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Principal Examiner Feedback

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Overall

The paper was well answered with access throughout for candidates of all levels and no indication of any timing issues. The level of calculus was generally good, but a number of candidates relied too heavily on calculator technology, despite warnings, failing to show sufficient working to justify the marks in places (question 4(b) the most common cause of this). A need to show clear workings should be stressed in order to avoid unnecessary loss of marks, especially when a question demands working be shown.

Question 1

A good source of marks for most candidates, though some used the wrong calculator mode, resulting in the loss of three accuracy marks. Most candidates demonstrated a good understanding of the required techniques to show a given function has a root on a given interval and how to apply iteration, and this was a suitable opening question for the paper.

Part (a) was generally well answered, with many candidates achieving both marks. The majority correctly substituted $x = 0.1$ and $x = 0.2$, showing the values and proceed to give a valid conclusion that met the required criteria. The mention of continuity in some form (tolerance on the exact wording was given) in the conclusion now exceeds the lack of mention as candidates have adapted to this requirement being needed.

The most common error was the use of degree mode on calculators, which prevented candidates from obtaining the accuracy required for the A1 mark, while some candidates presented truncated decimal values to just one significant figure rather than following standard practice of providing more precise numerical values. In such cases part (c) was often useful in determining whether the correct angle mode had been used, since the values happened to agree to one significant figure.

Part (b) was also well answered, with most candidates successfully reaching the required result. The typical approach involved setting $\mathrm{f}(x) = 0$ and correctly using the identity $\sec x = \dfrac{1}{\cos x}$ to facilitate rearrangement. Very few candidates used an incorrect trigonometric identity for the secant, more common was to omit the necessary inclusion of explicitly setting equal to 0 in their response. A few candidates worked backwards from the given result and were still awarded marks if their reasoning was valid. Some did not attempt this part at all, not seeing where to start it.

Most candidates also performed well in part (c), with the majority achieving all three marks. The most common mistake was the use of degree mode on calculators, which led to incorrect results. Candidates demonstrating the correct method could still gain M1 despite numerical inaccuracies, so the importance of showing working should be stressed. Others with similar incorrect answers were not credited because they did not show their method, making it unclear whether they had used a graphical calculator.

Most candidates who secured the first two marks proceeded to determine α using repeated iteration. A common numerical error was incorrect rounding, with 0.1628 being a frequently seen incorrect answer among those who had their calculator in radians mode.

Question 2

This was a very straightforward question with the majority of candidates scoring at least two out of the three available marks.

In part (a), while most candidates were able to correctly find the initial surface area of the pond covered by the weed by substituting $t = 0$, many did not gain the mark as they did not include the units (m^2) in their answer. Incorrect values we very rarely seen.

For part (b) the vast majority managed to gain at least the first mark by substituting $A = 25$ and arriving at a value for t. The most common approach was to rewrite the equation in the form $t = \dfrac{\log_{10} 25 - 1}{0.03}$ or $t = \dfrac{\log 2.5}{0.03}$ to reach $t = 13.26$ and using this approach candidates were usually successful in securing both marks. However, many used more complicated solutions by first making A the subject and using exponentials, frequently leading to errors being made. These usually manipulated the expression to read $25 = 10^{1+0.03t}$ and then proceeded to simplify to $25 = 10 \times 10^{0.03t}$ to give $2.5 = 10^{0.03t} \Rightarrow \log_{10} 2.5 = 0.03t \Rightarrow 13.26$

A common error was to rewrite $10^{1+0.03t} = 10 + 10^{0.03t}$. Candidates should also beware of premature rounding, which caused some to lose the A mark. Another error seen was confuse the role of A, and to write $\log_{10} A = 25$, leading to $25 = 1 + 0.03t \Rightarrow t = ...$ which failed to score any marks. In this part units were not required in the answer although many gave the answer as 13.26 weeks, which was condoned. Most candidates gave their answer correctly to 2 decimal places.

