ADDITIONAL MATHEMATICS

Paper 4037/12
Non-calculator

Key messages

Candidates should ensure that they understand the question demand after having carefully read the question itself. The understanding of the word 'Hence' is very important as it implies that work previously completed needs to be used. The demand 'Write down' means just that, no extra working is usually needed. A mark allocation will often indicate the approximate number of steps needed for a solution and should be considered as a guide. Unreasonable answers such as unpleasant fractions or non-integer answers where integer answers have been indicated should alert candidates to possible errors which with careful checking could be corrected.

General comments

It was evident that too many candidates have relied on their calculators in the past for even the simplest calculations. Many candidates made arithmetic slips which prevented them from obtaining correct work and hence marks. It was evident that many candidates had prepared well for the examination and were able to obtain the high marks they deserved. However, some candidates had not prepared sufficiently for the examination. It should be noted that more practice on the new syllabus topic of the coordinate geometry of the circle is needed, with attention being paid to the general properties of the circle which is assumed knowledge from IGCSE.

Comments on specific questions

Question 1

(a) Many candidates were able to identify the critical values associated with the given equation, although some candidates erroneously thought that $x = -1$ was a critical value. Correct sketches of the curve were not as common as expected. Too many candidates were unable to position the values 1, $\frac{5}{2}$ and 5 correctly on the positive x-axis. The cubic nature of the curve was often not recognised at all. What was intended as a straightforward starter question was anything but straightforward for too many candidates.

(b) The graph in **part (a)** had been intended to help candidates solve the given inequality, making use of the critical values and nature of the curve to be able to write down the appropriate solutions. Correct solutions were not as common as had been anticipated. It was again evident that some candidates were using the incorrect order of the critical values 1, $\frac{5}{2}$ and 5 in the solution of the inequality. Too many candidates simply gave the answers $x \leqslant 1$, $x \leqslant \frac{5}{2}$ and $x \leqslant 5$.

Question 2

(a) Most candidates were able to make correct use of the factor and remainder theorems to form two equations. Some arithmetic errors occurred in the simplification of these equations, highlighting perhaps too much reliance in the past on calculators to perform simple calculations. Some algebraic errors occurred when solving the equations simultaneously. The question stated that the values of a and b were integers. Candidates should go back and check their work when non-

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integer solutions are obtained. Often there has been a simple slip which could easily be remedied so that fewer marks in later parts of the question need be lost.

(b) Most candidates opted to use algebraic long division to first of all find a quadratic factor of $\mathrm{p}(x)$. This was completed with varying levels of success, with many candidates obtaining the correct quadratic factor of $2x^2+3x+7$. Too many candidates thought that because this quadratic factor could not be factorised that this was a reason for there being no real solutions to the equation $2x^2+3x+7=0$. One of the key phrases in the question demand was 'Show that'. Candidates were expected to make use of the discriminant of the quadratic either directly or by using the quadratic formula to show that the discriminant was less than zero. A correct conclusion was expected in order to obtain the final B mark, which was a follow through mark for those candidates who did not have a correct quadratic factor.

Question 3

(a) Most candidates were able to obtain two marks for the correct equations using the information about the sum of the first two terms and the sum to infinity of the geometric progression. However, poor algebraic skills when solving the simultaneous equations often made progress difficult. Candidates had more success when writing the sum of the first two terns of the geometric progression in the form $a+ar=9,$ rather than $9=\frac{a\left(1-r^2\right)}{1-r}$, as few candidates realised that the latter equation could be simplified to the former. Again, reading the question carefully would have informed some candidates that there was more than one possible common ratio resulting from the equation $r^2=\frac{16}{25}$. It was more straightforward for candidates to solve their equations for the common ratio as in the demand of the question, but some chose to find the first term initially, with varying levels of success, and then subsequently the common ratio.

(b) Provided the correct common ratios had been found, most candidates were able to find at least one of the possible values of the first term.

Question 4

(a) A large number of candidates were unable to 'complete the square' correctly; this is assumed knowledge from IGCSE Mathematics.

(b) The key words in this part of the question are 'Hence' and 'write down'. Candidates were expected to use their completed square form from **part (a)** to write down the coordinates of the stationary point on the curve. No further calculation is necessary. Solutions which made use of calculus were not awarded marks. Credit was given to those candidates who, although they had been unable to complete the square correctly, appreciated the relationship with this form and the coordinates of the stationary point.

(c)(i) Too many candidates saw 'f^{-1}' and immediately thought they had to find the inverse function. Reading the demand of the question is essential to prevent such misunderstandings. The mark allocation should also be a guide. One mark implies that very little work needs to be done. Again, it was intended that candidates make use of their completed square form from **part (a)** and just write down the value of their $-a$. A correct value from calculus was not penalised.

(ii) Completely correct sketches were rare. Too many candidates did not realise that they were sketching a one-to-one function and its inverse, even though the previous parts of the question had been leading up to this. Reading the question carefully might have prevented so many incorrect sketches. Most candidates sketched a quadratic curve in the first three quadrants or the first two quadrants depending on the coordinates of their stationary point. Credit was given for correct intercepts on both the initial quadratic curve, provided it was sketched in the appropriate quadrants and its reflection in the line $y=x$.

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Question 5

(a) Most candidates were able to obtain a mark for use of the power rule for logarithms. The second two marks depended on whether or not candidates were able to write 3 in terms of a base 10 logarithm and then make use of the subtraction rule for logarithms correctly. Many candidates were unable to deal with the 3 correctly.

(b) Most candidates were able to change the base of one of the logarithmic terms and write down the equation $\log_5(x+1) - \frac{1}{\log_5(x+1)} = 0$ or a correct equivalent. Candidates who had the greatest success in solving this type of equation were those who used a substitution for $\log_5(1+x)$ or equivalent. There were many correct solutions from this approach, although some candidates chose to discard the solution $x = -\frac{4}{5}$. A quick check in the original equation would have shown that rejection of this value was unnecessary. Although some candidates who did not use a substitution were successful, most used the power rule for logarithms incorrectly and were unable to make any further correct progress.

Question 6

It was intended that candidates realise that two separate equations could be formed and these could then be solved. Most candidates were able to solve the equation $2x^2 + x - 10 = 5$ using a correct method but some chose to discard the solution $x = -3$ or write it as $x = 3$. Fewer candidates were able to solve the equation $2x^2 + x - 10 = -5$ correctly. Too many thought that, as the resulting simplified quadratic could not be factorised, it had no solutions. It was intended that the quadratic formula be used. In spite of many candidates being able to obtain some marks in this question, there were a number of candidates who appeared to forget all the rules of solving quadratic equations. Candidates who attempted to square each side of the given equation were unable to make any reasonable progress.

Question 7

(a) Most candidates were able to write down the correct gradients, although there was the occasional sign slip or algebraic slip.

(b) It was evident that some candidates had not fully covered the coordinate geometry of the circle section of the syllabus. This is a new topic, but specimen papers and exemplar scripts in the school Support Hub give an idea of the type of questions which may be asked.

It was intended that candidates realise that the line *AB* and the line *BC* were perpendicular to each other, thus meaning that the line *AC* was a diameter of the circle. Finding the midpoint of *AC* and either the distance *AC* and halving it, or the distance between the midpoint of *AC* and either *A* or *C* to give the radius would provide enough information to write down the equation of the circle. Too many candidates did not relate the work they had done in **part (a)**, to the properties of the circle being considered. The word 'Hence' being used in **part (b)** should have acted as a guide here. Too many candidates started finding the equations of perpendicular bisectors and trying to find subsequent points of intersection, very often giving up or making both algebraic and calculation errors. Candidates should also consider the mark allocation of 4 marks which implies 4 to 5 steps/statements. In this case, midpoint, calculation of the radius and then the resulting equation itself.

