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Examiners' Report
Principal Examiner Feedback

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In Pure Mathematics P3 (WMA13) Paper 01

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General Comments

This paper proved to be a good test of candidates' ability on the WMA13 content and plenty of opportunity was provided for them to demonstrate what they had learnt. Marks were available to candidates of all abilities

In general presentation was very good. The candidates often showed all the work required using appropriate mathematical notation. There appeared to be less of an over-reliance on calculators and where the warnings in the question were to 'show all stages of your working' and 'not to rely on calculator technology' these were generally followed.

Candidates are advised to use diagrams where provided, to help them answer the question. This was particularly true in question 9(c) where a sketch of the 2 lines involved would show that both gradients were positive.

Question 1

Most candidates scored full marks in part (a), usually with the working $4-\frac{1}{2}(2)=\frac{15}{4}$. The most common error in this part was to find fg(1) instead of gf(1).

In part (b), finding the complete range of f was demanding for many candidates. Recognising that $\mathrm{f}(x) \ldots 0$ was seen frequently but candidates often did not realise that there was an upper limit, or if they did, had a non-strict inequality or sometimes reverted to decimals or had an incorrect value. Candidates who drew a sketch graph were usually more successful in finding both the bounds.

The majority of candidates were able to use a correct method to find the inverse function in part (c), with a few candidates making slips in their rearranging particularly when dealing with negative signs which meant they lost the accuracy mark. A few candidates misunderstood the notation for the inverse function as notation for the derivative and found $\mathrm{f}'(x)$.

In part (d), most candidates opted to solve this by setting $\mathrm{f}(x)=\mathrm{f}^{-1}(x)$ rather than $\mathrm{f}(x)=x$ which may have been simpler. Of those who started correctly, slips when rearranging were quite common although many were able to reach $3x^2 - x = 0$ or equivalent but many candidates divided through by x at this stage, meaning that they lost the $x = 0$ solution.

Question 2

Overall this question was very accessible to candidates with many scoring all 3 marks in part (a). However, part (b) was much more varied with only about 50% of students scoring both marks on part (b)(i) – they either tended to score both marks or zero marks and many students failed to score at all in part (b)(ii)

In part (a), the majority of candidates were able to find the correct value of R and the correct value of α. There were very few who obtained $R = \pm 25$ with most just opting to give the positive value for R. A small number forgot to find the square root and gave $R = 625$.

Some students obtained $\alpha = \tan^{-1}\frac{7}{24} = 0.284$ rather than $\alpha = \tan^{-1}\frac{24}{7} = 1.287$.

Occasionally, having found the correct values, some students wrote $\mathrm{f}(x) = 25\cos(x - 1.287)$ but this was ignored following the correct answers for R "and" α. Most students used radians and not degrees. The final A mark was withheld if the value for α was given in degrees.

In part (b)(i), students usually gained both marks or no marks when attempting to find the minimum value of $\frac{5}{90 - 3\mathrm{f}(2x)}$. If it was written correctly as $\frac{5}{90 - 3\times 25\cos(2x + 1.287)}$ about 50% of students realised that the minimum value was to be obtained by writing $\frac{5}{90 - 3\times(-25)}$ to give $\frac{5}{165} = \frac{1}{33}$. Typical errors were in forgetting to multiply by 25 thus giving $\frac{5}{93}$ or in using the maximum value to give $\frac{5}{90 - 3\times(25)} = \frac{1}{3}$. Some students considered the 3 possibilities of $\cos(2x + 1.287) = -1, 0, 1$ and then went on to select minimum value. Those who had made an error and had an incorrect α were still able to score both marks here.

Students found part (b)(ii) much more challenging with only about 25% of students realising they needed to solve $25\cos(2x + 1.287) = -25$ or $\cos(2x + 1.287) = -1$ and hence

$2x+1.287=\pi$. Those who understood the correct order of operations required to solve this equation occasionally only obtained 1 mark due to writing their answer to part (a) as $25\cos(x-1.287)$. It was also interesting to note that if α was only written to 2sf in part (a) then a rounding error emerged in this part of the question. In addition, some students forgot to replace x with $2x$ which gained no credit. Quite a few candidates set $25\cos(2x+1.287)=-1$ rather than $25\cos(2x+1.287)=-25$ and others wrote $25\cos(2x+1.287)$ as $25\cos 2(x+1.287)$ neither of which gained any credit.

<u>Question 3</u>

The majority of candidates were able to give the correct equation for the line in part (a) in a correct format and could then proceed to the more challenging part (b). Some candidates confidently offered the correct answer without showing any calculations. However, a small number of candidates failed to give the equation using logarithms and gave it as $y=-\frac{4}{7}x-2$ which usually led to unsuccessful attempts at part (b) and therefore no marks scored in this question. Candidates who calculated their gradient unsimplified as $-\frac{2}{3.5}$ and used this in their final answer could score full marks in part (a) but were penalised in part (b). This was unfortunately the case for a few candidates.

