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Examiners' Report/ Principal Examiner Feedback

Summer 2013

GCE Further Pure Mathematics FP2 (6668) Paper 01

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Further Pure Mathematics FP2 (6668)

Introduction

This was a paper with some straightforward questions and some more challenging ones and thus every candidate was able to show what they had learnt. It was disappointing to see otherwise good candidates make basic errors when using mathematics learnt in earlier modules, for example when constructing the induction proof in question 4 and trigonometric identities in question 8.

Sometimes the presentation of the work is poor, with equations straddling lines or very small handwriting with lots of scribbled out work. Poor presentation can lead to a candidate miscopying their own work or making other errors and so achieving a lower score. It is good practice to quote formulae such as the series expansion in question 3 before substitution. When an error is made on substitution the examiner needs to be sure that the correct formula is being used before the method mark can be awarded.

If a candidate runs out of space in which to give his/her answer than he/she is advised to use a supplementary sheet – if a centre is reluctant to supply extra paper then it is crucial for the candidate to say whereabouts in the script the extra working is going to be done.

Question 1

The first two marks for the partial fractions were obtained by the vast majority of candidates; it was very rare to see any errors in this part of the question.

The method of differences was again well known and, following on from comments in earlier years about such questions, sufficient working was shown at the start and end of the summation for the cancellation of terms to be convincing. There were some attempts that went beyond the nth term but these were few in number. Where candidates did lose marks was in the linking of the summation of the partial fractions from the first part to the summation that was asked for. Too many candidates just ignored the 3 in the required summation. Of those that saw it, there was a fairly even split between those that used the 3/2 factor before doing the summation and those that got the summation of the original partial fractions and then used the 3/2.

Question 2

The vast majority of candidates got part (a) fully correct with just a few getting $5\sqrt{2}$ through an incorrect application of Pythagoras' theorem. The majority of candidates were able to score at least one mark in part (b) through use of $\tan\theta$ either way up. Having found their θ most realised the argument was $-\frac{\pi}{6}(+2n\pi)$ but several responses kept the answer as positive or gave the answer as $\frac{\pi}{3}$ from the inverse tan of the incorrect quotient.

Most candidates read the modulus of w from the question and correctly divided by $|z|$. A number of candidates changed w from modulus-argument form, divided by z and then correctly expressed $\frac{w}{z}$ as a complex number. Many then completed correctly to score credit in (c) and (d), but even though for some the modulus and argument was clear from their expression, by not explicitly stating the modulus and argument they could not get full credit for their work. Many responses got the method mark in part (d) for subtracting arguments and in the majority of responses the correct answer of $\frac{5\pi}{12}$ was seen.

Question 3

Candidates were clearly well prepared for this type of question. There were very few poor attempts and many cases where full marks were attained. Most candidates, having worked out the values of the derivatives needed, wrote the expansion out straightaway without writing down the formula first. Luckily, most gave enough working for it to be clear that the correct formula was being used so it was rare for the method mark for the use of the correct formula to be lost. The mark lost the most frequently was that for the final answer where the use of $\mathrm{f}(x) = ...$ or (nothing at all) = ...rather than the required $y = ...$ was penalised. Candidates should be careful to check what the question actually asks for in all cases.

Question 4

Part (a) of this question proved to be a discriminating question on the paper, quite possibly being the worst answered. Perhaps candidates had not been prepared to find this topic on an FP2 paper, as not many seemed to have a clear idea of how to proceed, a fair portion of candidates not even getting to the inductive step, with numerous attempts at a direct proof, or arguments which essentially say “it is true because it is true”.

Most candidates were aware of the need to show the statement was true for $n=1$, usually the first thing done. Often this was followed by the $n=2$ (and sometimes $n=3$) case. But this did not access any marks until a correct inductive step was shown. It was after this stage that things went awry, though most candidates did at least show the need for an inductive step. However, it was not always set up correctly, with attempts at $r^k(\cos k\theta + \mathrm{i}\sin k\theta) + r(\cos\theta + \mathrm{i}\sin\theta)$ not uncommon. Over half of candidates did set up the correct inductive step correctly though.