Question 8

This was a question to test the candidates' knowledge of logarithmic curves and asymptotes. Few completely correct solutions were seen. It was essential that a correctly shaped and placed curve be drawn initially. Recognition of asymptotic behaviour was also essential. It was again evident that candidates were not fully appreciating the demands of the question as intercepts with the axes were often omitted, although many did give or imply the correct equation of the asymptote.

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Question 9

(a) This was an unstructured question designed to test the problem-solving skills of a candidate as well as knowledge of calculus. There were varying degrees of success with some candidates obtaining full marks and other making little or no attempt at a solution. It was essential the integration of $(2x+5)^{-\frac{3}{2}}$ be attempted. Unfortunately, some candidates chose to differentiate and were unable to make any meaningful progress. There were some arithmetic slips with the coefficient of $(2x+5)^{-\frac{1}{2}}$ and too many omissions of the arbitrary constant of integration. Omission of the arbitrary constant meant that candidates were only able to obtain a method mark for integrating a second time to obtain the form $p(2x+5)^{\frac{1}{2}}$. Candidates who had included arbitrary constants in their solution and attempted to find them and use them correctly were able to obtain at least the method marks and some A marks depending on the accuracy of their calculations, not having a calculator to help them. It should be noted that in questions like this, on a non-calculator paper, unknowns to be found are unlikely to be calculated from complex working and are also unlikely to be complex fractions, so a check of previous working should be made if figures are appearing to be unnecessarily difficult. Some candidates chose to find the value of x at the stationary point before finding the equation of the curve itself. It was essential that candidates have a clear plan of action as some candidates muddled the equations they were using towards the end of their solution.

(b) Most candidates with a correctly obtained x-coordinate for the stationary point, made use of the given second derivative, as was intended, to determine the nature of the stationary point.

Question 10

This was found a very challenging question and there were many poor responses. It was essential that the integrand be expanded out and simplified before any attempt at integration be made. If this was not done, then there were no available marks. Some candidates did attempt expansion of the integrand but often did not simplify sufficiently. Many reached a result of $2\sin^2\theta + 3\cos^2\theta$ and made incorrect attempts to integrate, rather than make use of the trigonometric identity and simplify further. Those candidates that did successfully simplify and obtain 2 usually proceeded to integrate and apply the limits correctly to obtain the final answer of 2π. It should be noted that many of the candidates who reached the stage of integrating 2, often used x rather than θ, but this was condoned on this occasion.

Question 11

This question tested the algebraic skill of candidates when dealing with factorials. It was a demanding question to stretch and challenge the more able candidates. Only a few candidates were able to obtain full marks. Many candidates were able to simplify the numerical factorials and obtain 42 or equivalent, but fewer were able to deal competently with the factorials involving n to obtain $n+2$ and go on to obtain 40.

Question 12

(a) Most candidates were able to gain marks for attempting to differentiate a quotient or a correct product. Most errors arose with the derivative of $e^{(x^2)}$. There were also quite a few candidates who, having obtained a correct expression for $\frac{dy}{dx}$, in terms of x, were unable to evaluate $\frac{dy}{dx}$ correctly when $x = 0$. This has shown, perhaps, an over reliance on calculators for basic calculations.

(b) Most candidates used their value obtained in **part (a)** in a correct method to find the corresponding rate of change of x.

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Question 13

There were a variety of approaches that led to successful results for candidates. The most common method was to obtain correct expressions for $\sin\theta$ in terms of *x* and substitute this into $y = 3\dfrac{\cos^2\theta}{\sin^2\theta}$. Unfortunately, for many candidates, they did not realise that they had to express $\cos^2\theta$ as $1-\sin^2\theta$ and make a further substitution. Of those candidates that did, some did not simplify their answer sufficiently to obtain the final A mark. Simplification in this question meant ensuring that there were no fractions within fractions in the final answer.

Another common method which was very successful for candidates that did attempt it, was to use $y = 3\left(\text{cosec}^2\theta - 1\right)$ and subsequently substitute in for $\text{cosec}\theta$, which led to a correct form of the answer in a couple of steps.

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ADDITIONAL MATHEMATICS

Paper 4037/13
Non-calculator

Key messages

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General comments

Overall, candidates demonstrated sound preparation across the paper, with many able to access the early marks in each question. Stronger responses were characterised by clear presentation, careful checking of critical values, and confident use of standard techniques such as factorisation, substitution, and application of identities. Weaker candidates frequently lost marks through algebraic slips, incomplete reasoning, or an inability to link their working to the demands of the question, particularly in areas involving inequalities, logarithms, and trigonometric manipulation. Centres are encouraged to continue emphasising the importance of showing complete methods, practising the handling of alternative forms, and reinforcing the connections between different topics. Some candidates displayed a poor understanding of logarithms.

The questions that presented least difficulty were **Questions 2**, **3**, **4(a)**, **10(a)** and **11**. Those that proved to be the most challenging were **Questions 3**, **8**, **9(b)** and **12(b)**.

Comments on specific questions

Question 1

(a) Many candidates produced correct answers. However, after factorising the quadratic and identifying -2 and 3 as the solutions, the range was too often incorrectly assumed to lie only between these two critical values. A simple check of one value outside the critical points would have guided candidates towards the correct solution. A small number of responses used the symbols < or > without including the equality, thereby omitting the possibility of $\leqslant$ or $\geqslant$ in their final answers.

(b) Candidates who began by squaring both sides of the inequality were generally successful, as this approach produced a quadratic that could be solved to find the critical values, after which a simple check quickly confirmed that the solution lay between them. Those who attempted to deal with the inequalities separately often identified the critical value at 3 but frequently misunderstood how to handle the modulus, commonly writing $3x - 4 < -x - 2$, which, although it produced $x = \frac{1}{2}$, led to the wrong direction of the inequality. It was also not unusual for candidates to find the correct inequalities but not to present them as a combined solution, for example writing $\frac{1}{2} < x < 3$ as two separate statements.

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Question 2

In general, this question was very well attempted, with nearly all candidates gaining at least one mark. Some marks were awarded where incorrect simplification occurred, but the method was still evident. The required differentiation could often be clearly seen even when the product rule was not explicitly applied. The most common error was writing $\frac{dy}{dx} = 2x \times 3e^{3x}$, which showed a misunderstanding of the product rule. A minority of candidates attempted the product rule incorrectly by introducing subtraction or alternatively tried to use the quotient rule.

Question 3

This question proved challenging for many candidates. Almost all recognised the need to differentiate $\sin 5x$ and did so successfully to gain a mark, but confusion between x and y was common, with some writing expressions such as $5\cos\left(\frac{5\sqrt{3}}{2}\right)$ rather than using the table to find $x = \frac{\pi}{15}$. Only a minority correctly identified x, although most of those who did went on to gain full marks. Many candidates used δx for the small change in x and recognised that $\delta x \approx \frac{0.01}{\frac{dy}{dx}}$, often gaining a follow-through mark even without the correct value of x. Those who correctly found $\frac{dy}{dx}$ and evaluated $\frac{0.01}{2.5}$ sometimes struggled to express this as a simplified fraction or decimal, and some practice with these basic number skills would help ensure that otherwise strong candidates do not lose marks unnecessarily.

Question 4

(a) Many candidates produced fully correct solutions, although the greatest challenge was in finding $v = 2T$. When this was successfully evaluated, at least two marks were usually awarded. The most common error was to assume $v = 2$. Candidates who recognised that the area could be expressed in terms of v generally gained at least one mark. A frequent mistake in applying the trapezium formula was to use $a + b = 12 + T$, while many attempted to calculate the area as triangle + square + triangle, which led to more errors than using the trapezium approach directly. A minority of candidates did not realise that T could not take the value 9.

