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Examiners' Report

Principal Examiner Feedback

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Pearson Edexcel GCE
In Mathematics (9MA0)
Paper 01 Pure Mathematics

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General Comments

This paper provided learners with plenty of opportunities to demonstrate what they had learnt. Responses scored well on the early questions, although Question 1(b) was more demanding than expected. It was between Question 6(c) and Question 8 where the paper particularly ramped up in demand compared to most of the other questions and a greater level of understanding of the underlying topics was required. Time did not appear to be an issue.

There were particular instances where some common errors were made. The following observations should be helpful to learners:

- clear conclusions are needed which match the question being asked e.g. 2(b), 4(b), 10(b)
- understand the difference between the limitation of a model and the limitation on a value 6(c), 11(c)
- show sufficient working on questions or parts which specifically ask for this

Whilst some solutions were a challenge to decipher, there were many impressive responses demonstrating a real flare for the subject, with clear working and precision in solving the problems.

Question 1

This question required learners to apply a transformation to a point in an unknown function and identify the new coordinates. However, many found it more challenging than was likely intended.

In part (a), the majority of responses scored the first mark for their coordinate $(4, -4)$. Where errors were seen, these were usually because the learner had translated in the y-direction or the wrong x-direction.

Part (b) proved to be the most challenging element of the question. A significant number of responses did not recognise that finding the inverse function required reflecting a point in the line $y = x$, where they just needed to swap the coordinates. Instead, many attempted incorrect transformations, such as reflecting in the x- or y-axis, swapping signs, or confusing the inverse with the reciprocal function.

Common incorrect responses included $(-6, 4)$, $(4, -6)$, $\left(6, -\frac{1}{4}\right)$, and $\left(\frac{1}{6}, -\frac{1}{4}\right)$, indicating misunderstanding of the effect of an inverse function on a coordinate. The notation also appeared to cause confusion for some. Overall, very few correct responses were seen, and this part of the question successfully discriminated between stronger and weaker learners.

Part (c) required learners to apply a sequence of transformations to a coordinate. Although full methods were not required, those who sketched diagrams or worked step by step were generally more successful, often gaining credit for identifying the correct x coordinate. A few responses showed initiative by creating their own version of the function to support their working. However, many responses did not have a clear structure, which limited access to full marks.

A common error was not applying the modulus correctly. Many learners evaluated $2\times(-4)-3=-11$ giving the incorrect coordinate $(6, -11)$, rather than applying the modulus: $2\times|-4|-3=5$, giving the correct y coordinate. This suggests that while the structure of the transformation was understood, accuracy in execution was sometimes lacking.

Other frequent incorrect answers included: $(12, 5)$, where the x-value was incorrectly doubled, $(6, 3)$, from adding rather than multiplying and $(9, -4)$, due to changing x instead of y.

Question 2

This question on circles was usually well answered with most learners able to score full marks.

Part (a) was answered well, with most responses able to identify the coordinates of the centre for the first mark and deduce the exact value of the radius. Only a few responses did not score the first mark, mainly due to an incorrect sign or by swapping the x coordinate and y coordinate around. The most common mistakes seen in this part of the question were related to not writing the value of the radius as a fully simplified surd.

In part (b), many different strategies were seen within the responses, all duly listed in the main rubric. The most recurrent approach, usually successfully implemented, saw attempts to find the distance or the distance squared of the origin from the centre of the circle before comparing it with the radius or the radius squared and concluded.

A smaller proportion of learners opted for reaching a quadratic equation, either in x or y, by setting $y = 0$ or $x = 0$ respectively, in the equation of the circle with the aim to find the intersections of the circle with the relevant axis and then check whether the x (or y) coordinates of the origin fell within these values. This approach was successfully implemented only by the most competent learners, who were also able to gain the final mark by reaching a correct conclusion.

Other approaches were usually poorly implemented or outrightly incorrect as they consisted of adding the radius to either the x or y coordinate of the centre and then comparing this with the distance from the coordinate axes.

A good proportion of the responses who were awarded the method mark, did not gain the final mark due to incorrect comparisons, such as $5 \neq 4$ or $25 \neq 24$ or incorrect final statements. The conclusion of "the origin does not lie in the circle" was often left out with some learners just writing "no". It is important to remind learners that reasons and conclusions should always be clear and complete and that it is often useful to use the wording of the question to ensure that the question is answered.