When approaching the inductive step, the intended method of expansion of the brackets was only used by a minority of candidates, and even here the collection of real and imaginary parts was often missing. Use of $\mathrm{i}^2 = -1$ was generally seen.

Most successful responses used the product of moduli and sum of arguments approach and in these cases it was seldom explained and so questionable how much the candidates really understood. There was very little rigour in formal proof shown.
A small minority used the Euler form, $z = r\mathrm{e}^{\mathrm{i}\theta}$ and the laws of indices. Students who tried this method were generally successful and gained at least 4/5 marks. However, many more students went straight from $r^k(\cos k\theta + \mathrm{i}\sin k\theta)r(\cos\theta + \mathrm{i}\sin\theta)$ to $r^{k+1}(\cos(k+1)\theta + \mathrm{i}\sin(k+1)\theta)$ hence failing to access the second method mark.

For candidates attempting the induction step in reverse, expansion using the compound angle formulae was the most common approach, and the expansion was usually correct. However, rearranging successfully to separate out the relevant factors was more problematic. Occasional attempts at assuming true for $n = k$ and trying to show true for $n = k - 1$ were seen, and attempts at dividing, and showing $\frac{z^{k+1}}{z} = z^k$ were fairly common, but all these tended to do was use laws of indices and not the inductive step at all.

Of the candidates who successfully proved the inductive step, only around half went on to gain the final mark for their concluding statements. The two common reasons were either missing the "if $n = k$ true" (and simply stating true for $n = k + 1$) or because they failed to state that it was true for **all** (postive integers) *n*. Stating that it was true for all real values was also seen fairly regularly.

In contrast to part (a), part (b) provided a very accessible two marks with the majority of candidates gaining both. Errors seen included not expressing the final answer as an **exac**t value, taking 1/5th roots instead of raising to the power 5 and, most commonly, failure to correctly evaluate $\cos\frac{15\pi}{4}$ and/or $\sin\frac{15\pi}{4}$ correctly. Some candidates failed to link parts (a) and (b) together, finding w^5 by expansion instead of simply using the formula from part (a).

Question 5

Overall this question was very well answered with the majority of candidates gaining full marks in the first few parts but losing marks in the curve sketching. Straightforward integration in part (a) and differentiation in part (c) gave candidates the opportunity to show their understanding of the methods required.

Part (a) was answered successfully by the majority of candidates. The integrating factor was usually found and used correctly. A few spotted that the initial equation could be reduced to exact form simply by multiplying by *x*. Some failed to multiply both sides by the integrating factor and a few only integrated one side of the resulting equation. Generally the method seems to be well learnt, with most appreciating that the left hand side was $\frac{\mathrm{d}}{\mathrm{d}x}(y \times \mathrm{IF})$). Once the equation had been prepared the resulting integration was fairly trivial and almost all attempts were successful. Very simple substitution in (b) with a follow through mark meant that most candidates gained full marks here as well, providing they wrote their answer in the correct form.

In part (c) the straightforward differentiation of x^{-2} caused problems with a small number of candidates. However, once again there was generally familiarity with the correct approach to the question. A number of candidates could not correctly identify values of *x*, after correctly arriving at $x^4 = 4$. An incorrect value of $y = 5$ was common amongst those candidates who didn't have $y = 4$.

More than half of the candidates made a successful attempt at drawing the graph, although the two branches most commonly resembled quadratic curves. Incorrect attempts varied: quadratic, cubic & quartic curves, graphs resembling $y = \frac{1}{x}$, graphs with only 1 branch and graphs which showed both $x = 0$ and $y = 0$ as asymptotes. The majority of candidates remembered to mark the minimum points on their correct graph and even sometimes on graphs with no minimum shown at those points.