(b) If **part (a)** was answered correctly, then **part (b)** was usually correct as well. A small number of candidates gave positive values, which was not appropriate in this context. Many responses were left blank.

Question 5

This question was generally very well attempted, with many candidates gaining full marks. Almost all secured the first mark for differentiation, and a large number correctly found both the gradient and the gradient of the normal, although a few mistakenly gave this as 2. Weaker candidates often stopped at this stage, while those who continued usually gained at least one further mark. Those who recognised x as a common factor and then successfully factorised the remaining quadratic tended to be the most successful. Candidates who attempted long division were often successful, although a greater number of errors were seen here.

Question 6

(a) Many candidates produced solutions that showed little connection to the given diagram and consequently gained few marks. The usual first step was to express BM in terms of a using Pythagoras' theorem, leading to $a \times \frac{\sqrt{3}}{2}$. Many candidates were unable to simplify $\sqrt{\frac{3}{4a^2}}$ correctly and a few applied the theorem inaccurately. From there, stronger candidates identified $\cos 30^\circ$ as $\frac{AM}{BM}$, which eliminated a and gave $\frac{\sqrt{3}}{2}$, and hence sec 30° as its reciprocal, producing $\frac{2}{\sqrt{3}}$.

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(b) Candidates needed to ensure that they showed a complete and clear route as this was a given answer. Most were able to begin correctly by adding the fractions, although combining them was not always correctly achieved. Where $\sec x$ *was* retained, the majority reached $\frac{2\sec x}{\sec^2 x - 1}$, which simplified to $\frac{2\sec x}{\tan^2 x}$. After this it was necessary to split the parts to show $2 \times \frac{1}{\sin x} \times \frac{\cos x}{\sin x}$, and this was the stage at which some candidates made errors. The most common alternative approach was to convert $\sec x$ to $\frac{1}{\cos x}$, but this led to a more complex fraction and errors were more frequent. These slips often reflected a weak understanding of the connections between trigonometric expressions. Candidates would benefit from regular practice of this type of question and from learning equivalent identities, for example recognising that $\sec^2 x - 1$ is more easily handled when converted to $\tan^2 x$ rather than changing $\sec x$ into $\frac{1}{\cos x}$.

Question 7

(a) This question was found challenging and many candidates were not able to gain any marks. Those who used vector bracket notation were more prone to errors. Some correctly obtained $\sqrt{26}$. The most common mistakes involved incorrect assumptions for *k*, with values such as $\frac{1}{3}$, $3\sqrt{26}$, $\frac{1}{3\sqrt{26}}$ or $\frac{\sqrt{26}}{3}$ frequently seen.

(b) This question was very poorly attempted. Some candidates continued from **part (a)** by trying to find magnitudes but were then unsure how to use them. Those who did set up an equation often omitted a constant multiplier on the vectors. Of those who did have a common multiplier, most had only a single one. Candidates who correctly identified and applied two multipliers almost always reached the correct answer.

Question 8

This question had a reasonably well-defined structure for candidates to follow. Presentation was sometimes poor, which hindered candidates in processing the requirements and checking their own methods. Successful candidates planned their approach carefully, first finding the *x*-coordinates of the points of intersection of the graphs. Weaker responses often stopped at the roots of the quadratic, $\pm\sqrt{12}$, which were of little use. Combining the two equations led to a quartic, and most attempted to solve this by substituting $p = x^2$ and working with the resulting quadratic. Some did not collect all terms on one side before factorising and so lost some method marks. The next stage was to integrate either the combined equation or the two separately using the correct limits of -2 and 2. Many integrated correctly, although slips were seen in substituting the limits. Some who worked with separate integrals did not combine them, which was essential. Those who simplified by integrating between 0 and 2 and doubling the result were often more successful. A few fully correct solutions lost the final mark as they did not simplify their answer, for example leaving $16 + \frac{16}{5}$ or $32 - \frac{64}{5}$. A number of solutions were poorly organised and did not reach the desired outcome.

Question 9

(a) In order to solve this equation, it was essential to express all terms in logarithms of the same base, but some candidates confused their methods which complicated later working. The usual first step was to change $\log_{25} x$ to $\frac{1}{2}\log_5 x$, although some incorrectly wrote $\log_{25} x$ as $\log_5 2x$ or $\log_{25} x$. The equation then needed to be multiplied through by 2, but this was often not applied to the first term. The next stage was to re-write either $2\log_5(5x-2)$ as $\log_5(5x-2)^2$ or to set the right-hand side equal to $\frac{1}{2}\log_5 5$. Once the logarithms were in the same base, one pair should have been

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combined using the laws of logarithms, but many applied these incorrectly. Where candidates changed the base to 25 or 10, the same principles should have applied, but errors were frequently seen, especially with base 25. When a quadratic in x was produced, some were unsure how to solve it, and although many performed the steps correctly, few recognised that the solution $x = \frac{1}{5}$ was invalid in this case.

(b) This was a challenging question, with many candidates making mistakes with indices or not progressing to a quadratic equation. The majority were able to make some headway by removing fractions from the equation, producing a form that could lead to a quadratic and thereby gaining at least one mark, even if they did not proceed further. The main difficulty was either not recognising the 'hidden' quadratic or being unable to manipulate the indices to achieve a quadratic form. Those who did form a quadratic generally used a substitution such as $u = e^{3y}$ or $u = e^{3y} - 4$, and most solved it correctly, rejecting the negative solution appropriately. Candidates who did not make significant progress often showed weak understanding of indices or made unhelpful substitutions at an early stage, for example setting $u = e^3$, which led to random errors. It was not uncommon to see logs applied to each term prematurely.

Question 10

(a) This question was generally very well attempted, with most candidates gaining full credit; the only recurring slip was in dividing 55 by 10 or equivalent. The most common errors were forgetting to multiply S_{10} by 3, attempting to use $a + l$, confusing the sum to infinity with the required sum, or mixing different formulae, and stating S_{10} and S_{20} without equating them.

(b) This question produced a very mixed range of errors. Candidates who correctly identified $r_b = r^2$ often introduced a numerator of a or a^2 in the sum to infinity, while many responses showed a confusing mixture of a and b terms in the fractions which prevented simplification. A few attempted to use the sum of nth terms instead, and some candidates lost accuracy marks at the stage of simplifying $\frac{r(1-r)}{1-r^2}$.

Question 11

(a) The centre of the circle should have been found routinely by recognising that the x-coordinate lay halfway between the lines $x = 0$ and $x = 4$, with similar reasoning giving the y-coordinate. The radius could then be seen as 2, being the distance from the centre to any of the given lines, although many incorrectly applied Pythagoras' theorem and obtained $\sqrt{8}$, the distance from the centre to a corner of the square formed by the lines. While most candidates knew the general formula for the equation of a circle, which is given on the formula page of the question paper, many were unable to determine the centre or radius accurately. Too often their working lacked clarity, with results for the centre or radius not clearly identified and incorrect values inserted into the equation without explanation.

(b) To prove the required expression, it was necessary to substitute $2x + a$ for y into the circle equation from **part (a)**. Many candidates managed this, although rearrangements often became unnecessarily complex when expanding $(2x + a - 1)^2$. Those who treated the expansion as $(2x + (a-1))^2$, leading to $4x^2 + 4x(a-1) + (a-1)^2$, generally reached the required expression more efficiently. An alternative approach was to expand the circle equation first and then substitute, which reduced errors in the rearrangement. The values of a could be determined by considering when the discriminant of $(4(a-2))^2 - 4 \times 5 \times (a-1)^2$ was equal to zero, and this was often correctly attempted, although producing the solution was not always successful. Some candidates attempted to solve the quadratic directly without recognising that the discriminant was the key to the method.