Question 3

This question tested arithmetic sequences, followed by finding the sum for a given number of terms.

Part (a) was usually answered well. There was a variety of ways which could be used to set up a valid equation or equations from the information given. The most common method was equating the common difference between consecutive terms resulting in a single linear equation that was easily solved for k. Some responses used slightly less efficient methods by using the nth term formula which created two linear equations in k and the common difference, d, which they then solved simultaneously. A few responses used the sum formula in addition to an nth term formula which proved quite time consuming and often incurred errors when solving. A minority of responses mistakenly treated the sequence as geometric and gained no marks. Occasionally learners deduced the value of k with little or no working by spotting that the second term must be $4k$ in order that the sequence was arithmetic ($2k$, $4k$, $6k$) and then simply divided 10 by 4.

Part (b) was also well attempted, although more errors were noted here. The responses seen usually found the values for the first term and common difference by substituting their value of k back into the original sequence. A few mistakenly used $d = 5$ as they did not acknowledge that the sequence was decreasing. Some simply used their value of k in place of d in the sum formula which gained no marks at all. The responses that had set up two linear equations in part (a) had often already evaluated d in part (a) when they were solving their simultaneous equations, but it was only when it was seen or used in part (b) that they gained credit. While full marks were often earned in this part, errors in applying a correctly quoted formula sometimes resulted in marks not being gained. For example, $(50 - 1) - 5$ instead of $(50 - 1)(-5)$ commonly resulted in 44 instead of -245 which lost the final mark. A few responses adopted an alternative approach of using $\sum -5n + 20$ and either used their calculators or standard sum formulae from Further Maths to evaluate it. Those who had treated the sequence as geometric in part (a) often continued to do so in part (b) gaining no marks, although a small number of responses did use their surd value of k to correctly find follow through values for the first term and common difference of an arithmetic sequence. A very small minority opted for the primitive method of writing out all 50 terms and adding them together individually. They were sometimes successful, but this was an extremely time-consuming method and would have compromised the time available for other questions on the paper.

Question 4

This question using the algebraic division and considering the properties of quadratic factors was very well understood and answered by the vast majority of learners.

Almost every response recognised that as they had been told that $f(-4)=0$ then $x+4$ was a factor of the cubic. Most responses proceeded by using long division, usually successfully with only a few minor errors. A minority of responses used the inspection method, and these were nearly always correct with the expression $(x+4)Q(x)$ obtained with little working.

Part (b) proved to be a little more challenging with many responses not being clear enough in their explanations. By far the most popular method seen was to use the discriminant of $Q(x)$ to show that $Q(x)$ has no real roots. Almost every response calculated the discriminant as -7 and state that as $-7<0$, then $Q(x)$ had no real roots. A significant minority then did not go on to say that "there was only one (real) root i.e. -4". Learners should be reminded that in this type of question they should be referring to the question asked in their final line of working to ensure full marks are scored. The other possible methods outlined in the mark scheme were seen in a minority of cases; the quadratic formula method was well handled, however some did not complete correctly as above. A small number of learners used completing the square and usually did it correctly with some, again, not concluding correctly as above. There was only a very small number of learners who used calculus.

Question 5

This question was well attempted by the vast majority of learners.

In part (a), most responses scored the mark, although it was sometimes unclear if they were using $\mathrm{d}x$ or δx but this was condoned for this mark. The most common error was the omission of $\mathrm{d}x$, which resulted in the mark not being awarded. Other errors included omission of the limits, using the incorrect limits (usually 0 as the upper or lower limit), incorrectly retaining the limit notation $\lim\limits_{\delta x \to \infty} \int_{1.44}^{2.89} \frac{2}{\sqrt{x}}\,\mathrm{d}x$ or include both $\mathrm{d}x$ and δx to give $\int_{1.44}^{2.89} \frac{2}{\sqrt{x}}\,\delta x\,\mathrm{d}x$.

Part (b) of the question was also usually answered successfully. This question was a show that and included the warning they solutions relying on calculator technology were not acceptable, so it was required that learners showed all steps of their working. Most understood the method and showed appropriate integration followed by correct substitution of limits and correct answer.