Question 3

This question saw a bit more of a mixed performance than the first two. It appeared that not a great many candidates *really* understood how to handle an inequality of the sort illustrated in this question.

While virtually all the candidates made some attempt at it, the quality of attempts varied greatly. Most realised that for an increasing function, its derivative had to be > 0, and nearly everyone successfully managed the differentiation, almost always via use of the quotient rule. Those who did not mostly made no progress at all, although a very small number made valid attempts by pure algebra to rationalise the function being increasing by considering what happens for $x_1 < x_2$. Such attempts, being far more algebraically heavy, are best avoided.

For those who did succeed in differentiating (or made valid attempts at such) there were broadly two groups in terms of progression. Approximately half cancelled the (x + 3), often precluding access to both the critical values (CVs). Some rather-concerning cancelling errors were made by a number of candidates, and other minor errors in processing the algebra were not uncommon, but many were still able to find the CV of $\frac{5}{2}$. Many realised that x could not equal 3, otherwise the derivative was undefined, but not all established the second CV from this fact, missing out on the final marks. Those who did identify both values were not always successful in using them correctly to form the range.

The second group were those who attempted to multiply out the numerator to reach a quadratic expression before solving. Though most were able to proceed correctly, otehrs made errors in simplifying, mainly as a result of not bracketing the 2nd term in the derivative; expressions such as $4x^2 + 24x + 36 - 8x^2 + 26x + 6$ were not uncommon. For those who reached

$2x^2 + x - 15$ (or equivalent), most factorised to give $(2x - 5)(x + 3)$ and the correct CVs of $\frac{5}{2}$ and -3. However, there were a significant number of candidates who, whether from correct or incorrect quadratic, simply stated the answer and lost the method mark as the question did not permit the calculator approach. Those who reached the -3 were able to score the B mark, though, but again with mixed success in forming the correct range.

Indeed, there was some confusion over the nature of the inequality signs throughout the question with an inequality introduced early on, realising $\frac{\mathrm{d}y}{\mathrm{d}x} > 0$ was need, but not keeping careful track of the inequality throughout leading with incorrect expression intermingled with recovered ones and so on. The final inequality often did not match the first one and hence many gave the wrong range, and a correct final answers, $-3 < x < \frac{5}{2}$ was not not often seen. The strictness of the inequalities was not required, and some did have equality included at one or both ends.

An important lesion to take from the question is that candidates need to heed warnings about where calculator usage is not acceptable and adjust accordingly. Even where factorisations were seen they often omitted multiples, likely backwards worked from finding the answers first, and though benefit of doubt was awarded in some cases whose who went directly to $(x+3)\left(x-\frac{5}{2}\right)$ were not permitted the mark for a valid non-calculator method.

<u>Question 4</u>

Most students found it easy to access this question and score well on it, with the B mark for showing D =0 being the most awkward for many.

In part (a) almost all candidates achieved the B mark for finding the correct value one of the constants A, B or C (usually A or B), slightly fewer were successful in finding all three, but only a very small minority found none of them. The majority used a method of long division and were mostly successful at scoring the first three marks. Long division errors sometimes led to a linear remainder with $D \neq 0$, losing the final B, and giving the remainder as -13 rather than $-13x$ was not uncommon. A very small number of candidates, who having completed the long division, then wrote the values into the expression incorrectly and lost marks for not linking the numbers correctly.

Those using the identity formed by multiplying through were overall more successful in obtaining the values correctly, with few processing errors made via this route.

There was some confusion about how to show $D = 0$. For many, an error in the long division (such as noted above) precluded any possibility of the mark. There were also a number who restarted the question again and used an expression for $(Ax + B)(x^2 + 4) + Cx + D$ achieving the correct expression but wasting considerable time. Others, who found values for A, B and C through equating coefficients, did not subsequently establish that $D = 0$ as they did not show the substitution of $B = 2$ into $4B + D = 0$ losing this mark as a result.