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Question 12

(a) Many candidates gave the correct response with or without the inclusion of x^r. The most common wrong answers seen were ${}^{59}C_r$ or equivalent, 2^{59-r}, x^r, 1, *r*, and 59.

(b) If the equation was written correctly, candidates usually gained full marks. The most common errors were the inability to express the combination as a fraction involving factorials, simplifying $\big(59-(r+1)\big)!$ incorrectly to $(60-r)!$, attempting to solve the equation with *x* included, or trying to solve it without the necessary '2' term.

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ADDITIONAL MATHEMATICS

Paper 4037/22
Calculator

Key messages

Candidates should take note of the key words and phrases in each question. For example:

- When an answer is required in a particular unit, such as **radians,** candidates should check they have stated their final answer in that unit.
- When the answer must be stated in a **particular form,** such as an expression for *y* in terms of *x*, candidates should check they have stated their final answer in that form.

It is important for candidates to show key steps in their method to earn marks if an error is made. A correct method will not be assumed from an incorrect value alone.

Calculators should not be relied on to solve equations or to work out the values of derivatives or integrals for particular values. Those who do this will be omitting necessary working. They should also check that their calculator is in the appropriate mode when solving trigonometric equations.

It is expected that candidates use correct algebraic methods when solving equations. Candidates who apply numerical methods, such as trial and improvement, are likely to be omitting necessary working.

General comments

Some candidates were able to correctly recall and apply specific techniques such as the simultaneous equations in **Question 1(a)**. Fewer candidates were able to analyse and solve problems. For example, finding the obtuse angle *AOB* in **Question 2(a)** was found challenging. Candidates omitted to check the reasonableness of their solution. For example, candidates who stated *AOB* was a value greater than 2π in **Question 2(a)**, should have considered whether this was likely to be correct.

Some candidates gave well-presented solutions. This made the logic of their method easy to follow. Other candidates needed to improve the presentation of their work. There were also several questions in this paper where candidates miscopied expressions or values.

When solving a problem that involves the calculation and statement of several different angles, candidates should take care to identify the angles clearly so that credit can be given. Annotating a diagram with angles that are to be found using simple labels such as *x* and *y* or using the 3-letter convention can be helpful when these are then used in their solution. Describing many different angles as θ, for example, does not usually lead to a logical and correct solution.

Candidates seemed to have sufficient time to attempt all questions within their capability.

Comments on specific questions

Question 1

(a) A good proportion of candidates solved the equations simultaneously and stated the correct coordinates. A few candidates made a sign slip when writing down one of the negative coordinates, commonly –9 became 9. Some candidates made sign slips when rearranging the equation after eliminating one unknown. Most candidates eliminated *y*, which was the most efficient method of solution. Eliminating *x* was more likely to result in an error being made. In the weakest solutions, candidates either attempted to solve $3+5x-2x^2=0$ or $3+5(4x-3)-2(4x-3)^2=0$.

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(b) Candidates were generally successful in finding the gradient of the perpendicular bisector. They either understood that *A* and *B* were both points on the line $y = 4x - 3$, therefore the gradient of *AB* was 4 and wrote down that the gradient of the perpendicular bisector was $-\frac{1}{4}$ or used the coordinates they had found in **part (a)** and then used $\frac{-1}{m_{AB}}$. A few candidates using this second method made slips when selecting coordinates to use or attempted $m_{AB} = \frac{x_2 - x_1}{y_2 - y_1}$ or $m_{AB} = \frac{y_2 - y_1}{x_1 - x_2}$. Most candidates attempted to find the midpoint of their two points. A good number of candidates were also successful in this. A few candidates used $\text{midpoint} = \left(\frac{x_2 - x_1}{2}, \frac{y_2 - y_1}{2}\right)$ or did not find the midpoint and instead used the coordinates of one of the points found in **part (a)** to form the equation of the perpendicular line. A good proportion went on to form a correct equation using their attempt at the midpoint and perpendicular gradient. A few candidates made no real progress beyond either finding the perpendicular gradient or the midpoint. Few candidates were able to identify the correct strategy to complete the problem. Many of those who did attempt a correct method, used methods that were more complex than necessary, given that the triangle was right-angled. A simple sketch may have helped with this. Some candidates made sign errors when finding *P* and *Q* and were therefore working with incorrect points, which was not accepted at this stage of the solution. Candidates should be aware that when a coordinate can be written in an exact form, for example a fraction or terminating decimal such as –1.9375, rounded decimals are not acceptable. In other responses, candidates attempted incorrect strategies to find *P* and *Q*, such as equating the equation of the perpendicular bisector with the curve $y = 3 + 5x - 2x^2$ and solving.

Question 2

This question involved an element of problem solving. Some candidates found that this was beyond their capability.

Accuracy of answers was also an issue in this question. In **part (a)**, candidates who worked in degrees and then converted to radians in the final step commonly stated insufficiently accurate answers or did not use the correct conversion factor. These candidates may have improved if they had simply worked in radians. In **parts (b)** and **(c)**, some candidates used working values accurate to 3 significant figures and then offered answers that were, consequently, inaccurate. These candidates may have improved if they had used working values that were of greater accuracy.

Some candidates needed to take greater care when reading the question as a few used a radius of 12 or 3 consistently throughout this question.

(a) A small number of candidates offered fully correct solutions. The most common efficient approaches were to find the length of *AB* using Pythagoras' theorem and then use the cosine rule on triangle *AOB*, or to use the cosine rule on triangle *AOD* to find angle *AOD* and then subtract this from π. Some candidates found angle *AOD*, doubled it, then subtracted from 2π before halving. This was not always done successfully. A few of these candidates forgot to double before subtracting from 2π and others forgot to halve. When an incomplete multi-step solution was offered, candidates who did not identify the angles they were using in some way were unlikely to be credited.

Some candidates misinterpreted angle *AOB* as angle *AOD* and other candidates misinterpreted the word 'obtuse' to mean 'reflex'. A few candidates may have improved if they had checked the List of formulas on page 2 of the examination paper for the correct structure of the cosine rule, as this was sometimes mis-stated. In the weakest solutions, for example, candidates treated triangle *AOD* as if it were right-angled and applied trigonometry on that basis, or simply stated the answer as $\frac{2\pi}{3}$, after dividing 2π by 6 then doubling, or candidates attempted to use the area of a circle in some invalid way.

(b)(i) Candidates who had the correct answer to the previous part of the question often offered a correct solution in this part. A few candidates offered an inaccurate answer such as 37.6. Some candidates

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earned partial credit for a correct calculation for the length of one of the arcs. Some candidates incorrectly included the lengths *AC* and *BD* in their sum for the perimeter. In the weakest solutions, candidates were attempting to use angles that were in degrees as if they were angles in radians, which was not accepted.

(ii) Candidates who had the correct answer to **part (a)** often offered a correct solution in this part. A few candidates offered an inaccurate answer such as 111.18. The most common plan was to sum the areas of the two sectors and add the areas of the two triangles. Some candidates were able to state a correct calculation for the area of one of the sectors. Some of these also stated a correct plan to solve the problem. A few candidates found the area of half of triangle *AOD* and then doubled it, instead of multiplying it by 4. Other candidates made slips when finding the area of triangle *AOD.* Common slips were, for example, to use $\frac{1}{2}(4)(6)$ or $\frac{1}{2}(4)(6)\sin AOD$. Some candidates made slips when finding other lengths they wished to use, such as the height of triangle *AOD*. Common slips in finding this were to either apply Pythagoras' theorem to triangle *AOD* as if it were right-angled or to misapply Pythagoras' theorem to half of triangle *AOD*. In the weakest solutions, candidates summed the area of the rectangle *ABCD* and the area of the circle with radius 6, treating each of the segments of the circle as if they were semi-circles.