There were sometimes errors with the coefficient, the most common being $\frac{1}{2} \times 2\sqrt{x}$ rather than $\frac{2\sqrt{x}}{\frac{1}{2}}$. Other errors when integrating usually occurred with the power (converting $\frac{2}{\sqrt{x}}$ to $2x^{\frac{1}{2}}$ then integrating or differentiating instead of integrating) or the use of $\ln x^{a}$. A small number of responses integrated correctly but then proceeded straight to the final answer without any evidence of substitution of the given limits and so were unable to gain any marks. Those who had the incorrect limits such as using 0 were also unable to score either mark, although transcription errors of 2.89 and 1.44 were condoned for the method mark. There were many cases of poor notation such as retaining the integral symbol after integrating and include $+c$ within the calculation but these were condoned on this occasion.

Question 6

This was the first modelling question on the paper.

In part (a), most learners demonstrated a strong grasp of the initial requirements, successfully forming and solving the correct pair of simultaneous equations to determine the values of A and B. However, a minority of responses overcomplicated their approach by unnecessarily introducing logarithms or misapplying algebraic techniques, leading to errors. Common mistakes included arithmetic slips, particularly with decimal values such as 17.6 or 11.9, and confusion between addition and subtraction within algebraic manipulation.

It was observed that learners relying on calculators tended to achieve more accurate results than those attempting manual algebraic solutions, with the latter occasionally making sign errors or misplacing powers. Some responses applied the power of 1.5 to B instead of t, or incorrectly simplified expressions such as 41.5 and 91.5. The final mark was sometimes not awarded due to omission of the complete model equation as their answer, or by not checking that their solution met the question's requirement for B to be a positive constant. A small number disregarded the model altogether and adopted a linear approach.

In part (b), the majority substituted $t = 0$ correctly into their model to obtain the numerical value of the nest's height, most frequently arriving at 20. However, a significant number did not include the correct unit (metres), resulting in the mark not being awarded. A recurring incorrect answer was 19.7, usually due to improper subtraction or mishandling of exponents. Learners should be reminded to include units in these modelling questions, particular where it does not just ask for the value.

In part (c), many responses identified the conceptual constraint that the height cannot be negative and explained this convincingly in words. However, fewer responses set up and solved an equation to find the critical value of T where the height is zero. Those who attempted to find the value of T were generally successful, though some struggled with the algebra or worked by trial and error to estimate the boundary. Issues included inconsistent use of inequalities when rounding and a tendency to provide descriptive rather than numerical responses.

Question 7

This was the first question on the paper where there was wide discrimination between the marks of responses, and many struggled with knowing how to handle a quartic function.

Part (a) involved using the given information and the figure to find the set of values that satisfied $f'(x) \geqslant 0$ and to represent this in set notation. Most identified the critical values that formed the boundaries of the regions where $f'(x) \geqslant 0$. In general, these critical values were used within a relevant inequality although these were often strict rather than inclusive. Some learners incorrectly interpreted the function giving incorrect inequalities or just considering the region between the two local maxima.

Presenting the regions in set notation was done to varying degrees of success. Although a large proportion were able to present their solution in an acceptable form including the brackets $\{\ \}$ and the union, $\cup$, there were many errors seen including intersection signs, no link between the regions, interval notation and strict inequalities. The majority used x as the variable within the inequalities but $f(x)$, $f'(x)$ and k were all seen. Of those using a correct form of set notation, very few mentioned x was a real number although this was not specifically required on this occasion. It was clear that a significant proportion of learners did not appreciate what was required for set notation.

Part (b) required using the given information and the figure to find the equation of the quartic. Many started with an appropriate form of a quartic however there were a few learners who considered quadratic or cubic functions.

Finding the equation of the quartic curve could be done very efficiently or with a lot of algebra. The most efficient method was to consider the factorised form based on the repeated roots of curve. Those who recognised this form were the most successful. The coordinates of the y-intercept could then be used to establish the equation of the curve. This stage was generally correctly done to obtain a negative quartic, however sign errors did lead to some positive quartics being generated. A common error was to assume that there was an additive constant translating the curve rather than a multiplicative scaling constant.