Part (b) was more challenging and as a result the spread of marks was far more varied. The most successful attempts were usually seen with candidates starting from the given equation and either equating their p and q correctly without any working or correctly changing it to an equation in logs and comparing it to their equation from part (a). Candidates who started from their equation from part (a) and tried to apply $10^{\text{lhs}}=10^{\text{rhs}}$ did this with varying degrees of success. Those who proceeded carefully step by step could score the first method mark but often struggled to use correct log work to lead to the answer. Many correct answers were seen following incorrect log work, which often lost 2 marks.

Question 4

Both parts of this question were correctly answered by many of the candidates.

In part (a), most factorised the denominator of the first fraction and combined the fractions correctly with the denominator $(x-3)(x+4)$, a few combined the fractions without using the lowest common denominator, giving themselves more algebra to do and not all of these spotted the factors of their cubic expression. The majority showed the final factorising step and reached the printed answer. Common errors were to miss out an x in the numerator of one or other of the fractions when combining and sign errors in the algebra.

In part (b) most candidates were able to correctly use the quotient rule and reached the correct answer. A few rewrote the expression and used the product rule, although not all of these correctly simplified their answer. There were a significant number of candidates who found the inverse of $\mathrm{f}(x)$ instead of the derivative.

Question 5

Despite being a textbook question, this question proved to be quite challenging for many candidates. Part (i) proved to be the most challenging with many candidates not realising that you cannot integrate $\sin^2 3x$ directly and that they needed to use the appropriate trigonometric identity. Those that did know the required method sometimes made sign errors in either the double angle formula or when integrating the $\cos 6x$ term. Others remembered the double angle formula in terms of an angle A and $2A$, forgetting to interpret this as $3x$ and $6x$, which meant they were unable to gain the M mark.

Candidates were much more confident with part (ii). Most were able to integrate to the required form but a few made slips with the coefficient, usually $\frac{2}{5}$ rather than $\frac{1}{5}$. A common approach was to use a trial function and differentiate this to compare with the integrand. It was sometimes unclear what a candidate's answer was with this approach, with the intended answer buried within various attempts to differentiate. A few candidates incorrectly multiplied or divided by x, and some attempted to use integration by parts. Although it was not penalised, it was disappointing not to see $+\ c$ on these indefinite integrals.

Question 6

Part (a)was done well and therefore allowed nearly all students to access the question. Very occasionally, a careless error in solving for A was made but this still allowed marks to be gained throughout the remainder of the question. There were a few spurious answers where 75–21 was not evaluated as 54.

The log work for part (b) was done well and students tended to show sufficient detail. The usual approach was to use $\theta = 25$ with t = 5 to obtain $25 = 21 + 54\mathrm{e}^{-5k}$ and then rearrange to get $\mathrm{e}^{-5k} = \frac{4}{54}$ before showing the correct log work to usually obtain $k = -\frac{1}{5}\ln\frac{4}{54} = 0.521$ or $k = \frac{1}{5}\ln\frac{54}{4} = 0.521$. Occasionally, k was incorrectly rounded but usually the correct simplified exact answer had been shown so full marks were given. Another correct approach was to take ln of both sides which resulted in the following:

$$25 = 21 + 54\mathrm{e}^{-5k} \Rightarrow 4 = 54\mathrm{e}^{-5k} \Rightarrow \ln 4 = \ln 54 - 5k \Rightarrow k = -\frac{1}{5}\ln\frac{4}{54} = 0.521$$

Occasionally $\theta = 50$ was used and this could only gain the 2nd M if the log work was done correctly which lead to a value of 0.124 for k.

In part (c), candidates usually scored 1 mark or 3 marks. They mostly understood that the rate meant that they had to find $\frac{\mathrm{d}\theta}{\mathrm{d}t}$ and most reached an expression of the correct form with the correct answer $\frac{\mathrm{d}\theta}{\mathrm{d}t} = -0.521 \times 54\mathrm{e}^{-0.521T}$ seen in the majority of cases. Very occasionally there was the misconception to add or subtract 1 to the power which scored no marks. Some attempted to substitute values into the original equation without using the derivative at all.

Students who left k in the expression could still score this mark giving $\frac{\mathrm{d}\theta}{\mathrm{d}t} = -54k\mathrm{e}^{-kT}$. For the second method mark it had to be perfectly clear that $\frac{\mathrm{d}\theta}{\mathrm{d}t} = -9$ and not $\frac{\mathrm{d}\theta}{\mathrm{d}t} = 9$. Many arrived at a correct answer of T = 2.19 but through incorrect working by ignoring or crossing out signs to make their equation solvable and these only scored the first method mark. Those who rounded incorrectly in part (a) to obtain k = 0.52 could still access all 3 marks in part (c) as this value of k when used correctly still gave T = 2.19. If left in terms of k, the following was obtained $-54k\mathrm{e}^{-kT} = -9 \Rightarrow -kt = \ln\dfrac{1}{6k}$ and then k substituted to give $T = 2.19$. Those who tried to use the exact value of k in the exponential were often confused with the negative sign and had $\theta = 54\mathrm{e}^{-\frac{1}{5}\ln\frac{2}{27}T}$ rather than $\theta = 54\mathrm{e}^{\frac{1}{5}\ln\frac{2}{27}T}$. Overall this part was not well answered as candidates were missing that a decrease requires a negative value.