Question 3

Some good solutions to this question were seen. Better responses were logically written and methodical with each expansion carefully stated and considered as far as needed. The relevant terms of each expansion were then selected and multiplied. It was important at this stage to cancel any powers of *x* that had been included and to sum the values 1024, –122880 and 1658880 to demonstrate understanding of 'the term independent of *x*'.

Some candidates stated the correct, unsimplified terms from the expansion of $\left(2+\frac{3}{x^2}\right)^{10}$, but then made a slip when evaluating these, losing accuracy. Other candidates made a sign or arithmetic slip when expanding $\left(1-4x^2\right)^2$. Some candidates applied the binomial theorem to this expansion, rather than simply expanding $\left(1-4x^2\right)\left(1-4x^2\right)$. This also resulted in unnecessary errors.

Candidates also sometimes miscopied expressions or values in this question.

Candidates who were using incorrect values needed to show the multiplication of the terms from their expansions in order to be credited for the sum of their products. Some candidates omitted to show this part of their method and could therefore not be credited for it.

A few candidates offered a sum of expressions including *x*, or a list of values, as their final answer. Rereading the question may have helped these candidates, as the wording of the question should have indicated to them that the answer was a single value.

A few candidates made no real progress beyond stating the expansions. In the weakest responses, candidates offered no expansions and selected only one of the three terms, usually 1024, or were unable to offer anything of value. Candidates who were unable to recall the correct structure of the binomial theorem may have improved if they had referred to the List of formulas on page 2 of the examination paper.

Question 4

(a) A good proportion of candidates were able to find the correct gradient and *y*-intercept for the line, with Some going on to complete this part of the question successfully. A few candidates spoiled a correct solution by offering something like $y = \ln 15.5 - \ln 2x^3$ as their final answer, which was not ignored. Other candidates offered a final answer of $e^y = -2x^3 + 15.5$, which did not fully answer the question. Other errors that were made included:

- using an incorrect operation in their final step and offering a final answer of $y = e^{-2x^3} + e^{15.5}$ or similar

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- finding the gradient correctly, and stating $e^{y} = mx^3 + c$, but then incorrectly using $e^{13.5} = -2(1)^3 + c$ to find c
- attempting to find $\frac{y_2 - y_1}{x_1 - x_2}$ or $\frac{x_2 - x_1}{y_2 - y_1}$
- attempting to use calculus in some way.

A few candidates found and used the perpendicular gradient. Some candidates made no real progress beyond finding the gradient and *y*-intercept. Other candidates made no real attempt to answer.

(b) Candidates found this part of the question challenging and few offered a fully correct solution. Some candidates earned a method mark for an initial correct inequality following from an equation of the form $y = \ln(a + bx^3)$. A few candidates incorrectly stated their answer as $x < \pm\sqrt[3]{7.75}$. Common incorrect solutions, which were not credited, either started with $\ln(15.5 - 2x^3) > 0$ and ended with $x < \sqrt[3]{7.25}$ or started with $15.5 - 2x^3 = 0$ and ended with $x > 1.98$. Many candidates made no attempt to answer.

Question 5

(a) A reasonable number of correct answers were seen. Common errors were to give ${}^{12}C_6 = 924$ or $6! = 720$ or an incorrect evaluation of ${}^{12}P_6$.

(b) Candidates found this part of the question more challenging. A fair number of correct answers were seen. Common method errors made were to evaluate ${}^{3}P_1 \times {}^{9}P_4 \times {}^{2}P_1$ or $3! \times {}^{10}P_4 \times 2!$ or ${}^{3}P_1 \times {}^{10}P_4 \times {}^{3}P_1$.

(c) Candidates found this part of the question to be the most challenging with fewer fully correct answers seen. Some candidates earned a partial mark for a correct calculation or a final answer of 13 440. A few candidates made a reasonable attempt at the required product but made an error with at least one component of it. Some candidates made no real attempt to answer.

Common method errors were to sum rather than multiply, or to consider the two bullet points in the question as connected by 'or' rather than 'and', or treating the bullets as two distinct cases. Sometimes, in the product ${}^{3}P_1 \times {}^{4}P_1 \times {}^{8}P_2 \times {}^{5}P_2$ or $2 \times {}^{3}P_1 \times {}^{4}P_1 \times {}^{8}P_2 \times {}^{5}P_2$, not all terms were given correctly for example, ${}^{8}P_2$ was replaced by 8 or ${}^{10}P_2$ or ${}^{9}P_2$. Some candidates evaluated ${}^{3}C_1 \times {}^{4}C_1 \times {}^{8}C_2 \times {}^{5}C_2$ or $2 \times {}^{3}C_1 \times {}^{4}C_1 \times {}^{8}C_2 \times {}^{5}C_2$.

Question 6

(a) A small number of candidates stated a correct velocity vector. A few candidates spoiled a correct answer with an incorrect form, such as $\begin{pmatrix} 10\mathbf{i} \\ -24\mathbf{j} \end{pmatrix}$. Some candidates were partially credited for stating the correct Pythagoras' theorem for the magnitude of the direction or for stating the magnitude as 13. The vector $26\begin{pmatrix} 5 \\ -12 \end{pmatrix}$ was a very common incorrect response. Many candidates did not offer a vector as their answer, but stated that the velocity was, for example, 2 ms^{-1} or attempted to use calculus or suvat equations in some way. Some candidates made no attempt to answer.

(b) In order to be credited in this part, candidates needed to use the velocity vector they had generated in **part (a)** in conjunction with the initial position $\begin{pmatrix} 3 \\ 6 \end{pmatrix}$. A few candidates were successful. Some candidates stated their position vector as $\begin{pmatrix} 10t - 3 \\ 6 - 24t \end{pmatrix}$ and this may have arisen from an attempt to

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match their structure to the given position vector of *Q*. A few candidates offered $\begin{pmatrix}3\\6\end{pmatrix}+\begin{pmatrix}5\\-12\end{pmatrix}t$, commonly following no attempt at **part (a)**. This was not condoned.

Many candidates misinterpreted the question and thought that they were finding the position vector of *P* when *t* was 0. When candidates had written the correct position vector in terms of *t* before making this misinterpretation, the incorrect subsequent working was ignored and the solution credited. However, some candidates did not state the position of *P* in terms of *t* and simply stated their answer as $\begin{pmatrix}3\\6\end{pmatrix}$. This was not condoned.

In the weakest responses, candidates offered vectors such as $\begin{pmatrix}3t\\6t\end{pmatrix}$ or $\begin{pmatrix}5t\\-12t\end{pmatrix}$ or vectors without *t* such as $\begin{pmatrix}3\\6\end{pmatrix}+\begin{pmatrix}5\\-12\end{pmatrix}$. Many candidates made no attempt to answer.

(c) Many candidates made no real attempt to answer this part of the question. A creditable attempt was dependent on candidates using a vector of the form $\begin{pmatrix}3\\6\end{pmatrix}+t\left(\textit{their}\begin{pmatrix}10\\-24\end{pmatrix}\right)$ for the position vector of *P*. A few candidates offered fully correct solutions. In these responses, candidates were careful with the signs in the difference of the two position vectors and took care when simplifying and expanding before reducing the expression to the required form. Candidates who were working with $\begin{pmatrix}-8-2t\\-4-t\end{pmatrix}$ sometimes made slips when dealing with the negatives, particularly when squaring the components from this form. Candidates whose components were positive did not have this issue. A few candidates spoiled a correct answer by reducing the coefficients of each term and stating their final answer as $d^2=t^2+8t+16$. This was not condoned for full credit.