Those who took other approaches had a lot more to do to ascertain the coefficients of the terms within the quartic. With these methods algebraic mistakes were often seen. Common methods involved considering the general form of a quartic with the x-intercepts and the x coordinates of the stationary points, or recognising the factors from the single roots of the quartic combined with an unknown quadratic factor or considering the cubic form of the derivative and integrating or combining with the general form of the quartic. Many learners were able to arrive at some of the equations linking the coefficients with appropriate substitution of values, however, not all response found all the equations and accurately proceed to a correct equation for the curve. It was common to see algebraic errors in the formation and solution of the equations.

A common mistake with all of the methods was to present an expression rather than an equation of the curve. There was a wide variety of responses to this question, with some not attempting it and others having multiple attempts to find the equation of the curve generating solutions which was at times difficult to follow.

Part (c) involved assuming that the quartic intersects the x-axis at exactly four places with the aim to find the range of possible translation factors of the curve. Many responses found the y coordinate of the local minimum. Those who found a quartic in part (b) were often successful at this. Common errors were not appropriately using the y coordinate to describe the translation factor or not considering the minimum value. Those with positive quartic functions could not score the final mark as the figure provided already showed that this was not the case.

Question 8

This question tested proof by exhaustion which many learners found challenging. Part (a) was usually more successfully answered, although many were able to make progress in part (b).

Part (a) was mostly answered well with many managing to spot the error and correct it. Most learners were able to see and correct the error in the expansion with some correcting not just the error but the work afterwards, showing that the expansion was equivalent to $5n-1$. Occasionally a response would highlight the mistake but not correct it, thus gaining no credit. Some assumed that there were other or further errors, often thinking that the factorisation was incorrect. For example, suggesting that $25k^2+10k+4$ should be factorised as $5(5k^2+2k)+4$.

In part (b), many responses never considered the remaining cases despite the partially provided proof. Several responses just reiterated what was already in the questions using $m=5k$, $m=5k+1$ and $m=5k+2$ again (but with the correction). Some assumed the work was pretty much complete and just wrote a concluding statement. A few responses looked at odd and even numbers and considered $2k$ and $2k+1$, or even $10k$ and $10k+1$.
Many learners did not pay adequate attention to the mark allocation in part (b) with 4 marks indicating a much larger quantity of work required, and they simply copied the proof shown in the question but with the correction made from part (a). The majority of those who realised that the question was asking for something beyond correcting an error, managed to complete the question successfully, using either $5k+3$ and $5k+4$ or $5k-1$ and $5k-2$. A few chose $m=-5k-1$ and $m=-5k-2$.

Learners who chose correct cases would usually then successfully manage to give a general conclusion. Occasionally, the consideration of a case such as $5k+5$ or $5k-3$ was seen but gained no credit owing to the fact that it was a repetition of one of the cases printed in the question. Lack of accuracy with the k^2 and k terms resulted in accuracy marks not being awarded in this question with errors such as '$(5k-1)^2=25k^2-20k+1$'

In some cases, responses gave fully accurate working for two correct cases but did not gain the final mark owing to the lack of any kind of conclusion or acknowledgement that their proof was complete.

Question 9

This question was generally well-answered, with most learners demonstrating a good grasp of the concepts. However, some common pitfalls were noted, particularly in differentiation and the inclusion of units.

Part (a) required the learners to set the given model equal to zero and solve. Many made good progress in this part, by setting $v = 0$, mostly dividing by t and attempting to rearrange to the form $e^{0.2t} = 15$ or $e^{0.2T} = 15$. The majority reached a correct answer rounded to the required degree of accuracy or left in a simplified exact form. Errors were rare but often stemmed from a fundamental misunderstanding of logarithms or not dividing by t.

Part (b) involved differentiating the given model, setting this equal to zero and rearranging to the given form. This was generally well-answered, however a significant number of learners lost all the marks by not using the product rule. Accuracy marks were typically not awarded due to sign errors as a result of not using brackets correctly. Learners who wrote out the product rule separately before substitution were more likely to avoid such errors. In addition, some learners struggled with algebraic manipulation after differentiation, particularly when taking natural logarithms too early or when simplifying fractions.

