similar in part (b) except in that the scheme was less forgiving for the circular reasoning via modulus-argument forms in this part, which even more clearly were simply adding the arguments to find the new argument before concluding it was the sum. Such attempts could score at best just the initial mark for identifying the correct arguments of *z* and *w*.

The first B mark was less secure in this part than in part (a) as well, as some candidates had difficulty finding arg *w*, a common error being to give it as $-\frac{\pi}{3}$. Those who sketched the Argand diagrams were generally much more successful in finding the correct arguments for both *z* and *w*. However, those who evaluated *zw* were usually successful in finding its argument, though some confused the ratio in the tangent when doing so. This resulted in

many learners trying to force the result into giving $\frac{\pi}{3}$ as the sum from incorrect earlier arguments by seemingly randomly trying to add π or $\frac{\pi}{2}$ or multiples thereof to the arguments with no clear certainty that they know what the arguments were.
Learners should include clear conclusions, full details of working with values for the arguments clearly linked to the relevant defined complex number.

Question 2

In contrast to question 1, this was very well answered overall, proving to be an accessible vector model question, which traditionally causes problems. The context was straightforward enough to not obscure what was needed and learners made good progress with many identifying the shortcoming of the model at the end.

Part (a) was mostly very well done, with almost all learners using the correct formula, to attempt the distance. Alternative approaches were rare and the most common errors were slips in copying one vector entry, or arithmetic slips when simplifying. Another common error was with the "$-d$" in the numerator where some responses missed the d completely and others made a sign error on it. There was a small proportion of learners who used a wrong vector in the formula (such as using the $3\mathbf{i}+3\mathbf{j}-\mathbf{k}$ or the $6\mathbf{i}-2\mathbf{j}+\mathbf{k}$ too early in the question), but these were infrequent.

Likewise part (b) was also well done. Most candidates found the direction vector and successfully used one of the points to produce the right-hand side of the equation. However, some neglected that an equation needs a left-hand side as well, i.e. '**r** =', and so lost the accuracy mark. Numerical slips were occasionally made (e.g. one coordinate of the direction incorrect), but these were rare.

Learners were slightly less successful in part (c), though still the majority made good progress. Learners were more likely to use incorrect vectors than in earlier parts, for example using the anchor point of the line rather than the direction vector in the scalar product and so losing all three marks. But many were successful in applying the formula with correct vectors and to produce either the angle or it complement. Many used $\sin\theta$ directly when calculating the required angle, and these responses were almost always correct. Candidates who found $\cos\theta$ first sometimes gave their final answer as 18°, either forgetting to subtract the value from 90° or not realising which angle they were being asked for.

Once again part (d) was successfully answered by the majority of learners, though few realised that they could use the direction vector already found in (a) and embarked on long winded methods before eventually reaching the correct value. Whereas in part (a) most gave an exact value rather than decimal, here a decimal was favoured, probably due to the use of the angled calculated in part (c). But either was acceptable. There were a few arithmetic or calculation slips made, but accuracy overall was good.

Finally, in part (e) there were a few misconceptions, but most did allude to the straight line versus the parabolic flight of a projectile, clearly stating or indicating that it would not be a straight line. A few responses did allude to the arrow penetrating the target which also gave them the mark for a considered answer. However, many just stated 'air resistance' or 'not a particle' or variation on this, and did not think enough about this specific question, which was not acceptable as learners are expected to engage with the model in hand. There were also a number of learners thinking it would travel less than distance found for various reasons given, not appreciating that the whole point of the model was assuming the shortest distance approach had been taken.

Question 3

This question was well attempted with the proof by induction being well constructed by many candidates. The proof by induction of powers of matrices seems to be the most favoured of induction questions historically, and this was no exception. The work on transformation was also carried out well, although there was confusion over which matrix was required in the final part by some learners.

As notes, the induction in part (a) was generally well done – probably better than in past years – with many scoring full marks. If marks were dropped it was usually the final accuracy mark for an incorrect conclusion or less likely the initial B mark, where not enough detail was shown. The procedure of assuming, setting up and carrying out the matrix multiplication and reaching the required form was usually done very well. However, many did steps in aside working rather in in situ, making some responses a bit hard to follow. Slips in arithmetic were uncommon, but there were a few who did not manage to set up a suitable product. A small number of cases of trying to work backwards and use inverse matrices were seen, but these were not generally successful in establishing the induction, though credit for equivalent work carrying out the multiplication was given. Candidates should be aware that they need to show sufficient working in proof steps, with no errors present.