Question 6

Overall this question was very well answered by the vast majority of candidates.
Most candidates used the method outlined in the main mark scheme in Part (a). Factorisation was used well with only a small minority making errors with the $2x^2 + 4x = 0$ quadratic. A small number used the quadratic formula for the other quadratic. Some candidates found the 4 values correctly but then went on to state that they were rejecting one or more of the values found. There was a small number who used the squaring both sides method with most of those continuing successfully.

In part (b) almost all scored the first B1 for the line. Some found algebraically where the quadratic curve would meet the axes and so were able to draw a good quality curve. A minority did not see the link between parts (a) and (b) and so had not got their line and curve meeting at the correct number of points. Quite a few failed to score the 3rd B mark as they did not have the link above or because they simply failed to label the points of intersection demanded.

Almost everyone scored the marks in part (c), even some who had not got their line and curve meeting at the correct number of points in part (b). There was only a very small number of candidates who gave their inequalities as "less than or equal to" but it was important that this was provided for in the scheme.

Question 7

This question was accessible to most candidates and it was clear that almost all had some idea about the methods required to solve second order differential equations.
Part (a), was generally well attempted with most candidates able to apply the product rule accurately to $y = vx$ and if this was done without error the final result was usually easily attained via substitution. Some of the candidates with weaker calculus skills treated v as a constant and they went on to score very few marks.

Candidates who were unable to complete part (a) could, and often did, score full marks in part (b). Almost all candidates attempted to form an auxiliary equation although there were many errors. Some candidates did not notice the absence of $\frac{\mathrm{d}v}{\mathrm{d}t}$ in the differential equation and used $4m^2 + 4m = 0$. Although this was the most common error there were many auxiliary equations seen with errors in the coefficients. Having solved the auxiliary equation correctly a minority of candidates were unable to give the corresponding complementary function. Almost all candidates used the correct particular integral and most completed the substitution accurately to find the correct coefficient. Most candidates used the sum of their complementary function and their particular integral as a solution to the differential equation although some candidates had either y or a blank rather than v on the left hand side of their final answer.

Part (c) was an easy mark for candidates and many who had made previous errors were able to gain this mark. Those candidates who had not found the answer to part (b) in the form $v = \mathrm{f}(x)$ sometimes left this part blank and a few candidates divided by x rather than multiplying.

Question 8

This was unsurprisingly a challenging question for many candidates, although the majority scored well in part (a) and in the early stages of part (c). There was a good number of clear accurate solutions which demonstrated a thorough understanding of this topic but many candidates made what are quite elementary errors for Further Mathematics students. There was much poor use of trigonometric identities, even such basic ones as $\sin 2\theta = 2\sin\theta\cos\theta$ and an inability to determine $\cos\theta$ from $\sin\theta = \frac{\sqrt{2}}{\sqrt{3}}$ or $\tan\theta = \sqrt{2}$ using an appropriate method. A some couldn't get from $\sin\theta = ...$ or $\tan\theta = ...$ to $\cos\theta = ...$ without using the inverse trigonometric functions on their calculators. Relatively few established why the positive root was correct. This difficulty was also evident in part (b) where calculators were often used to give decimal answers. It was prevalent in part (c), where the majority of candidates knew the correct area formula, substituted for *y* correctly and were able to change $\sin^2 2\theta$ into an expression in $\cos 4\theta$. Most however used their calculators to reach the given answer rather than find an exact value of $\sin 4\theta$ using identities after their (mainly successful) integration.

Many candidates used the double angle formula for $\sin 2\theta$ to obtain expressions in $\sin\theta$ or $\cos\theta$ before differentiating. A wide variety of different methods to reach the solution were seen, depending on when the identities were used. A minority of candidates obtained incorrect derivatives of *y*, as a result of incorrect differentiation of $\cos\theta$ and/or $\sin\theta$ and/or $\sin 2\theta$ and/or $\sin^2\theta$ and/or $\cos^3\theta$. Perhaps inevitably there were sign errors in many responses. Integration and differentiation notation is still challenging for a significant number of candidates.

Grade Boundaries

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