Part (c) involved using the given iterative formula and appeared accessible to almost all learners. In part (i), the vast majority gained the two marks in the first part with only occasional rounding inaccuracies such as giving the answer to 3 significant figures instead of 3 decimal places or only calculating the second iteration t_2. In part (ii) many responses did not include units in their final answer or used incorrect units. A large number also spent time writing down a list of subsequent iterations, not realising that for a one-mark question the final answer is sufficient.

Question 10

This question tested learners' knowledge of vectors and proof of the properties of a triangle. It should be noted that in part (b) that, despite it being possible to gain full credit by finding the length of vectors and Pythagoras' Theorem in a few lines, many learners chose to use more involved methods. This often led to them not gaining full marks due to errors in their working.

In part (a), many gained both marks by successfully adding the vectors, correctly identifying and combining the **i**, **j**, and **k** components. Common errors included misreading the vector QR as $6\mathbf{i}+6\mathbf{j}$, or subtracting the two given vectors. It should be noted that subtracting vectors was seen in a significant minority of responses. This was likely due to confusion arising from a misinterpretation of the vectors as position vectors, where $\overrightarrow{PR}=\overrightarrow{OR}-\overrightarrow{OP}$. Learners should be encouraged to sketch a diagram as a guide.

Part (b) was well answered by most learners. Many responses lacked clarity when attempting to prove that the triangle was both isosceles and right-angled. In demonstrating that the triangle is isosceles, some calculated the magnitudes of the sides correctly but did not gain the accuracy mark as they just stated it was isosceles without reference two sides being equal.

It seemed that learners found it harder to prove the triangle was right-angled. Most successful responses used Pythagoras' Theorem to show that the triangle was right-angled and most of these responses gained full marks. When learners used the scalar dot product method, many of them did not show the calculation and therefore did not gain credit, whilst others were not very successful in showing the triangle was right-angled, with some learners incorrectly using it to show a perpendicular gradient of -1 instead of 0.

The least successful responses tended to involve SOHCAHTOA, mainly because this approach was more involved and thus required a fuller explanation, which was not always in evidence. As this was a 'show' question, a conclusion (either overall or separate for each property) and an assumption that the triangle was-right angled was required to score full marks. There were lots of incorrect attempts at the cosine rule, which learners either could not remember correctly, or did not rearrange correctly. A significant minority of responses attempted to show the right-angled property by splitting the triangle in half to create two right angled triangles and then used trigonometry.

Question 11

This was a modelling question relating to the value of a car. Many correct answers were seen in the early parts, although learners often struggled to give a clear explanation in the final part.

In part (a) many responses substituted in $t = 0, V = 20000$ and proceeded correctly to $A = 18500$ to score the first two marks. The majority were able to rearrange the equation appropriately to find k, with accurate logarithmic manipulation following an equation of the required form. Calculation errors were rare and primarily arose from minor slips rather than conceptual misunderstandings. The most common reason for not gaining the final accuracy mark was due to not writing out the full exponential model explicitly after finding A and k. However, a small number retrieved this mark in part (b) by correctly stating the equation at the beginning of their working. There were only a few examples of not using enough significant figures or incorrectly rounding the value of k. Misreads were fairly common on this question (usually 1200 instead of 12000 or 15000 instead of 1500) which often meant that learners were unable to proceed to a value of k as they ended up with an equation with no real solutions.

In part (b), most were able to identify the need for differentiation. The execution of the method was well-attempted, although some struggled to make the necessary links for the final part of the solution. The intention was that the question would be answered in terms of A and k but many used their own model from part (a) which could also score all the marks. Nearly all learners who completed (b) included $\frac{\mathrm{d}V}{\mathrm{d}t}$ in their solution. Some learners tried to use the given answer in their working but to score full marks they needed to conclude that $\frac{\mathrm{d}V}{\mathrm{d}t} = -k(V - 1500)$.