When a solution was attempted, common errors were to be working with a position vector for *P* that was not of reasonable structure, such as one that did not have initial position $\begin{pmatrix}3\\6\end{pmatrix}$ or that did not include *t*, to add their position vectors, instead of subtracting, or to write the difference of the vectors as d^2 and to carry out some spurious algebra using the components, such as finding $(2t+8)(4+t)$.

(d) Candidates were required to use the expression for d^2, or *d*, from the previous part of the question to justify the two particles not colliding. A small number of candidates were able to do this successfully. As candidates were required to show that the particles did not collide, it was not sufficient to equate the expression for d^2 to 0 and then solve for $t = -4$ without interpreting this result. It was necessary to continue and explain that *t* was greater than or equal to 0, for example. A few candidates omitted this interpretation. Some candidates equated d^2 to 0 and then found the discriminant which was not helpful. Many candidates equated the components of the position vectors of *P* and *Q*. This was not accepted as a method of solution in this particular question, as the question required them to use the expression for d^2 to make their argument. This was indicated by use of the word 'Hence'.

Question 7

Candidates are advised to take care when writing the arguments of trigonometric functions. There were very many miscopy errors in this question. Some of these errors resulted in much simpler solutions and, therefore, a greater loss of marks.

(a) This was a fairly routine application of the product rule and most candidates attempted to answer. A good proportion of candidates stated a correct solution. A few candidates were unable to differentiate cos2*x* correctly, but were able to apply the product rule using their derivative. Common errors in this case were to write the derivative as –sin2*x* or 2sin2*x*. Some candidates were able to differentiate cos2*x* but were unable to apply the product rule. Common errors in this case were to state an answer of –2sin2*x* or –2*x*sin2*x*.

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(b) In order to make progress in this part of the question, candidates needed to have a correct derivative in **part (a)**. A small number of fully correct responses were seen. Some candidates offered a correct, or partially correct, expression but omitted the constant of integration. A few candidates used $\int \cos 2x \, dx = \sin 2x$ in an otherwise correct solution. Other candidates made a sign or arithmetic slip when their final step was to divide through by –2. Candidates who rewrote their initial relationship as $2\int x\sin 2x \, dx = -x\cos 2x + \int \cos 2x \, dx$ were less likely to make a sign slip in the final stages. Some candidates made an initial correct step such as $x\cos 2x = -2\int x\sin 2x \, dx + \int \cos 2x \, dx$ but were unable to make progress beyond that. A common error in these cases was to use $\int \cos 2x \, dx = -k\sin 2x$ where k was $\frac{1}{2}$ or 1. Candidates whose use of notation was poor, such as those who omitted to write 'dx' where needed, often did not offer any solution of value. For example, some candidates wrote $x\cos 2x = \int -2x\sin 2x + \cos 2x$ followed by $x\cos 2x - \cos 2x = \int -2x\sin 2x$. In the weakest responses, candidates did not attempt to use **part (a)** in any way and offered answers such as $\frac{x^2}{2} \times -\frac{1}{2}\cos 2x$. Some candidates made no attempt to answer.

Question 8

(a) Candidates who were careful with the notation they used and who thought about the most efficient methods of solution were the most successful in this question. The most straightforward method of solution was to form the three terms $t + 4.5$, $t + 10.5$ and $t + 28.5$, to then use these terms to form two expressions for r in terms of t, equate and then solve. Candidates who used this approach were almost always successful. Some candidates made sign or algebraic slips in the final stages of their solution. These candidates may have realised this if they had checked that the value of t that they had found produced the terms of a geometric progression. A few candidates stated one expression for r in terms of t but made no real progress beyond that. Some candidates confused themselves by using, either a as the first term of both progressions, or t as the first term of both progressions, and treating it as if it were a consistent quantity. A few candidates used alternative methods which involved finding the first term of the geometric progression and/or the common ratio in this part of the question in order to find the value of t. These methods were also fairly successful, although forming an equation in one unknown in these cases involved more algebraic steps, so was not as simple as equating expressions for r.

Some candidates, after forming an equation in t such as $(t+4.5)\left(\frac{t+10.5}{t+4.5}\right)^2 = t + 28.5$, wrote down the correct value for t without any attempt to simplify their equation. This was not given full credit as necessary working had been omitted. Similarly, candidates who used trials also lost marks for omitting necessary working.

(b) A few candidates offered a correct solution in this part of the question. Other candidates were able to use the value, or values, they had generated in **part (a)** in a correct method. A common error, once again, was for the value of t to be used as the value of the first term of the geometric progression, with candidates attempting to evaluate $\frac{their(-1.5)+10.5}{their(-1.5)}$. Other candidates stated an incorrect value for r without clear working to indicate their method. Many candidates made no attempt to answer.

Question 9

(a) A good proportion of candidates were able to state or indicate the correct value. The answer $x > -\frac{5}{2}$ was acceptable but $a > -\frac{5}{2}$ only was not credited. A few candidates seemed confused by the inequality and, after stating $x > -\frac{5}{2}$, they went on to destroy their answer by stating, for example, $a = -2$ or $a = -3$.

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(b) There were some correct answers to this part. The use of correct notation was expected. Candidates could write the range required as f $\in \mathbb{R}$ or f(x) $\in \mathbb{R}$ or $y \in \mathbb{R}$, for example, but not $x \in \mathbb{R}$. To be consistent with this, the answer 'the set of real numbers' alone was not accepted as it was incomplete. A common incorrect answer was f(x) $\geqslant 0$. Some candidates were confused by the reference to the value of a in this part and answers such as f > $-\frac{5}{2}$ were seen.

(c) Many candidates formed the correct composite function and went on to offer a correct solution. A few candidates stated only the positive solution. Other candidates offered both solutions initially but then spoiled this by rejecting the negative value. The justification for this usually involved the domain of f, rather than the domain of g, indicating confusion over the domain of the composite function. A few candidates were able to form a correct initial equation, equating the composite function to 4, but were unable to progress beyond that. In these cases, it was common for candidates to make an incorrect order of operations error, such as subtracting 7 from 4 before dealing with the logarithm, or for them to write $2x^2 + 7 = \ln 4$ or similar. Some candidates needed to take more care with brackets when forming the composite function as, when brackets were omitted and not recovered in later work, no credit was given. In the weakest responses, candidates attempted to form a product of functions rather than a composite function. Again, some candidates were confused by the reference to the value of a in this part and some attempted to substitute $x = -\frac{5}{2}$, for example, at some point in their solution.

Question 10

The solution to this question involved several steps. To begin with, candidates needed to solve a disguised quadratic in e^x to find the point of intersection of the curves. Many candidates were successful in doing this by stating and using a substitution to form and solve a simpler quadratic equation. Candidates needed to write the values they had found in terms of e^x and then take logarithms, rejecting the invalid case.

Most candidates stated the exact value for x. A few candidates stated only the decimal value and so lost some accuracy. Some candidates incorrectly manipulated the exponentials, treating them as if they were logarithms. In these cases candidates wrote, for example, $5e^x + 6e^x = 2$. There were many miscopy errors in this part of the solution and some candidates were writing the power of both exponential terms as x or as $2x$. This greatly simplified the solution. In weaker responses, candidates often wrote, for example, $e^x\left(5+3e^x\right)=2$ and then proceeded to state $e^x = 2$ and $\left(5+3e^x\right)=2$ or stated $\ln 5e^x + \ln 3e^{2x} = \ln 2$. In the weakest solutions, candidates made no attempt to solve to find the point of intersection and used the limits 1 and 7.