Part (b) was more variable in terms of its completion. The integration of

$Ax + B$ was done very well, with only a very small minority going wrong at this stage (achieving a cubic term was noted a few times). While a good number of candidates could integrate the entire expression accurately, there were some who obtained expressions like $Cx\ln(x^2 + 4)$ or similar, as well as a few who ignored the result from part (a) and made a very poor attempt at rearranging the fraction. Some candidates did not even have a ln term as part of their solution and so could score no further marks.

Those who did complete the integration to the required form usually went on to complete the substitution and corresponding subtraction correctly. However, there were a number of candidates who failed to achieve the final A mark leaving their final answer in terms of ln4, or such expressions as $36 + \frac{13}{2}\ln\frac{1}{2}$ or $36 + 13\ln\frac{1}{4}$. As the question stated a ln2 term was required this would suggest that some candidates still lack confidence when rearranging logs.

It is also noteworthy that a significant number of candidates ignored the instruction that algebraic integration was required and therefore solutions purely by calculator technology were not acceptable, with several cases seen of the answer being given with no integration at all carried out. It is important that candidates show they can carry out the skills the specification is testing and not rely on a calculator to do the work for them.

Question 5

Though most were able to make progress through this question, marks were often lost in parts (b) and (d), which provided a bit of discrimination in this question.

For part (a) nearly all candidates were able to find the initial temperature correctly by substituting $t = 0$ into the given equation to find $H = 304$. The most common error, which was itself rare, was to state $H = 24$, which indicated a misunderstanding of e^0 and a failure to complete the calculation using a calculator. It was common to omit the correct units (°C), though this was not penalized in this question.

Generally, the standard of the graphs in part (b) was quite poor, with relatively few scoring both marks. Most candidates did draw an exponentially decreasing curve, but were unable limit it to the correct quadrant only, or had an incorrect asymptote. A few scored for a correct asymptote without a correct graph (usually an increasing exponential graph in such cases), though this was not common. However, the M mark was attained in one of the two ways by most.

The accuracy mark was much less successfully achieved, due to either an incorrect shape, or failing to give the equation of the asymptote. The curve had to be asymptotic to H=24 (or y=24) and it was not sufficient to label 24 on the H-axis given that the question clearly said to state the equation of the asymptote. Many candidates incorrectly extended their graph into the second quadrant even though it was given that $t \geq 0$. The quality of the drawing of the curve was variable and a significant number of candidates took little care to ensure a single, smooth curve was drawn without extra inflexions.

Part (c), by contrast, was very well answered with the majority of candidates able to achieve full marks, demonstrating a confident ability to re-arrange an equation involving exponentials and logarithms. Nearly all candidates were able to substitute H as 144, obtain a correct expression of the form $A\ e^{-0.05t} = B$, and then use logs correctly to obtain 16.95 for the value of t. However, a minority of candidates failed to round their answer correctly, leading to the loss of the A1 mark.

Most candidates followed Method 1 from the mark scheme, which proved to be the most effective and widely used approach. However, some attempted a more convoluted method, which often resulted in errors. Additionally, candidates who calculated values at each stage frequently introduced rounding errors by using truncated values instead of the full calculator display answers in subsequent calculations, while a small number of candidates lost the negative sign in the exponent during their rearrangement, leading to a negative answer.

Responses to part (d) were quite mixed, with many unable to proceed beyond differentiating H. The majority of candidates did successfully differentiated the given equation to obtain the required differential in terms of t. While some errors were made during differentiation, these generally still resulted in a valid form of the answer, allowing candidates to be awarded the first M1 mark, though the usual inclusion of extra t's in the derivative did occur in a minority of cases. The differentiation skills were, however, very good in the main.

Among those who continued their method, the most common approach was to express the exponential term in terms of H by rearranging the original formula. Candidates who instead attempted to rearrange to make t the subject were more likely to make errors, particularly in simplifying their expressions after substituting into the differential. Those who successfully reached the later stages demonstrated a strong understanding of the correct approach and processes, often earning both the M1 and A1 marks. The most efficient solutions were those who identified 280 $e^{-0.05t}$ could be replaced directly by $H - 24$, but many took longer winded approaches first rearranging the given equation to find $e^{-0.05t}$ in terms of H before substituting.