Those who worked in terms of A and k and differentiated to get $-kA\mathrm{e}^{-kt}$ tended to be more successful in completing the proof, as the substitution step was more direct: simply rearranging $V = 1500 + A\mathrm{e}^{-kt}$ to isolate $A\mathrm{e}^{-kt}$ and replacing in the derivative. When they used numerical values, it would typically result in $\frac{\mathrm{d}V}{\mathrm{d}t} = -0.227 \times 18500\mathrm{e}^{-0.227t}$ which was the most successful form, as they continued from here with a logical method to get to the final stage of the proof. A very efficient way to do this was by rewriting $-0.227 \times 18500\mathrm{e}^{-0.227t}$ as $-0.227\left(1500 + 18500\mathrm{e}^{-0.227t} - 1500\right) = -0.227(V - 1500)$, which made their proof very clear and easy to follow. Those using $\frac{\mathrm{d}V}{\mathrm{d}t} = -4191.3\mathrm{e}^{-0.227t}$ or $\frac{\mathrm{d}V}{\mathrm{d}t} = -4199.5\mathrm{e}^{-0.227t}$ were often unable to rearrange it in the desired form or made errors and wrote down the correct answer at the end, without clear steps in their working

There were several alternative methods that were used by a minority of learners. Those who attempted to start with the given answer, separate the variables and then integrate rarely scored more than one mark. A common error was to omit the $+c$, but of those who included the $+c$, they were often unable to rearrange to make V the subject or did not include a conclusion. Some learners rearranged the original equation to a form without the exponential and then used implicit differentiation.

Another alternative method was to rearrange to get $t=-\frac{1}{k}\ln\left(\frac{V-1500}{A}\right)$ then proceed to find $\frac{\mathrm{d}t}{\mathrm{d}V}$ before finding $\frac{\mathrm{d}V}{\mathrm{d}t}=\frac{1}{\frac{\mathrm{d}t}{\mathrm{d}V}}$. Here the most common error was with the coefficient when trying to apply the chain rule to $\ln\left(\frac{V-1500}{A}\right)$. These learners were still usually able to score two marks if there were no other errors.

Learners should note that the question asks for a limitation of the model so if there was ambiguity in their answer, it was assumed that the comment was referring to the model. A large proportion made sensible comments relating to the model's limitation, with the most common correct answers being a reference to the car’s value approaching but never going below £1500, or suggesting the model does not take into account any additional damage to the car, or that, according to the model, the value only decreases whereas it may also increase in value.

Responses that did not score the mark included vague statements or those which misunderstood the mathematics, such as claiming the model suggested the car could have a negative value or saying damage would impact the value without any reference to the model. A number of responses did not gain the mark due to omitting units, e.g. stating “1500” instead of “£1500”.

Question 12

This question tested knowledge of the intersection of lines and curves. The majority of learners found this question accessible, but some learners did not gain marks due to work particularly for part (b) appearing in part (a) and then no reference made that this should also be for part (b). For others it was for just generally not labelling the question parts and not being clear which part it belonged to, if not attempted in order. Learners should be reminded of the importance of clearly labelling and identifying each part of a question.

Generally, part (a) was answered well. Many of the responses, in demonstrating the verification, substituted $x = 6$ into both equations to show that both y values were the same although a significant minority then forgot to write a conclusion or to say that the lines intersect where $x = 6$.

A less popular approach was to cross multiply to achieve a cubic followed by substituting $x = 6$ to show the equation = 0, stating $x = 6$ is a root so they intersect. Similarly, the long division approach was less popular however, learners who used this approach were often successful.

A significant number of responses did not include an appropriate conclusion. In show/verify/prove-type questions, learners should be advised to always finish with a statement which reiterates whatever they were being asked to show/verify/prove – usually, the wording can be lifted directly from the question.

A few learners used their scientific calculators to find the three roots, one of which was

($x = 6$), thereby gaining only the mark for the special case.

In part (b), the majority of responses equated the equations of C and L and then arranged to obtain a cubic equation. Missing or invisible brackets and a lack of working were the common errors seen here but, overall, there was a high level of accuracy shown in this part of the question. Learners should be advised to take extra care on questions such as this to ensure their working 'flows' from one line to the next, with every step shown and no errors in the algebra. Some responses did not gain the marks in (b) because they had expanded the brackets in (a) and did not use it in (b).

In part (c), many responses correctly identified $x - 6$ as a factor and attempted algebraic division or coefficient comparison to find the corresponding quadratic factor.

However, several did not show full working and instead used their calculators to find the remaining roots, thereby not gaining method and accuracy marks since the question specifically required the solution to use algebra. Some assumed that quoting the quadratic formula was sufficient and then proceeded directly to calculator-based solutions without showing the substitution steps. Some preferred to complete the square and were successful, although this approach often led to errors. Most responses recognised that only the negative solution was valid since point Q was in the third quadrant; with only a few incorrectly including both solutions.