The conclusion was where a marked improvement from previous years was noted, with fewer incorrectly worded responses, where the bold statements were not correctly given. There are still many who make the common mistake of simply asserting both the $n = k$ and $n = k + 1$ cases are true without the "if.. then.." connotation. A few omitted the $n = 1$ case in the conclusion or the "true for all n", but most seemed well versed in giving all of the emboldened points in the scheme in a conclusion.

Part (b) had a bit of a mixed responses, though most were able to give a correct description of the transformation. A common error was giving an incorrect mirror line such as ($y = 0$) or stating "x-axis" instead or giving no line of reflection at all. Occasionally, candidates confused the transformation with a rotation about the origin. There were also a few learners who described the transformation as scaling of factor -1 parallel to the x-axis, which was given credit as a valid alternative description, but is not to be encouraged. This type of transformation will be a rotation or reflection, and so these types should be expected.

There was again good work seen in part (c), which was mostly completely correct among those who attempted it. The only notable error was the incorrect order of matrix multiplication when performing transformations in a relatively small number of cases.

Part (d) was a bit less successfully completed, and indeed there were numerous cases of this part being left out by learners who did not know how to proceed. Those who attempted it seldom set up an incorrect equation for their answer to (c), though a few did set up the multiplication the wrong way round, and some others did not use $\mathbf{C}$ but $\mathbf{A}^n$. After setting up a suitable equation most proceeded to find either 2^n or n, but a few stopped at this point, forgetting to substitute back into the matrix, while others substituted back into the wrong matrix, $\mathbf{C}$ instead of $\mathbf{A}^n$.

Question 4

This proved a useful question for discriminating across grades with good access in part (i) for all grades but a demanding part (ii) that gave the better learners opportunity to show case their ability.

Part (i) was well done overall. The majority gained the first two marks for the links between *a* and *c* and/or *b* and *d*, though there were occasional slips particularly with the used of the modulus. Some forgot to square the 5 to give $a^2 + b^2 = 5$, for example, while others squared the 13, giving $a^2 + b^2 = 169$ but most usually had one correct to gain the method mark. Only a minority had subtraction between the terms or left an i in the equation.

Proceeding from this point there were several different approaches to the problem, but most were able to manipulate their equations to find the required values by some means (the mark scheme shows the most common approaches). The non-standard nature of the simultaneous equations occasionally caused confusion with some unable to correctly solve, either giving incorrect answer or assuming a =2 in order to find the remaining values and so lost the final two marks. A few did not read the question properly and stopped when they found *a*. Perhaps some took *a* as given by a misread of the question. Those who managed to successfully find one correct value legitimately almost always gained full marks, though occasionally errors square rooting 9 occurred. Putting the *b* and *d* values in order was done well.

Part (ii) was more troublesome for learners, especially (b). Most were able to sketch the loci to give two circles for (a) with the majority recognising that there was one on each axis. Relatively few had them on the negative parts of the axes. Drawing them to scale was less well done, though, and hence many failed to realise that the circles did not touch or overlap. Also, many marked the centres and radii rather than marking the *x* and *y* intercepts, so not heeding the directive of the question regarding labelling. An relatively common error was to have 17, rather than 19, for the second intercept on the larger circle. Overlapping circles were quite common, though as long as sufficient labelling was given these could still gain at least one mark, but it did mean the second mark was quite often lost. So, knowing the loci were circles was shown by the majority but scales and positions were not considered by all.

For (ii)(b) learners were much less secure on how to proceed to find the answer, and as such proved to be a good discriminator. Many candidates either did not attempt the question at all or did a lot of unnecessary algebra with the 2 cartesian equations, attempting to find the intersections of the circles (rarely leading to successful solutions).

Not many used the diagram they had drawn to realis that $|z - w|$ was the distance between points on the circles, so that they were looking for closest points. Those who did were able to spot what to do, so those who had incorrect diagrams disadvantaged themselves, particularly those with crossing circles. Many were able to gain the first mark for finding the distance between the centres, albeit that they did not always proceed to show how it related to the problem in subsequent work. Those who assumed the circles touch or cross usually did no work to show it, so could not gain the next marks, though a few did at least find the maximum distance. There were a small number of cases of correct extreme values, but incorrect inequalities used, so most who were able to identify the correct method were able to score full marks.

The alternative method of the line through the centres was far less common to see, but occasionally did lead to successful solution. However, this method was laborious and rarely led to full marks.

Question 5

A deceptively simple looking question with a very efficient solution for those who appreciated the geometry of the situation and could see the third equation was the sum of the first two, this nevertheless produced a plethora of responses and proved difficult to mark.

