Examiners' Report
Principal Examiner Feedback

Summer 2017

Pearson Edexcel GCE
In Further Pure Mathematics FP2 (6668/01)

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Introduction

This was a relatively straightforward paper which held no surprises for well-prepared students.

There were instances of notation errors and omissions such as a shortage of dx at the end of integrals and many missing equals signs. This made it difficult to follow certain solutions. Students were also writing $\sin xy$ when they meant $y \sin x$. Students should remember that examiners mark what is written on the page. Missing brackets or poorly written final answers can result in the loss of the final mark(s), or sometimes more, of a question.

Students should be advised on the value of common factors in their work. Frequently students are seen to multiply out factorised expressions, thus making their calculations more awkward and more difficult to read. Often it caused them to need to solve a quartic or even quintic expression when it could have simply been a quadratic.

Question 1

Part (a) was answered correctly by the vast majority of students. The most common method was to multiply out the brackets, but several students tried a difference of two squares or partial fractions- most were successful here although a significant number did not include all the necessary fractions. Part (b) also proved accessible for the vast majority of students. It was very rare to see a student not score full marks here. A few used a proof by induction solution. Part (c) proved to be the differentiator in this question, with some students trying to subtract the $3n^{\text{th}}$ and the $(n-1)^{\text{th}}$ terms, rather than attempting to find the sum of the first $3n$ and $(n-1)$ terms and subtract. Most students who attempted the subtraction of two sums scored at least 2 marks in this part with either errors in algebra or the sight of two quartics putting them off developing their answer any further.

Question 2

This question was attempted well by most students. There were a variety of approaches, the most common one was shown as Alternative 1 on the mark scheme, where they attempted to multiply both sides by a positive multiplier. The one used most often was $4x^2(x+2)^2(x+2)^2$. Although $(x+2)$ was in both denominators, few realised that there was no need to multiply by $(x+2)^2$ twice and this led to repeated roots that were superfluous. Some expanded the brackets and these then tended to make mistakes as they could not see how to factorise their quartics. Many students lost marks using this method as they did not multiply both sides of the inequality by the same positive multiplier. There were errors due to poor cancellation and often the critical value of 0 was not given, which meant that the last three marks were not available to them as four critical values were required for the last method mark. Students who cancelled the factor of $(x+2)$ from both sides or multiplied by $x(x+2)$ gained very few marks.

Those who used the first method on the mark scheme, collecting the expressions on one side first and attempting a common denominator, were usually very successful in solving the problem. The four critical values were usually stated correctly and the correct values were used appropriately in their final inequalities. Most students using this method considered the different regions and changes of signs to determine their final inequalities.

Some students sketched the graphs but a common mistake here was not noting 0 as a critical value. The question stated that algebra must be used so a method relying solely on using a graphic calculator scored no marks. Students who cross-multiplied but also stated the critical values 0 and -2 were able to gain full marks.

Many students dropped the last accuracy mark by using the wrong inequality sign, effectively not considering the asymptotes at 0 and -2. A few used set notation for their answers and those who did were usually correct.

Question 3

This question proved to be quite polarising with many students scoring full marks and many students scoring half marks. The key to this difference seemed to be in the calculation of the argument of z^3 which caused the loss of three accuracy marks. Among the incorrect responses it was extremely common to see $\frac{\pi}{3}$ for arg z^3. The students who drew an Argand diagram were the most successful ones in this regard and usually went on to score full marks. Other errors seen were in trying to simplify the general expression for *z* after applying De Moivre's theorem and getting the resulting angles wrong. It was rare to see only one or two solutions or more than three. It was also rare to see the modulus calculated incorrectly.

Question 4

This was a generally well answered, accessible question with the majority of students able to achieve the method marks throughout, and certainly in (b) and (c). The main difficulty students had with this question was with part (a) where many students did not use the chain rule to successfully obtain the first derivative and so lost all accuracy marks in the question. Those who were successful in (a) generally went on to score full marks for the question.

Although there were a number of fully correct solutions to part (a), the initial differentiation of the function caused difficulties for some students. Most did manage to access the method for attempting the chain rule, though sign errors were common. For those who did not achieve the method, many did achieve $\pm\frac{1}{(1-2x)}$ simply forgetting to multiply by $\frac{\mathrm{d}}{\mathrm{d}x}(1-2x)$.

Most of the correct attempts arose from first applying the logarithmic index law to achieve the form $y = -\ln(1-2x)$ and thus ease the differentiation. Those attempting to apply the chain rule directly were more susceptible to accuracy errors (in sign and/or multiple) creeping in.