A significant number of responses did not recognise that $x-6$ was a factor for part (c) and instead tried to solve the cubic by factorising out an "*x*", or they did not attempt it. A handful went on to find the *y* coordinate, which was not required, and some seemingly did not fully understand the requirement of an "exact" answer, as they gave the *x* coordinate as a rounded decimal.

Question 13

This unstructured question required learners to evaluate a definite integral and it was approached in a wide variety of ways with varying degrees of success. The question included a calculator warning which made it clear that solutions relying on calculator technology were not acceptable.

Integration by substitution and integration by parts were the most common methods by far and seen in roughly equal measure. For the substitution method, most learners chose to use $u = 2x + 1$. A few proceeded no further than rewriting the integral fully in terms of u as they did not recognise that the resulting expression could be split up into two distinct terms which could be integrated directly. Successful attempts using integration by parts required $u = x$ and $\frac{\mathrm{d}v}{\mathrm{d}x} = (2x+1)^{-3}$. Some learners who rely on acronyms and found that the "LATE" method to decide the choice of u and $\frac{\mathrm{d}v}{\mathrm{d}x}$ did not help them in this instance. Many chose to restart the question when they realised that they were not making any progress. Most responses that executed these methods and mistakes in the early stages tended to be made with their coefficients rather than the powers. Less commonly seen was first splitting the integrand into partial fractions or using a less efficient substitution such as $u = (2x+1)^3$ or even a trigonometric substitution. Some responses negated to heed the calculator warning and jumping to the given answer without any evaluation of limits.

Overall, whilst most learners could begin the question by a viable method, sustained accuracy and attention to fine detail were required in order to achieve full marks, many had to restart their solutions or amend earlier work which made it very challenging at times to determine what work was credible, or which solution they wanted to be marked. Due to no errors being allowed for the final mark learners risked not being awarded this mark by not clearly identifying their final attempt.

Question 14

This question was a good differentiator at the later end of the paper. Success with this question was somewhat mixed, with some learners scoring most marks in part (b), whilst part (a) proved to be more challenging as it tested not only their knowledge of trigonometric identities but also their algebraic manipulation skills.

In part (a), most responses attempted the proof by using both compound angle expansions to reach an expression in $\sin x$ and $\cos x$, usually gaining the method mark and in most cases also the first accuracy mark. Once a correct expression was achieved, some stronger responses reached the given result by simplifying the terms. The most common mistakes committed while implementing this approach, were sign errors, especially for the compound angle expansion of $\cos(x+30°)$, incorrect multiplication by $\sqrt{3}$ and bracketing errors, which were not condoned in this 'show' question.

A smaller proportion of responses used the *R*-alpha method with $R\cos(x+30° \pm \alpha)$, which required learners to find both *R* and α correctly to reach $2\cos(x+30°-30°)=2\cos x$ as requested.

Part (b) was generally answered well, most responses used the result in part (a) to set up the equation $2\cos\theta = 3\sin 2\theta$ and then proceeded to reach and equation in $\cos\theta$ and $\sin\theta$ by applying the double angle formula on the right hand side, gaining the first method mark.

From here, almost all responses reached the equation $\sin\theta = \frac{1}{3}$, through either factorising correctly $\left(\text{i.e. } 2\cos\theta(1-3\sin\theta) \text{ or } \cos\theta(2-6\sin\theta)\right)$, or dividing both sides by $\cos\theta$. Those that divided both sides by $\cos\theta$ usually did not find that there was a further solution, $\theta = 90°$.

Those learners who reached $\sin\theta = \frac{1}{3}$ or equivalent, were usually able to gain the dependent method mark by finding at least one of the solutions of the equation in the given range.

Responses that factorised the equation correctly, usually gained full marks by finding all solutions. Learners who used a calculator solely to find the correct angles scored no marks.

Question 15

This question using differentiation to find a minimum was generally answered well. It was usually part (a) which provided most challenge, often resulting in work which was difficult to follow.