Most had an idea of what to do and tried to solve the equations simultaneously in some way, but with varying degrees of success. The most successful method used to find p was to form the matrix of the equations and set the determinant equal to 0. A few candidates found the determinant but failed to set it to zero.

Once p was found, it was very much easier to find q and those candidates approaching the question this way had much more success. Most candidates knew that the equations had to be consistent and used this with their p to find q, though a few at this point instead reverted to solving the equations simultaneously, even though they had p. Many others went directly for the method of solving the equations, but many made slips causing problems, and so many managed to get method marks but lost the accuracy.

Alternatively, to using the determinant, many learners were also able to find p and q by tackling the question as a whole, eliminating one variable and using linear dependence to find p and q. Occasionally candidates spotted the most direct method subtracting equation 1 from 3 and comparing coefficients with equation 2, but most took more convoluted roots, with varying degrees of success in eliminating one of p or q from the equations.

Other methods were also used, with some successfully finding one point in common, or the common line, and solving from there. Some used the cross product to deduce the direction vector of the normal and used this in conjunction with the common line or with another normal direction from other equations. Various attempts at using vector or scalar products of various vectors formed from the equations were seen.

Question 6

Learners demonstrated a solid understanding of roots of polynomials with the majority scoring highly on both part (a) and part (b), and this was one of the better answered questions of the paper overall. The clearest solutions were those where learners stated the product, triple pair sum and also the sum and pair sum at the outset, rather than embedding these in their workings.

Part (a) was very well answered. Generally, learners substituted into the correct identity and most achieved full marks here. There were occasional errors for example omitting the 3 from the numerator or a sign error and the product of roots given as $\alpha\beta\gamma\delta = -\frac{6}{2}$, meaning at most one mark could be scored. A few could not combine algebraic fractions correctly e.g. $\frac{3}{\alpha}+\frac{3}{\beta}+\frac{3}{\gamma}+\frac{3}{\delta}=\frac{12}{\alpha+\beta+\gamma+\delta}$. There were very few who attempted to find the transformed quartic and then identify the sum of roots.

In part (b) candidates were usually able to state the relationship between the square of the sum, the sum of squares and the pair sum and were confident in reaching the required result. Those who did not (or wanted to show the derivation for the benefit of the marker) had little trouble in finding the square of the sum of four roots. Those who quoted from memory however sometimes misquoted the identity, e.g giving it as

$$(\alpha+\beta+\gamma+\delta)^2=\alpha^2+\beta^2+\gamma^2+\delta^2+4(\alpha\beta+\alpha\gamma+\alpha\delta+\beta\delta+\gamma\delta).$$

Learners who did not state the values for the sum and pair sum often made sign errors when substituting into the identity (ie $2\left(\frac{A}{2}\right)$ instead of $2\left(-\frac{A}{2}\right)$) and it was often not clear that these were using the correct expressions for the sum and pair sum, thus forfeiting a mark. Most candidates were able to reach a 3 term quadratic and solve using a valid method, including by calculator. A lot of mistakes came from simple calculation errors such as $\left(\frac{-A}{2}\right)^2=\frac{A^2}{2}$ or $-2\times\frac{-A}{2}=2A$, and double sign errors were sometimes made meaning the "correct" final answer was not a guarantee of fully correct work, and markers had to check diligently.

Question 7

Although being overall one of the more challenging questions on the paper, this question did give some access to most candidates, but only the better learners were able to produce fully correct solutions. The structure given meant many were able to access all the last part of the question even if falling down on some of the earlier parts.

Part (a) was well answered, with most learners showing sufficient evidence of their working. Most learners realised that they needed to work out $\frac{\mathrm{d}x}{\mathrm{d}\theta}$ and set it equal to zero, although a small minority mistakenly used $\frac{\mathrm{d}y}{\mathrm{d}\theta}$ and were unable to make much progress in this part. Learners who simplified $x = r\cos\theta = a(1+\sin\theta)\cos\theta$ to $x = a(\cos\theta + 0.5\sin 2\theta)$ before differentiating tended to perform better overall, as this allowed for a more straightforward differentiation process without having to apply the product rule. Those who did not simplify beforehand gave themselves a more difficult differentiation task, followed by a more complex trigonometric equation to solve, but nevertheless were mostly able to do so correctly. Some candidates struggled to use trigonometric identities to simplify expressions or to solve $\frac{\mathrm{d}x}{\mathrm{d}\theta} = 0$ accurately, with occasional sign or algebraic slips when rearranging. Most candidates went on to find $\sin\theta = \frac{1}{2}$ or −1, but some failed to consider the geometrical interpretation and reject the $\sin\theta = -1$ equation, giving a point with $\theta = \frac{3\pi}{2}$. Most candidates were able to proceed to correctly find the value of *r* for their θ values and so identify the coordinates of *A* and *B*, although some did not specify which was which, and some had clearly incompatible coordinates which they did not seem to realise.