Those who did the first derivative correctly generally succeeded with the second and third derivatives, albeit sometimes in a very laboured attempt. This generally arose from failing to cancel common factors in the first derivative so proceeding from $y' = \frac{2(1-2x)}{(1-2x)^2}$ and using the quotient rule, obtaining increasingly complicated expressions for the later derivatives.

Other incorrect responses to this part, where no method was gained, often involved long, repeated and complicated attempts which in many cases failed to eliminate log terms from their responses and so included log terms as either multiples or denominators of their expressions.

Only very few student attempt the implicit method, and these were usually well done for the first derivative but were seldom successful in the higher order derivatives if students did not return to an expression in *x*.

Part (b) was answered well with the majority of students achieving both the method marks. Cases of an incorrect Maclaurin formula were rare. However, working was often not shown, relying on the evaluation of their values for *y* at $x = 0$ being implied by their expression. Students should be encouraged to show their full working, so that when an incorrect substitution is made the method is still clear; some lost marks here when their values did not imply correct use of $x = 0$. Also, many did not write out the correct formula for the Maclaurin series before substituting, with again the same potential for loss of marks, especially as they were often doing two things at once. Fortunately in this case the values were easy to verify in most cases, and so marks were picked up under implication, but those who showed no working risked losing both marks.

Students who had obtained incorrect derivatives involving log terms in part (a) often found that their coefficient of x^3 was zero. When this occurred, many simply omitted the x^3 term completely, forfeiting the second method mark.

There were a reasonable number of attempts at the alternative method to (b), which were usually successful. This meant that even with a significant loss of marks in part (a) they could achieve full marks in (b), and some of the students who realised they had errors in (a) did opt for this approach.

Some students did not link the series to the function *y* = … or $\ln(1-2x)^{-1}$... but used an undefined f(*x*) = … and so lost the final accuracy mark even when all else was correct.

The first two marks of part (c) were gained by most students regardless of what had gone before, with ±0.401 being seen in many attempts. A few who obtained the negative result attempted to apply the modulus to make it positive, rather than checking back through the work to see why they obtain an unexpected negative result in the first place.

Some attempted a rearrangement of the log term first, usually ln(3) − ln(2), which yielded a different, but valid, approximation with values of $x = \frac{1}{3}$ and $x = \frac{1}{4}$ and giving 0.341. Other forms were possible but seldom seen except ln(3) + ln(1/2), but as this required a value $\left(x = -\frac{1}{2}\right)$ outside the domain of the function it was unacceptable. Again in this part it would be advisable for students to show the substitution explicitly so that the method can be secure even if a processing error is made.

Question 5

This question proved to be a valuable source of marks for most students.

In part (a), the method of using an auxiliary equation was well known and most students produced the correct complementary function. Some did leave e^0 in their answers but this was not penalised although it is good practice to simplify answers fully.

The correct form of the particular integral was well known and students usually could differentiate successfully twice and substitute to find the unknown constants. A minority chose to use the complex exponential form of the particular integral. Students using this approach should be advised to convert their answer into real functions by the time the general solution is written. Some errors in solving simultaneous equations were seen here.

The concept of adding the particular integral and the complementary function was known by nearly all students and very few lost a mark by not using $y =$... in their answer. This is an improvement on recent years.

In part (b), students knew the steps to perform and only errors carrying through from (a) and occasional slips in algebra prevented students achieving the correct values of the required constants. There were few errors in the differentiation needed in this part.

A very small minority of students used the alternative approach to this question beginning by integrating both sides of the original equation with respect to x and then using an integrating factor. Although some good solutions via this method were seen, others got lost during the process of integrating by parts twice with sign errors being prevalent.

Question 6

On the whole a good attempt was made at this question though some students were clearly thinking that parts of the area below the initial line were going to come out negative.

Most students were able to write the formula for finding the area (including the half). Squaring was done correctly and most went on to use a correct identity for $\sin^2 \theta$. Most used the correct identity but some there were some sign errors introduced at this stage and some students made mistakes with the a^2. A few tried to integrate $\sin^2 \theta$ without changing it. The integration was usually done correctly. Errors at this stage included sign errors and incorrect integration of $\cos 2\theta$ but this was a minority.