A few candidates found $\frac{dH}{dt} = -14e^{-0.05t}$ then set this equal to $a + bH$, substituted for H and solved for a and b. This was a valid method and could score full marks, although again was a longer than necessary approach. The Alternative method on the mark scheme, where candidates made t the subject, differentiated to find $\frac{dt}{dH}$ and then found the reciprocal, was rarely seen and also had mixed fortunes when used.

Amongst all this, there was also much poor notation, and a lack of working was not uncommon. A lack of clear ordering of work, as well as missing mathematical symbols such as equals signs, made some answers difficult to follow. Improved clarity and structure in working would benefit candidates in demonstrating their understanding more effectively.

Question 6

Aside from the domain being omitted in part (a) this was a very successfully answered question by most candidates, who were much more comfortable with this question than the two preceding ones.

In part (a) the majority were able to find the correct expression for the inverse function, typically using the method of making x the subject and then swapping x and y. The main scheme was by far the most common, though a few did divide through by the $x-2$ first. Algebraic slips were rare, while a small number attempted the derivative or reciprocal instead of inverse, clearly not understanding function notation. Also a few candidates left their answer in terms of y or had an incorrect label for the inverse. But all these were in a small minority and the correct answer was usually attained for the rule of the inverse.

However, more candidates than not neglected to state the required domain, which resulted in the loss of the B mark for it. An expectation that f^{-1} refers to the function, which includes the domain, and not just the rule is expected.

Moving on to part (b), again most candidates showed a good understanding of the method, correctly substituting to an unsimplified $\mathrm{ff}(x)$ and proceeded to the use a correct method to find a simplified answer. Through many achieved the correct answer, algebraic slips were much more common here than in part (a), losing the A mark. The common errors that did occur were omitting either 3 or – 2, poor algebraic manipulation and sign slips. Not multiplying the 3 and –2 by $(x-2)$ when multiplying out the fraction did occasionally occur resulting in the second M also being lost.

Part (c) was successfully answered by nearly all candidates who attempted it. Most were able to find the coordinates of the transformed point correctly, with or without workings shown. There were only occasional errors in finding one or the other coordinate where misunderstandings of the transformation occurred.

Question 7

The performance in this question was somewhat mixed, with many candidates not showing confidence with modulus graphs, and many who were able to navigate the first part did not realise there was only one solution to (b) but proceed to solve the both equations with no attempt to identify which branch was valid.

While many correct sketches were seen for both functions in part (a), there were also many inaccuracies, either in shape or location. The majority realised a V-shaped graph was required in both cases, though very occasionally, single straight lines, inverted Vs, W shapes or even curves were drawn. However, a V shape with vertex on the y-axis was quite common to see, as well as ones in (ii) which still had vertex on the x-axis.

Where the correct shape with vertex on the x-axis was drawn in (i), most candidates were able identify the correct coordinates of the vertex, $\left(\frac{a}{3},0\right)$, and the y intercept $(0, a)$ (often these were both just labelled on the axes with values) but a small number of them placed the vertex on the origin or the negative x-axis by mistake.

Whilst the graph of $y = |3x - a| - b$ was also often correctly sketched, there were more errors seen for this function than for part (i). The y coordinate of the vertex was sometimes omitted, and a vertex located somewhere on the x axis was not uncommon. Failure to appreciate $a > b$ often led to an incorrect negative y-axis intercept, albeit labelled $a - b$.

However, even when the sketch in part (i) was incorrect, candidates were still able to pick up marks for the correct y intercept in (i), and for a translation down and again a correct y intercept in (ii) as long as it was on the positive y axis. Translation left or right were also occasionally see, which would result in at best a correct y intercept.

