Examiners' Report
Principal Examiner Feedback

Summer 2022

Pearson Edexcel GCE
Further Mathematics (8FM0)
Paper 01 Core Pure Mathematics

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Question 1

This was in general a very accessible question with the majority of candidates achieving 5 or more marks. All candidates managed to at least make an attempt on this question.
In (a) the majority of candidates answered successfully. The common mistake was to give the answer of $k = 24$, instead of $k = -24$. It was disappointing that candidates did not make a quick check if their value worked in the equation. A few just gained 1 mark as they failed to arrive at a matrix that was a multiple of the identity thus not showing that the found value of k worked for all elements.
For part (b) some of the successful candidates evaluated the matrix **AB** and concluded, however many just stated that **AB** was a 2 by 2 matrix and thus not possible to add to a 3 by 3 matrix. The most common misunderstanding for this part was that of the requirements of matrix multiplication with a number of candidates stating that **AB** was not possible to be calculated due to the dimensions.
Part (c) was a very accessible question - most gained full marks. A small number of candidates used simultaneous equations and thus gained no marks since the questions asked for candidates to show how the matrix can be used to solve the equations. Some actually calculated the inverse going through all steps – whilst it is nice to see their ability it was a shame that these candidates had spent a lot of time disproportionate for the number of marks available. The question paper did say 'Hence use your calculator…' candidates are reminded that they can use their calculator to find inverse matrices and matrix algebra when matrices are fully numeric.

Question 2

Both parts (a) and (b) of this question proved to be very accessible to the vast majority of candidates, but the geometrical aspects of (c) caused significant problems for a similar majority who were unable to go on and score any marks at the end of this early question in the paper.
In (a), the majority of candidates were able to correctly find both $|w|$ and $\arg w$, with occasional errors creeping in both. For $|w|$ it was most common to see $2\sqrt{7}$ found from incorrectly squaring $4\sqrt{3}$. For $\arg w$ degrees were relatively rare, with the most common error to not recognise that the w lies in the fourth quadrant. The success rate for those that drew an Argand diagram first was significantly higher, and it had the added benefit that they would score the first mark in (b) immediately as well. Occasionally $\arg w = \frac{11\pi}{6}$ was seen, note the question stated $-\pi < \theta < \pi$, and generally only lost the final mark because $-\frac{\pi}{6}$ had already been seen. Unfortunately, a number of candidates lost the final mark because they did not give their answer in the required form, $r(\cos\theta + i\sin\theta)$,instead dealing with the negative in the argument and just writing down $8\left(\cos\frac{\pi}{6} - i\sin\frac{\pi}{6}\right)$. We were able to ignore subsequence work for those who had already written down the correct answer.
In (b), w was generally in the correct position, although some candidates would be well advised to pay more attention to the relative location of where points should be placed on diagrams. Similarly, the half line was generally well placed on the negative part of the imaginary axis with a positive gradient, but again, more attention needed to be paid as to whether the half line would pass above w or below it.
In (c), the majority of candidates that were successful identified that the line Ow met the half-line at a right angled and proceeded to attempt to use coordinate geometry techniques to solve simultaneous equations and then find the distance between w and this intersection point. The most significant problem encountered with this strategy was inaccurate use of gradients, which arose due to the use of trigonometry to find them. Candidates who had problems here generally

scored M0M1A0, but some did have multiple attempts and eventually found the correct gradients and produced a correct solution. It was far less common to see more direct attempts using the main scheme, with many who tried this failing to identify the correct triangle to use or drawing multiple diagrams to no avail. That said, there were some excellent and concise solutions.

Question 3

This question on matrix transformations proved to discriminate between the least confident and the rest of the cohort quite well. There was a significant proportion of concise solutions scoring full marks to all parts of the questions, while other responses were mixed and there was a significant minority of students scoring less than half marks on this question. It was surprising to see how many candidates tried to work in two dimensions in this question.

In (a), was found correctly in approximately half of the responses, with an array of alternatives seen: $(-8,3,2),(-8,3,-2),(8,3,-2)$ etc.

Typically, parts (b) and (c) were answered well. The provision of the matrix for the rotation enabled the vast majority of candidates to attempt part (b) successfully, although a disappointing number of students gave inexact answers for *R* or made slips with the exact values of $\sin 120^\circ$ or $\cos 120^\circ$. More significant errors were seen, including multiplying *P* by the matrix the wrong way round, or using their position vector for *Q* instead of *P*, which led to no marks being scored in this part. In part (c), generally candidates subtracted the position vector for *P* from their answer to (b), with occasional sign slips, but the most common error was to stop there: not actually finding the distance between the coordinates of their *R* and *P*. Some students with inexact coordinates for *R* were able to recover and give an exact answer for the distance.

Part (d) was inaccessible to some candidates as they had incorrectly used *Q* in place of *P* and as a result their vector $\overrightarrow{PQ}$ was not of the correct form to be able to reach a dot product of 0. For those who had proceeded correctly to this point, this part was fairly straightforward, and they made light work of it. The most common issue was an omission of a conclusion, with some candidates reaching 0 and stopping there, presumably thinking that they had done enough.