The next part of the solution involved forming a correct plan, using an appropriate difference of integrals. It was clear from the diagram that the upper limit of the integrals used needed to be 0. The lower limit should have been their value of x from their attempt to equate the equations of the curves and solve. It was fairly common for the limits to be reversed and for the lower limit to be 0. Some candidates earned credit for their plan later in their solution when they subtracted their areas in the correct order. Many candidates worked with two integrals and subtracted the values they derived from these. A few candidates subtracted the equations of the curves before integrating a 3-term expression. A few other candidates stated a single integral for the difference of the curves but omitted brackets around $4 - 3e^{2x}$, resulting in the plan being incorrect.

A good proportion of candidates were able to correctly integrate both $3e^{2x}$ and the remaining terms. In weaker responses, candidates sometimes integrated $5e^x$ as, for example, $5e^{2x}$ or $5e^{x+1}$ or $\frac{5e^x}{5}$. These candidates often integrated $3e^{2x}$ in a similar way. In some weak responses, candidates differentiated the constant terms instead of integrating them.

A reasonable proportion of candidates were able to substitute their limits, which needed to be 0 and an exact value, into an expression of appropriate structure. Candidates who used an inexact value for one of the limits in this step were not credited. The question required a solution in exact form and this could not be achieved using rounded values.

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A few candidates were credited for a partially correct answer. Few candidates offered fully correct responses.

Some candidates rearranged the equation of each curve to make x the subject. They then attempted to use limits for y rather than x. The techniques involved in integrating with respect to y in this way are beyond the scope of this syllabus and no candidate who started in this manner made any real progress.

Question 11

(a) Candidates found this question to be fairly challenging and fully correct responses were not common. A few candidates found three correct solutions. In good responses, candidates stated and used a substitution, such as $y = \tan 2x$, before factorising. This made the correct method much more obvious. Candidates should be aware that, for a double angle to be credited, it needed to be identified as $2x$. Writing, for example, $\alpha = 75.96$ was not sufficient to be credited unless α was defined as $2x$.

Some candidates found a correct pair of values from $\tan 2x = 4$. Occasionally the larger angle from solving this equation was not stated or was incorrect and stated as 52°, following a double angle found using 180 – 75.96. A few candidates stated only $x = 0$ from $\tan 2x = 0$. Even when a second solution was stated from this equation, it was common for $x = 90°$ or $x = 180°$ to be omitted. Some candidates divided through by $\tan 2x$, rather than factorising, losing solutions.

A few candidates offered working that was somewhat suspect when solving $\tan 2x = 0$. Candidates should be aware that the more secure method of solution is to find the appropriate double angles first and then divide these by 2, rather than finding a value for x and attempting to manipulate it.

In the weakest of solutions, candidates attempted to solve the initial equation by separating it into, for example, $\tan^2 2x = 0$ and $-4\tan 2x = 0$,then solving or candidates attempted to 'prove an identity' rather than solving an equation.

(b) Candidates seemed to find this part of the question more accessible than the previous part. A small number of candidates offered fully correct solutions. A good proportion of candidates were able to rewrite the given equation in terms of $\sin(y + 1.2)$. A good proportion of these candidates were able to write at least two correct compound angles, with a few candidates managing one correct compound angle only. Candidates should be aware that, for a compound angle to be credited, it needed to be identified as $y + 1.2$. Writing, for example, $\alpha = 0.253$ was not sufficient to be credited unless α was defined as $y + 1.2$.

A reasonable number of candidates offered two correct values of y. Some rounded –0.947 to –0.95 without ever stating a more accurate value. These candidates may have improved if they had taken note of the instructions on the front cover of the examination paper. Some candidates omitted the angle –4.59 or miscalculated the compound angle as $-\pi + 0.2526\ldots$, resulting in the common incorrect value, –4.09.

Other candidates either worked in degrees and then converted to radians or used rounded working values for their compound angles and lost accuracy for some of their solutions.

In weaker solutions, candidates usually made an incorrect initial step such as

$\text{cosec}\, y + \text{cosec}\, 1.2 = 4$ or $1 + \cot(y + 1.2) = 4$ or $\cos(y + 1.2) = \frac{1}{4}$.

Some candidates made no attempt to answer.

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ADDITIONAL MATHEMATICS

Paper 4037/23
Calculator

Key messages

Candidates should ensure they read each question carefully and make sure they answer each part of the question in full. When a question asks for an exact answer, candidates should leave their answers in surd form or in terms of π or e as appropriate.

Candidates should take care to note the key words in the question. When an answer is required in a particular unit such as radians, candidates should check their final answer is in that unit. When an answer is required in a particular form, such as $ax + by + c = 0$, candidates should check their answer is in that form.

Extra care should be taken when substituting negative values into expressions as sign errors and other arithmetic slips are relatively common.

General comments

When a part of a question includes the key word 'Hence...', it is expected that candidates use a previously found result to answer the current part of the question. This was the case in **Questions 3(a)(ii)** and **8(b)**.

When the command word in a question is 'draw', rather than 'sketch', it is expected that candidates draw an accurate graph. Candidates should plot points and join their points appropriately. For a non-linear graph, the points should be joined with a smooth curve and not with ruled sections. For a linear graph, the points should be joined using a ruler and not free-hand. The points need to be plotted carefully so that the graph can be used in any later question parts. An accurate graph was required in **Questions 3(b)** and **9(a)**.

When candidates need to correct part of their working, they should cross the work out neatly and re-write it rather than trying to over-write a number, as this is hard to read.

Candidates should show their method and set out their work clearly, this is especially important in 'show that' questions. Also showing working means method marks can still be earned following an arithmetic or algebraic slip.

Comments on specific questions

Question 1

Most candidates used the factor and the remainder theorems to form a pair of simultaneous equations in a and b which they then solved successfully. A number of candidates made algebraic or arithmetic slips when simplifying the equations which led to incorrect solutions. A few candidates fortuitously found the correct values for a and b from an incorrect process such as incorrectly simplifying $-2(-b)$ to $-2b$ or thinking that subtracting $-4a + b = -8$ from $9a - b = 27$ would eliminate b; these candidates did not earn full credit. Candidates who used a long division method generally made less progress with this question than those who used the factor and remainder theorems.

Question 2

(a) (i) Around half of the candidates drew the correct reflection of f(x) in the line $y = x$. Some candidates did not pay careful enough attention to the scale provided on the axes or else continued their curve into the 2nd quadrant. Some candidates did not know the correct relationship and common incorrect responses were to draw a reflection in either the x-axis or the y-axis.

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(ii) Just under half of the candidates correctly stated that the graph of $\mathrm{f}^{-1}(x)$ is a reflection of $\mathrm{f}(x)$ in the line $y = x$. A number of candidates did not refer to the relationship between the graph of $\mathrm{f}(x)$ and the graph of $\mathrm{f}^{-1}(x)$, even if they had drawn a correct sketch, and instead made general statements about the two functions such as 'they are one-to-one' or that the domain of $\mathrm{f}^{-1}(x)$ is the range of $\mathrm{f}(x)$. Candidates are advised to read questions carefully and pay attention to the key words.

(b) (i) Many candidates made a correct attempt to find the inverse function and demonstrated a good understanding of the process with most swapping the variables and proceeding to make *y* the subject. Only a few candidates left their final answer in terms of *y,* instead of completing the method. Candidates who did less well on this question tended to use the laws of logarithms incorrectly or make poor use of brackets. For example, incorrectly rewriting $\ln x = \sqrt{y-2}$ as $\ln x^2 = y - 2$ instead of $(\ln x)^2 = y - 2$ or incorrectly simplifying $(\ln x)^2$ to $2\ln x$. A few candidates incorrectly thought that $x = \mathrm{e}^{\sqrt{y-2}}$ could be squared to remove the square root and wrote $x^2 = \mathrm{e}^{y-2}$.