Part (b) saw a much wider variety in the quality and form of responses from candidates and was probably the least well answered part of this question. There was no single dominant method, and a range of approaches were adopted – some more coherent than others. A notable shortcoming was the limited use of diagrams: many candidates launched into algebraic or trigonometric manipulation without visualising the problem, which often led to confusion or misinterpretation. A clear diagram would have helped the learners better understand the geometry involved and helped guide them toward a more structured solution. There were some excellent solutions, particularly where diagrams were utilised to help explain their reasoning. A significant number of candidates gave minimal explanations making it more difficult to understand their reasoning. A small minority of candidates failed to attempt this part of the question, often because of an incorrect answer to (a) which was incompatible with the geometry of the diagram and therefore not knowing where to start.

Part (c) was a very familiar question, which was done well overall, and with the value of *a* given many were able to make good progress as this part was not dependent on earlier work (one reason why it was more successfully answered then part (b)). The most efficient solutions were by candidates who took the a^2 term outside of the bracket. The majority used the identity $\sin^2\theta = \frac{1}{2} - \frac{1}{2}\cos 2\theta$ to achieve an integral of the correct form, though errors with the numerical/algebraic processing caused problems for some learners. A common error, for example, was made in squaring r to expand the brackets, but neglecting to square a, while forgetting to double the sin term was also relatively common. The $\frac{1}{2}$ in the formula was seldom omitted, though sometimes applied, while very few neglected to square r at all.

The main difficulty with this part was in choosing which limits to use to apply to the integral, as none were stated in the question since the integration happens around the whole circle, so any range spanning 2π was suitable. But many attempted to use symmetry, leading to some errors where doubling of an integral with wrong limits was used. The most common correct approaches were equally split between

- $2 \times \frac{1}{2}\int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} r^2 \, \mathrm{d}\theta$
- $\frac{1}{2}\int_{0}^{2\pi} r^2 \, \mathrm{d}\theta$
- $\frac{1}{2}\int_{-\pi}^{\pi} r^2 \, \mathrm{d}\theta$

But as common as these was $2 \times \frac{1}{2}\int_{0}^{\pi} r^2 \, \mathrm{d}\theta$, an incorrect doubling as the 0 to π region was not half of the overall shape. Other limits were also seen, though less common, such as $-\frac{\pi}{2}$ to $\frac{3\pi}{2}$ (correct) or e.g. doubling the integral over $\frac{\pi}{6}$ to $\frac{5\pi}{6}$ (incorrect). In some cases, the learners split into two integrals, often repeating the same work twice over before combing to a final answer, but usually these methods did amount to a correct combination of limits used.

For those who selected a correct combination of limits/doubling, applying the limits proved little problem, though evidence was not always shown and had to be taken on trust, particularly where a lower limit leading to 0 was involved, and many correct answers were seen to this part.

Question 8

This question was answered extremely well by the vast majority of candidates, providing a good source of marks late in the paper. Even at the lower grade boundary it would not be uncommon to see good attempts at this question.

Part (a) saw most candidates pick up the first four marks with relative ease, applying the product rule successively to reach the third derivative. Most went on to find the correct value for *k* by continuing to the fourth derivative, though a few did not simplify the second derivative correctly, making subsequent differentiations unnecessarily complicated, a lack of simplification and carelessness leading to making mistakes.

There were numerous cases of fully correct differentiation up to the fourth derivative; however, some failed to conclude with the required result $\frac{\mathrm{d}^4 y}{\mathrm{d}x^4} = -4y$, even though they correctly reached expressions such as $\frac{\mathrm{d}^4 y}{\mathrm{d}x^4} = -4\cos x \sinh x$. The conclusion needed to be explicitly stated to earn full credit.

Errors with signs caused problems for some and a significant minority made errors using the product rule. A small number of candidates attempted to use Leibniz's theorem, but this often proved counterproductive especially when it came to complete part (b).

Unfortunately a notable minority of learners misread the question, either as $\cos x \sin x$ or as $\cosh x \sinh x$, both of which reduced the complexity of the problem if an appropriate identity was apply. However, some credit was permitted for equivalent work for provided the product rule was used to find the derivatives, but reducing to a triviality e.g. by writing $y = \frac{1}{2}\sinh 2x$, resulted in no marks. Learners should be advised to read carefully each question to avoid such errors.