Part (e) was more mixed for those that got this far. There was a significant proportion of candidates that made no attempt, having failed to make progress earlier in the question. Again, many candidates produced concise solutions, having recognised the important of the previous step in identifying a right-angle. Others made the connection but did not identify the correct angle to be right-angled and as a result included the wrong side lengths in their calculation for the area.

Question 4

This was an accessible question which saw good variation in marks, from the weakest candidates (who occasionally secured no marks) right up to a pleasing number of candidates who secured full marks.

The absence of the x^2 term (and hence the sum of pair products = 0) caught a large number of students off guard – many spotted this as seen by a huge number of scribbles (often leading to mistakes where they forgot to fully change their solutions), but many others didn't.

In (a), a majority of candidates reached the correct result for the M mark but without the B and A marks due to using an incorrect value for the pair sum (commonly – 7/3). Unfortunately a few did achieve 25/9 but did not explicitly show the full formula or that they were substituting 0 and thus could not gain the relevant marks as this could not be implied. A very small minority attempted to use a nonlinear transformation which fortuitously arrived at the correct answer due to the pair sum equalling zero, however as this was an incorrect method scored 0 marks. Part (a) was also the most frequently 'skipped' part of this question, somewhat surprisingly.

Part (b) was generally well answered, very few chose to use the method of finding the transformed quartic. The majority of candidates reaching a correct result for the M mark

(though a reasonable minority showed poor fraction manipulation, failing to change the numerators) and the most common error was with the sign on either numerator or, more commonly, denominator. However, overall this part was well answered.
Part (c) was also attempted well, the MS being generous in allowing a majority of candidates to achieve 2/3 marks and a pleasing number achieving all 3. Candidates attempting the linear transformation rarely picked up more than the first M mark, mainly due to forgetting to evaluate their e/a for their expanded expression. Students attempting the other route of expansion were more commonly rewarded with 2/3 for an expansion allowing two values to be substituted in.

Question 5

This question had something for everyone and differentiated well between the candidates varying abilities. From the weaker candidates who were at most able to access the familiar part (a), to those who had a reasonable attempt at (c) all the way up to the strongest mathematicians who could fully articulate a correct response to (b) whilst also appreciating the constraints of n and scoring full marks in (c), though this was few and far between.
The proof in part (a) was pleasing, there appears to be a general improvement in the quality of proofs being presented, with more attention to detail, fewer missing brackets etc. The procedures involved in finding the sum of n terms using the natural number series were well known and many scored full marks on this part of the question. The only errors seen were due to careless algebraic slips which often resulted in a loss of the final mark in this part.
In part (b), the demands of this question were beyond many of the cohort and there was a clear lack of recognition of series of this type. As always, with non-routine series such as this, candidates need to list the first few terms of the series and then recognise the type of series involved. The few candidates who did as such often gained the 2 marks available in this part. Other partly successful methods involved the use of 2 (or 3 though the 3rd was often disregarded) linear sequences, though this seldom achieved full marks.
One particular response that deserves merit here was a fully successful attempt at proof by induction.
In part (c), the high demands of the question defeated much of the cohort and the final answer of $n = 49$ was very rarely seen. A few candidates did achieved answer $n = 49$ and $n = 3$ and did not reject $n = 3$. Many of the candidates could partly deal with the summations, both of which did not start at the usual $r = 1$, but the resulting terms and algebra needed to find n defeated the vast majority of the candidates. Moreover, there was clear evidence of candidates who, having been unable to prove the result in part (b), then made no attempt at part (c).

Question 6

This question, which required candidates to work with a model of a tennis ball, proved quite challenging for candidates and tested their ability to apply vector methods to a real-life scenario. There was a great deal of confusion between the position vector of the tennis ball and the direction vector for which it was moving, and less confident students mixed these up frequently.
In part (a), the vast majority of candidates correctly identified the coefficient of **k** in the position vector and solved the quadratic having set it equal to 0. Of these, all of the candidates correctly selected the positive value for λ. There was some inaccurate solving of the quadratic, and, as mentioned above, some candidates used the direction vector instead. Surprisingly, many candidates solved the **i** or **j** component of the position vector set equal to 0, which generally meant they continued to make dimensional errors and scored quite poorly in this question.
Part (b) was generally well answered, with candidates providing a mixture of decimal and fractional forms for $\frac{64}{25}$. For those that found an incorrect value for λ, for whichever reason mentioned above, this mark was still accessible, but many substituted into the position vector, instead of the direction vector.