The most common score for part (b) was M1A0. Many candidates attempted to solve both $3x-a-b=5x$ and $-3x+a-b=5x$ (or equivalents) giving both solutions, and so only gained the method as the incorrect answer was not rejected. They did not realise that, with a gradient of 5, $y = 5x$ would never intersect the right-hand branch of the modulus graph with gradient of only 3, meaning only the second equation was required. Only a few who solved both equations went on to reject the incorrect one, with fully correct solutions generally being those who realised there was only one solution from the outset. It was also noteworthy that a few candidates identified both equations but then tried to solve them simultaneously rather than solving for x.

Question 8

This was a good discriminating question with a varied approach to solving both trig equations. Some candidates solving both using very efficient methods and gaining full marks in just a few lines of working whilst other completed several pages and still did not achieve all the marks.

Part (i) was generally a well answered question with most candidates able to gain most marks, and full marks seen often. Missing a second solution was the most common cause for loss of the last A mark, while some went on to find an incorrect second solution in the wrong quadrant. The vast majority of candidates seemed well prepared with the ideas of solving trigonometric equations and the use of reciprocals $\operatorname{cosec}\theta = \frac{1}{\sin\theta}$ and double angle formulae for $\sin 2\theta$ and got at least one correct value for θ, correctly identifying 0.424 or less frequently 1.15 as a solution. Weaker candidates were still often able to score at least the first B mark for knowing the correct identity but would often then fail to correctly take the sin θ across correctly, resulting in further marks as they did not reach a suitable equation. The candidates who reach an expression for sin 2θ usually were able to correctly undo the sine, though some did forget to divide by the 2, losing the last three marks.

The few candidates who used the Alt Method, squaring both sides and using trigonometric identities to lead to a quadratic equation in $\sin^2\theta$ or $\cos^2\theta$ etc, often made it successfully to a value for θ but did not know how to reject any extra answers that resulted (if they did). Common errors for this part were; the use of degrees, rounding too soon, or using incorrect methods to find second value, or not finding the second value.

For part (ii) again a large majority of candidates reached at least one of the answers. Many recognised and used the compound angle identity for $\tan(2x-70)$ and quickly attained at least one solution, with correct process for taking the inverse and proceeding to x. A minority of candidates recognising the compound angle identity used $\tan(2x+70)$ in error but were able to score 2 out of 4 marks. But there were many more who used the more circuitous solutions via finding tan $2x$ or even applying the double angle formula to get equations in tan x first. The latter would often fail to proceed to a solution, giving up before reaching a polynomial in tan x. In these methods, candidates were less successful in arriving at the correct solutions, though of these cross multiplying to form an equation in $\tan 2x$ was the more successful approach. However, poor algebra in the re-arrangement, led to many candidates progressing no further in both alternative approaches.

Answers in radians were uncommon. It is much more common to see degrees used in radians questions rather than vice versa.

<u>Question 9</u>

This proved a good discriminating question towards the end of the paper, but also another question where undue use of a calculator seemed common, with numerous cases of correct coordinates from no, or even an incorrect, derivative was observed. It can only be assumed that these were being obtained from some graphical calculator approach, which was not permissible and so such responses could not score marks. Some cases of going directly to the equation $\ln 4x + 2 = 0$ were also observed, again not acceptable, as it was not clear where this equation had arisen from with no evidence of a derivative.

Part (a) was reasonably accessible, with many stating or obtaining from working a correct x coordinate. Those who did not earn the mark usually knew they needed to solve $f(x) = 0$ but sometimes went wrong after reaching $\ln(4x) = 0$, with $x = 1$ or $x = 4$ being the most common errors. Other incorrect values were also seen.

Part (b) produced a wide range of responses. Candidates who failed to realise that they needed to use the product rule to find $f'(x)$ were unable to earn any marks. Attempts at differentiation using product rule were usually accurate, with errors most likely to arise from differentiating the $\ln(4x)$ term, resulting in an extra factor 4 in the denominator. It was pleasing to see confidence in manipulating indices to obtain the correct derivative in most cases.