Part (b) was a routine question, but some errors were made due to the number of terms that needed to be evaluated. Not all candidates expanded to the x^5 term, providing only two non-zero terms. Some incorrectly identified that $\frac{\mathrm{d}^4 y}{\mathrm{d}x^4}$ was non-zero, resulting in three non-zero terms without need of the fifth derivative, losing the B mark by default. Many found the fifth derivative from scratch instead of using the printed result, not picking up on the point of part (a). Usually these result in correct results, but an awareness of question structure is advised.

Once the values of the derivatives were found, the Maclaurin series was usually constructed correctly. However, many candidates did not explicitly show the individual derivative values, instead writing the series directly. While correct answers were credited, marks could be forfeited if there were errors and the structure of the method was unclear. Candidates are strongly advised to first compute and clearly state the values of the derivatives at $x = 0$, and only then proceed to substitute them into the Maclaurin series formula. Attempting to combine all steps at once often leads to errors and lack of clarity. It is also important that factorials are included in the working to demonstrate use of the correct formula. A small number of candidates lost the final mark for failing to write the expansion in its simplest form often by failing to evaluate the factorials.

Question 9

This proved a relatively straightforward closing question compared to some final questions, and many were able to score full marks. Giving a fully simplified form for (b) proved to be the main stumbling block, though not selecting the correct root for (c) was also relatively common.

Part (a) was well-answered by most candidates, though not all used the standard formula, but many used implicit differentiation to approach the problem to prove the result. The most common mistake was simply to have a 1 in the numerator rather than 3, which occurred in both methods. When using the formula another error that occurred, albeit infrequently, was to omit the 3 in the square root, giving $\frac{k}{\sqrt{1-x^2}}$, which scored no marks.

Those using implicit or reciprocal differentiation by rearranging the initial question, were generally successful, but again occasionally made slips, losing the 3, or sometime failed find the correct expression for y in terms of x, either leaving in terms of y or giving an incorrect expression. Some gave $\frac{\mathrm{d}y}{\mathrm{d}x} = \frac{3}{\cos(\arcsin 3x)}$ which was reluctantly accepted for the answer, but learners should aim in such questions to eliminate the trigonometric terms.

Again in part (b) there was a mix of responses, with many favouring an approach via implicit differentiation by taking the arccosine of both sides first, rather than just applying the result to (a) in the chain rule. Whichever method was used, again the differentiation itself was usually correct, but the issue arose in the simplification, and losing the minus was seen fairly often. Many using the main scheme could not simplify $\arcsin(\sin 3x)$ to $3x$ so lost the A mark for not reaching simplest form. Although some later simplified it in part (c) during working, they could not recover the mark for part (b) from it. Those using the alternative approach usually got to $\frac{\mathrm{d}y}{\mathrm{d}x} = \sqrt{1-y^2} \times \frac{3}{\sqrt{1-9x^2}}$ but often did not proceed to an answer involving just x. Answers in terms of y or involving trigonometric functions, such as $\frac{\mathrm{d}y}{\mathrm{d}x} = -3\tan(\arcsin 3x)$, were not accepted for the accuracy mark as they were not deemed in simplest form (as not a simplified function in x) but progress could be made in part (c) from such forms.

Success in part (c) often depended on the final form of part (b). Those who had simplified fully to the expected answer usually made good progress in setting up the equation and reaching a value for x^2. These would go on to find values for x but many did not appreciate that a single x coordinate was mentioned in the question, indicating only one of their solutions was valid, and so giving both. Those who did pick up on this cue would often evaluate the derivative at both values to determine which was correct, though some just selecting the positive value (possibly not even remembering the negative possibility) and so lost the accuracy at the end. Only a minority were able to get the single correct answer at the end. It should be noted that a sign error in part (b) would lead to the same equation in part (c) but would not score either accuracy mark.

Those who left the answer to part (b) in an unsimplified form had less success. Though they could set up the equation needed, if they could not see how to simplify, they usually just stopped and did not reach an answer. However, some were able to make the simplification during the working in part (c) and so were still able to achieve the correct result, with the same proviso about selection of the correct root as above.

Routes to the answer via alternative forms for the derivative in part (b) were also seen, for example, the $\frac{\mathrm{d}y}{\mathrm{d}x} = -3\tan\left(\arcsin 3x\right)$ form of the solution in (b) was used by a fair proportion to reach $\sin\left(\arcsin 3x\right) = -\frac{4}{5}$ via right angle triangles, from which the correct value could be deduced. Though uncommon, such approaches, if attempted, were usually successful in reaching the correct answer.