Marks in part (c) varied between no marks, full marks, and just the second method mark, but of these, full marks was the least common. The vast majority of candidates were able to identify that they needed to use $\cos\theta = \frac{\mathbf{a.b}}{|\mathbf{a}||\mathbf{b}|}$ but the choice of vectors used varied quite dramatically. It was clear that as the equation of the plane was not given explicitly a number of candidates found it impossible to access this question as they had no directional vector for the normal. For those candidates that did attempt to use the scalar product most used their answer to (b), but the second vector was frequently one of $(1,1,0)$ or $(0,1,0)$ or the position vector particle at their λ from (a). These candidates typically evaluated the dot product and distances correctly for their vectors and scored the second method mark only. Of those that used a correct combination of vectors, the most common approach was using $(0,0,1)$, with other methods seen rarely. These candidates typically went on to score full marks, although occasionally incomplete methods were seen: stopping before the acute angle with the plane had been found or 7.49 was given as an answer, without the requested level of accuracy in the question.
Part (d) was similarly mixed for the same reasons as the errors in (b), although some candidates picked up the second method mark for using their new value of λ in the correct vector expression. Some candidates lost the final accuracy mark due to calculation errors or a lack of accuracy in the **i** component.
Clearly, by parts (e) and (f), many candidates had moved on to another question, as responses at this stage became less common. The candidates that had made progress to this stage had a good understanding of the model by this point and generally gave concise and clear responses to both parts. In (e), candidates made the correct decision based on their **k** component, but they should be encouraged to use *both* values in their comparison and to be explicit with their wording.
In (f), some very good answers were seen, but unfortunately there were the common comments about air resistance and gravity, both of which did not relate to the model and as a result scored no marks. Candidates are remined to look back at the question and identify where the modelling accords – tennis ball is modelled as a particle, modelling the top of the net as a straight line.

Question 7

This was, for the most part, a reasonably well-answered question in nature, with very few blank or zero responses for a question so late in the paper. A significant majority of candidates scored the first two marks as usual, for the basis and assumption steps. A pleasing number also understood the correct way to proceed in writing the $(k + 1)$ matrix as the product of their assumed matrix by the case when $n = 1$. However, from here a number of candidates did not proceed to multiply the matrices, thus gaining no more marks. Of those that did, the standard was generally good to reach the first A mark also. However, the final A mark was much more seldom awarded. Some candidates did not put their matrix in terms of $(k + 1)$ or made slips in doing so. More common, however, was confusion over the conclusion required – a number of students wrote the conclusion as a summary of steps and (rightly) scored A0 for this (e.g. "assumed true for $n = k$, shown true for $n = k + 1$, $n = 1$ shown true therefore true for all…). Candidates are reminded that their conclusion needs to imply that **if** true for $n = k$, **then** true for $n = k + 1$

Question 8

This was definitely the most poorly responded to question on the paper, with a lot of responses being left blank or only the odd part attempted. This is likely due to two factors, the difficulty of the question, which showed a clear divide between the stronger mathematicians and those who have struggled to access a deeper understanding, but also the likelihood that a number of students will have ran out of time as is often the case with mathematics.

For those that did attempt the question part (a) was generally answered quite well with the main mistake been $a = 8$.
In (b) a number of students concluded that they've not been taught how to differentiate trig functions meaning that the first two marks were inaccessible, it was disappointing to see they had not appreciated maximum and minimum points of the trigonometric curves. Furthermore a number of students also answered part (b) using a full calculator solution, whilst students abilities to master new technology is encouraged and pleasing to see and whilst the question was not explicit that full calculator use should not be the case students should be encouraged to look at the number of marks awarded to each part of the question and understand the need to show a proportionate amount of working, using their technological abilities to check their solutions.
For those students who did attempt this question, both models achieved some success. For model A B1B0 was commonly awarded and quite frequently full marks for this model. For model B those that did attempt to differentiate, set equal to zero and solve the common misconception was failing to appreciate that the value of x found was not the distance from the base thus losing the third mark they did however attempt to find the y value appreciating the need to multiply by 2 to find the diameter. Other mistakes in this part of the question were poor differentiation skills poor arithmetic skills and poor algebraic manipulation skills which is very surprising and disheartening to see from further mathematicians.
The mark in part (c) wasn't always accessible to the students as many had not achieved all four answers in (b), however candidates still went on to attempt this part. For those that had achieved four comparable answers in (b) the majority of them choose the correct model with a suitable explanation, some however went on to choose the wrong model as they focused on purely the diameter although the difference between the diameters was very marginal.
Part (d) was probably the most familiar part of this question to candidates, they understood the need to use the correct formula and had a good understanding of the limits required. Many achieved the B mark, though a minority failed to recognise the need to attempt y^2 resulting in no marks. For those that had an understanding of the procedures required there were major concerns with the algebraic manipulation to find y^2. Many failed to reach the minimal requirement of a constant and x^6 term thus losing out on the rest of the marks, a very costly mistake that should not be occurring at this level. For those who did manage to reach the expected requirement few were actually correct, however they did then go on to achieve the M marks and this was only penalised in the last mark. Another surprising point to note was very few candidates were showing the substitution of the limits into their integrated expression which then caused examiners to have to check very carefully the workings out, often resulting in M0 due to, likely, an arithmetic slip - it is advised to all candidates undergoing exams to always share intention and make methods clear.
Finally in part (e) a number of candidates confused themselves with the real life situation being portrayed, many comparing their answer in (d) to 1100 or just 100. For those that did interpret the situation correctly nearly all went on to conclude correctly. There are unfortunately still candidates who when making a comparison are not referring to the given and calculated values.

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