Question 7

In part(a), many candidates differentiated and reached the correct expression for the derivative, set their derivative equal to 0 and rearranged to the correct formula. Mistakes in the differentiation included a missing x in the $\sin 3x$ term and difficulties differentiating the e^{-x^2}.
A small number of candidates tried to integrate the expression by parts

Part(b) was answered correctly by the majority of candidates. A few used degrees so could gain the first method mark but on the whole most candidates scored full marks in this part.

Part (c) was found far more challenging with very few candidates gaining any marks. Candidates were generally unable to identify a suitable function. Many just substituted their values into the expression for y. Those who did choose a suitable function, usually used their $\mathrm{f}'(x)$ as their function. Some did not satisfy the demand of the question and used repeated iteration and scored no marks.

Question 8

In part (a), most candidates were able to apply $\tan 3x = \tan(2x + x)$ and then use the addition formula to express $\tan 3x$ in terms of $\tan x$ and $\tan 2x$. They were also then able, using the double angle formula for $\tan 2x$, to express $\tan 3x$ in terms of $\tan x$ only. Some errors did occur when trying to simplify the resulting fraction to reach the given result thus losing the accuracy mark. Candidates who initially wrote $\tan 3x$ as $\dfrac{\sin 3x}{\cos 3x}$ generally made little progress.

In part (b), candidates who recognised that they needed to use the result from part (a) and an identity connecting $\sec^2 3\theta$ and $\tan^2 3\theta$ usually reached the correct three-term quadratic equation in $\tan 3\theta$. Most candidates could then solve their three-term quadratic to find two values for $\tan 3\theta$. Many candidates could then successfully find at least one of the solutions correctly, usually 0.37, but many candidates were unable to correctly identify the three solutions in the given range correctly, often finding additional solutions in the range, or missing one or two of the solutions. Some candidates, who did not use the result from part (a), re-wrote $\sec^2 3\theta$ as $\frac{1}{\cos^2 3\theta}$ and then usually failed to end up with a solvable equation and hence scored no marks in this part.

Question 9

This question presented many hurdles for the candidates as it was clear that many were unfamiliar dealing with an expression of the form $x = \mathrm{g}(y)$.

Part (a) was attempted by the majority but most candidates identified the solution to $3y + \frac{\pi}{4} = 0$ and failed to recognise solutions in the required range.

Part (b) was generally better attempted with the majority of candidates finding $\frac{\mathrm{d}x}{\mathrm{d}y}$ first before attempting to reach the answer in the required form. There were a very small number of candidates who made y the subject and went directly to $\frac{\mathrm{d}y}{\mathrm{d}x}$. These candidates tended to be very successful in this approach. Once candidates reached $\frac{\mathrm{d}x}{\mathrm{d}y}$ they were confident in recognising the need to find the reciprocal and square it. They were less confident in finding the expression in terms of x and there were lots of slips with the algebra here as they tried to navigate the square root, as well as the identity. A small number of candidates used Pythagoras' theorem to deal with this and their expression tended to be simpler and was therefore usually more successful. A few candidates attempted to expand $\cos\left(3y + \frac{\pi}{4}\right)$ using the compound angle formula, but were unsure how to proceed after taking the reciprocal and squaring.

Although candidates understood what they needed to do it part (c) it was not a well attempted as candidates were confused about which gradient to consider. Common errors included failing to recognise that they had $\left(\frac{\mathrm{d}y}{\mathrm{d}x}\right)^2$ from part (b) and therefore reached incorrect gradients. The most common error was to get the normal and tangent mixed up for the two lines and therefore they often had one gradient negative. This implied that candidates were perhaps not considering the diagram when selecting the gradients. These errors were very costly for these candidates.

<u>Question 10</u>

There were many correct solutions in part (a). Errors seen included only writing down the y coordinate for (ii).

Part (b) was successfully started by most candidates with correct boundaries found by a vast majority of candidates. However, many subsequently tried to combine both of their inequalities into one incorrect inequality. This was usually condoned as the correct answer had been seen previously. There was a relatively high proportion of candidates that solved for k rather than for x which scored no marks.

Part (c) was often attempted but very rarely scored any marks. It was a discriminating question at the A/A* boundary with candidates needing to reason with the gradients of the lines involved, rather than produce long algebraic work. Very few candidates deduced that the gradient of the line needed to be smaller than the gradient of the modulus graph to give 2 possible intersection points, leading to the lower boundary for k. A few candidates spotted that the maximum value of k occurred when the line passed through the verted of the modulus graph. These candidates were the most successful and usually scored 2 marks or full marks. The majority of attempts seen, involved finding the intersections using algebra, often leading to two values for x in terms of k, but candidates were then at a loss as to how to proceed further, failing to understand the need to look for boundaries of k, e.g. looking for the values of k that lead to those two points of intersection being only one point, the vertex. A few candidates found one of the intersections of the modulus function with the straight line, equated this with their known x coordinate of the vertex $\frac{10}{k}$ to find boundaries for k.

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