Those who succeed in attaining a correct form for the derivative knew they needed to solve $f'(x) = 0$ and most were successful rearranging to $\ln(4x) = \text{constant}$, with poor algebra leading to spurious extra x's accounting for those who did not reach such an equation. However, it was less common for full marks to be earned. Some struggled to simplify or manipulate their $f'(x)$ correctly, or they failed to reach a correct expression for x following $\ln(4x) = -2$. The last mark of the question was particularly discriminating, with candidates finding it difficult to substitute their exact value of x to reach a simplified exact value for y, with many leaving the answers in an unsimplified form. A significant number of candidates resorted to using decimals for the y coordinate instead of keeping exact.

Irrespective of their success on earlier parts of the question, the majority of candidates knew how to start part (c) and earned at least the first method mark by multiplying their y value by −2. However, a large number still struggle with the ideas of domain and range and were unable to determine the correctly range even with the final mark being a follow though.

The most common error was to get the inequality incorrect, usually directed the wrong way, or sometimes a strict inequality rather than a loose one. Others included a lower bounded to the range as well, usually $0 \leqslant g(x) \leqslant -2\times$ their y coordinate. Multiplying their y-coordinate by 2 rather than −2 was also an error observed in numerous candidates. Candidates knew to write the range using g(x) or y, and interval notation was not uncommon to see.

Question 10

Most candidates were able to complete the paper in the time allotted and so were able to make progress in this question, with the first three marks proving very accessible, but the latter part of the question discriminating well among the higher grades.

For part (a) $\frac{dx}{dy}$ was given correctly in the vast majority of responses, although there were occasional errors with the coefficient or the negative sign. The weaker responses generally used a form of the chain rule as though the initial expression was for $\cos^2 2y$ leading to responses that included $k\cos 2y \sin 2y$. Only a few applied the double angle formula first, before using the chain rule on the equation in cos y or sin y. It is also noteworthy that many went on directly to $\frac{dy}{dx}$, clearly having misunderstood part (a) as asking for this, though most had a correct $\frac{dx}{dy}$ initially for which to award the marks.

Part (b) is where candidates struggled most. The majority were able to score either one or two marks, but only a minority achieved the fully correct answer. Candidates showed a good recall of the reciprocal identity $\frac{dy}{dx} = \frac{1}{dx/dy}$ to earn the first mark but attempts to rewrite $\sin 2y$ in terms of x had varying degrees of success. Only seldom was the mark scored for the rewriting of sin $2y$ without an attempt at the reciprocal seen.

In the attempts to get to the derivative in terms of x many candidates found the manipulation difficult and were unable to clearly show how to reach the required result, sometimes making 'leaps of faith' to arrive at a final expression in the necessary form. All the methods shown on the mark scheme were seen used by candidates in their attempt, all with varying degrees of success, though the triangle methods were generally the most successful.

A small proportion ignored the "Hence show that…" and instead rearranged $x = 3\cos 2y$ to $y = ...$ and differentiated with respect to x – this method earned no marks as it did not follow the instruction of the question and used means outside of the specification.

In part (c) the main method on the mark scheme was by far the most common method used by candidates, and the first method mark was earned by most who made an attempt at this part (it was occasionally lost if their work led to $x^2 = p$ where $p < 0$). As required, candidates did invariably give an exact value for a, but some candidates did resort to giving a decimal value for b. Candidates who did not find the correct value of k in (b) were still potentially able to earn both the M marks in this part and often did so. A few candidates who had sign errors, e.g $k = 0.5$ or setting $\frac{dy}{dx} = \frac{1}{4}$ did manage to achieve the correct values but could only score the method marks as the solutions came from incorrect working.

This part was also accessible to candidates who could not answer part (b) correctly (or indeed some who did, but opted to revert to the original derivative), with a significant proportion using the answer in terms of y to find y first. Candidates who used this alternative method setting $-\frac{1}{6\sin 2y} = -\frac{1}{4}$ were usually able to find the exact value for b but struggled to find the exact value for a, instead resorting to decimals, and losing the final two marks, though a few did succeed via this route.

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