In part (a), learners were required to use the given information about the area of the composite shape and show that the perimeter could be expressed in a specific form. The majority of responses formed a correct equation for the area of the shape, although there were some that omitted the rectangular area and others made an error with the sector area. Some responses used a longer approach of considering the sector as a proportion of a whole circle rather than using the more succinct sector area formula. The formula for the perimeter was also correctly stated by the majority, although the sides of the rectangle were sometimes omitted or internal sides were included.

There were a variety of approaches which were successful in eliminating θ from the perimeter. The most common approach was to make θ the subject of the area and then substitute into the perimeter. A few unsuccessful attempts involved making r the subject of the area and substituting into the perimeter.

There were some neat, logical solutions to this problem. However, there were also many very poorly presented solutions. It was common to see work jumping around the page and arrows being used to try to link the parts of the equations. There were responses that made errors in their algebra and when realising that they could not achieve the given form, worked back to track their error. These learners should be praised for checking their work and trying to identify the error, but this does lead to messy and unclear work, so the learners should be encouraged to rewrite the solution should they have time to make sure that they have a clear argument.

Part (b) required the use of algebraic differentiation to find a stationary value. Since the equation of the perimeter was given in the question, this task was accessible to all learners regardless of their success in (a). Differentiation was generally accurately carried out, although there were a few incorrect attempts which confused differentiation with integration and tried to introduce logs. The majority of the learners recognised the need to equate the derivative to zero to find the stationary point. Although most were successful finding a value, errors were made in the rearranging to make r the subject.

In part (c), learners were asked to prove by further differentiation that the value of r found gave the minimum perimeter. Most were able to make some progress and find the correct second derivative. The criteria for a minimum value was less well applied. Some responses did not use a correct inequality whilst others did not correctly evaluate their second derivative at the value of r. Incorrect second derivative notation was also not credited.

Question 16

This proved to be a challenging question demanding good algebraic skills and attention to detail. For a final question on a paper, most made an attempt.

In part (a), many responses did not successfully manage to fully substitute for all elements of the integral. The main issue was the correct substitution for d*x*. Responses commonly successfully substituted *u* in everything except the 'd*u*', with some omitting it. Additionally, many did not achieve marks because they did not successfully substitute and achieve $2\cos u$ in the denominator with others attempting to substitute $\mathrm{d}x = \dfrac{\mathrm{d}u}{2\cos u}$. Many responses were not presented in a logical structure and did not gain marks because they did not bring together the elements of the substitution into a single expression which showed the progress of the substitution, the manipulation and simplification to the required result. This occasionally resulted in just amending to the result because they knew what the required form was but did not know how to get there.

A large proportion did not spot the need to use the identity $\sin^2 x + \cos^2 x = 1$ and often just square rooted all the values in the bracket achieving $(2 - 2\sin x)$. Some learners misapplied identities, using for example $\cos 2x$. Those who did use the identity correctly tended to go on to also gain the accuracy mark, but a few had $\dfrac{1}{4\sin^2 u}$ and ended with $4\operatorname{cosec}^2 u$. Those who did compete the full substitution often did it in stages leaving the substitution for d*x* until the final stage of their proof which was condoned but should not be encouraged.

A good proportion also changed the limits into angles in degrees and so did not gain the mark for changing the limits. The limits were often given as 30 degrees and 60 degrees, costing the final mark.

In part (b), it was notable that those who did not reach a correct answer in part (a) often did not go on to attempt this, even though these marks were available to them. Even though they were told that the integral was a multiple of $\operatorname{cosec}^2 u$ some learners tried unsuccessfully to integrate their very complex answers to (a).

A large number did not appear to know the integral of $\operatorname{cosec}^2 u$ or did not use the formula booklet correctly and some attempted very convoluted methods of integration. Those that did not score at all got muddled in the initial stage, choosing to use ln or some other given integration from the formula book that they had misread or misinterpreted. A significant number got confused between the integral of $\operatorname{cosec}^2 u$ and $\operatorname{cosec} u$, which meant they ended up with expressions involving $\ln(\tan u)$ or $\ln(\operatorname{cosec} u + \cot u)$. However, several responses obtained the correct answer of $-\dfrac{1}{4}\cot u$, although a few omitted the negative sign, and others stated the answer was $\cot\frac{1}{4}u$. There was a proportion who did not include the negative sign and consequently amended the resulting negative in their final answer.

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