Problems now occurred when the limits were substituted. A variety of valid approaches were used. Those who chose 2π and 0 were mostly successful. Those who chose other limits generally dealt with them correctly by adding the areas of different regions or doubling where necessary but mistakes were made in some cases. Mistakes with the signs of the trigonometric terms both here and when integrating and arithmetic errors were made.

The area was equated to the given area correctly. It was here that some lost marks for failing to use the half that they had dropped earlier. Some made mistakes when rearranging the equation, again often with a sign. All those who completed this successfully were able to give the correct answer of 5.

Question 7

Almost all the students attempted this question and it was mostly done well. The most common error occurred when integrating the $2\sin x\cos x$ term.

In part (a) the majority divided by $\cos x$ and found the correct integrating factor. Most fully multiplied both sides and integrated. However, some failed to divide the $\cos x$ on the right hand side, thereby not having $\sec^2 x$ available to integrate. Others omitted the 1 entirely. A small number, having found the correct integrating factor, did not multiply one or both of the terms on the right hand side by it. When finding the integrating factor some differentiated $\tan x$ rather than integrating it.

After multiplying by an integrating factor some generated a right hand side term of $\sec x$ which they then integrated to $\ln\left(\sec x + \tan x\right)$. This complicated the solution and many made little further progress. Integrating the right hand side was where most students had problems; $\tan x$ was usually obtained without difficulty but $2\cos x\sin x$ was often not done correctly. The main errors were $2\cos x\sin x$ changed to $2\sin 2x$ or $2\sin x$. Even if the expression was correctly changed to $\sin 2x$ there were a few integration errors, such as $-\frac{1}{2}\cos x$ or $-2\cos 2x$. The majority replaced $2\cos x\sin x$ with $\sin 2x$ in order to integrate, although some did integrate $2\sin x\cos x$ directly to $\sin^2 x$ or $-\cos^2 x$. Occasionally the constant was missing and there were a few mistakes multiplying through by $\cos x$. Some students replaced $\cos 2x$ by $2\cos^2 x - 1$ in the final answer. Others left the final answer as $y\sec x = \ldots$, but then often gained full marks in part (b). A few students took the final term $c\cos x$ and replaced it with a constant k, leading to errors in part (b).

In part (b) students' knowledge of the surd forms of sine and cosine was mainly good and the manipulation of the surds was generally well done. Shortcomings in dealing with fractions meant that some were unable to reach $\frac{35}{8}$ but nearly all kept $\sqrt{3}$ in their answer as required. Where there were errors in part (a) the student often obtained the M marks from correct substitution.

Question 8

The methods in this question were generally well known and consequently the question was answered well, though minor errors were relatively common. The main scheme was the most common method and also the most successful. Recognising the transformation produced a perpendicular bisector (alt 2) was also a popular and successful method in part (a).

The same technique (Pythagoras) is used in both parts, and most errors occurred here, where students were writing for example $w-3\mathrm{i}$ in the form $a+\mathrm{i}b$ after substituting $w=u+\mathrm{i}v$ or did not multiply $u+\mathrm{i}v$ by i when using $\mathrm{i}w-1$. Students should be encouraged to spend an extra minute writing down all details and making sure that the result is correct, thus avoiding dealing with complicated incorrect expressions later on. It was not uncommon to see a difference of squares rather than a sum resulting from Pythagoras and it was clear that some students were unsure exactly how to work out the modulus of a complex number.

Part (a) was the better answered of the two parts. The large majority of students achieved full marks or 4/5. The lost mark was most commonly down to the errors mentioned above. Attempts to realise denominators unnecessarily were very rarely successful in full and resulted in a lot of excess work.

Part (b) definitely proved more demanding than (a) though many achieved close to, if not full marks. Errors mentioned above were common again in this part along with the use of 5 rather than 25 when using Pythagoras. Most realised that completing the square was required for a circle equation. Students who attempted to realise the denominator and collect into $u+\mathrm{i}v$ to then use real^2 + imaginary^2 = 5^2 scored well but due to the extremely complex algebra involved did not get much further than attempting to use Pythagoras. Another method that generally resulted in zero marks was to start with $|z+a+\mathrm{i}b|=r$. Using an inverse method was less rarely seen than in previous years and this is likely due to the fact that the rearranged transformation had already been used in part (a).

Finally many students lost marks due to not listing *a*, *b* and *c* and those who left it in 'complex modulus' form often lost marks by missing the 0 out. Thus when asked for values of *a*, *b* and *c*, it is advisable in questions like this (Question 1(c) is similar) to explicitly write down their values at the end.

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