(ii) A good number of correct answers were seen. The most common error was to write the range as $x \geqslant 2$.

(iii) Most candidates were able to find a correct expression for the function gh(*x*). However, many candidates did not fully simplify their answer, leaving it as $\mathrm{e}^{\sqrt{\frac{1}{x^2}}}$ and so were unable to earn full credit. A few candidates did not recognise that the fully simplified form is $\mathrm{e}^{\frac{1}{x}}$ and rewrote it incorrectly as e^{-x}. Some candidates did not pay attention to the domain of the function h which was restricted to $x > 0$ and gave their answer as $\mathrm{e}^{\pm\frac{1}{x}}$.

Question 3

(a) (i) Most candidates were able to rewrite the quadratic equation in the form $(x+a)^2 + b$ by completing the square. Most candidates were successful with only a few arithmetic slips made. The most common errors were to write *a* as $+\frac{1}{2}$ instead of $-\frac{1}{2}$ or to write $-6 - \frac{1}{4}$ as $-\frac{23}{4}$. Some candidates used the method of equating coefficients to find the values of *a* and *b*, but did not earn full credit if they did not state the correct final form.

(ii) Candidates needed to interpret their completed square form to find the coordinates of the vertex. The answer candidates offered needed to correspond to their answer to **part (a)(i)**, as the question used the command word 'hence'. Solutions which did not follow, such as those from use of calculus, were not credited. Candidates who had an incorrect expression in **part (a)(i)** were able to earn both marks in this part provided they used their answer correctly.

(b) Most candidates knew the correct shape for the graph of $y = |x^2 - x - 6|$, however many candidates did not gain full marks due to poor accuracy. Candidates who did well in this part of the question plotted the points corresponding to each integer value of x from $-4 \leqslant x \leqslant 4$, and marked the coordinates of the turning point on the axes. Candidates who did less well tended to only plot the points $(-2, 0)$, $(3, 0)$ and $(0, 6)$ and just made a rough sketch of the ends of the graph. Some candidates joined their points with ruled sections – this was often the case for the two end sections. Most candidates made a good attempt at drawing cusps, with only a few turning the cusps into minima.

(c) Candidates who had not drawn an accurate graph were unable to use their graph to accurately solve the inequality. Many candidates knew to draw the line $y = 4$ and found 4 critical values from

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where their curve met this line which gained some credit. A few candidates disregarded the instruction to use their graph choosing an algebraic method instead, which could not be credited.

Question 4

(a) (i) A good number of candidates were able to integrate the exponential function. Some poor notation was seen, such as including the integral sign after the expression had been integrated. Common incorrect answers were misremembering the rule and differentiating to give $5e^{5x-2}$ or increasing the power by 1 and writing $\frac{1}{5}e^{5x-1}$.

(ii) This part proved more of a challenge and slightly fewer fully correct answers were given. Most candidates knew the integral should involve a natural logarithm but had difficulty identifying the correct coefficient of $\ln(4-3x)$. Common incorrect answers were $-3\ln(4-3x)$ or $\frac{1}{3}\ln(4-3x)$. Some candidates omitted to write brackets around the argument.

(b) Many fully correct answers were seen and most candidates gave sufficient working in this 'show that' question. Successful candidates gave the correct integral and showed the substitution of the limits to reach the given answer. Some candidates just rewrote $\sec^2\left(\frac{1}{2}x\right)$ as $1+\tan^2\left(\frac{1}{2}x\right)$ and then substituted in the limits rather than integrating.

Question 5

(a) Nearly all candidates gave the correct answer in this part.

(b) Many correct solutions were seen, showing a good understanding of the need to consider permutations or the product rule for counting.

(c) This part was more challenging and some candidates did not consider the size of their answer – often giving a higher value for the number of ways to make a number greater than 750 000 than they found in **part (b)** for a number greater than 700 000. Candidates who were more successful considered the cases logically: first considering the 1st digit to be 7 and recognising the need for the 2nd digit to be 5 or more, and then considering cases where the first digit is 8 or 9. A very common incorrect response was $3 \times 4 \times {}^7P_4 = 10\,080$ arising from candidates not separating out the two distinct cases. Many candidates did not make any progress or tried to use combinations rather than permutations.

Question 6

This was an unstructured question on finding a perpendicular bisector. Most candidates made reasonable progress and had formed a sensible plan to tackle the question. Many fully correct answers were given. The majority of candidates equated the equations of the curve and the line and then solved the resulting quadratic to find the coordinates of *A* and *B*. Arithmetic slips, either in simplifying the quadratic equation or finding the *y*-coordinates, were common and candidates who made an error but showed their working for finding the midpoint of *AB* and the gradient of *AB* were able to gain method marks. A very common error was to give the equation of the bisector in an incorrect form with non-integer coefficients. Candidates are advised to re-read the requirements of questions to make sure they have fully answered it.

Question 7

Candidates were well prepared for solving this quadratic trigonometric equation and a high number of candidates earned full marks. The majority of candidates used the correct trigonometric identity to simplify the equation to a quadratic in $\tan 3x$. Most candidates then factorised the quadratic equation and solved the resulting pair of equations. Some candidates stated and used a substitution to simplify the equation. A few of these candidates stated an incorrect substitution such as $y = \tan^2 3x$, which led to them wrongly finding $y = \tan^2 3x = 1$ rather than $\tan 3x = 1$. A common error was to reject the solutions to $\tan 3x = -2$ as the

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principal value was negative, rather than to add multiples of $180°$ in order to find further, positive solutions. A few candidates rounded prematurely and lost accuracy.

Question 8

(a) A good number of correct answers were seen. Common incorrect answers were $\frac{\pi}{6}$ or $\frac{2\pi}{3}$. The question required an exact value in radians, however some candidates gave their answer in degrees or as a rounded value in radians.

(b) Most candidates earned partial credit for calculating some relevant areas but fully correct answers were less common. It was hard to follow the work of some candidates as they did not state which areas they were calculating. Candidates who did well in this question calculated the areas of sectors *AOB* and *AQB* and triangles *AOB* and *AQB*, clearly showing which area they were finding at each step. They then used these areas to subtract the area of the smaller segment from the larger. Candidates who did less well did not state which areas they were calculating and had no clear plan for finding the required area.

Question 9

(a) Nearly all candidates were able to draw the required line. A few candidates did not plot the points accurately enough or drew a free-hand line.

(b) Candidates who did well in this part of the question transformed the equation $y = Ax^b$ into the linear form $\ln y = b\ln x + \ln A$ and recognised that the gradient of their graph in **part (a)** was equal to *b* and the *y*-intercept was equal to ln *A*. Candidates who did less well found the gradient and *y*-intercept but either did not link it to *A* or *b* or wrongly thought *A* was the gradient and *b* the *y*-intercept.

Question 10

(a) In this question candidates were required to differentiate the equation for s and equate their derivative to zero and solve to find t. Many candidates found the function challenging to differentiate as they had to use a combination of the chain and quotient rules. A few candidates tried to use the product rule, but often did not rewrite the original equation correctly as a product.

Some candidates stated the correct value of *t*, following an equation that had not been simplified sufficiently to justify this statement. Candidates, who have likely used their calculator to avoid the algebraic steps needed, should be aware that this was not given full credit as necessary working had been omitted.

(b) (i) Few fully correct answers were seen. Some candidates found the displacements at $t = 5$ or $t = 0$, but not both and, of those who found the distance travelled in the first 5 seconds, many forgot to double their answer to give the total distance when the particle returned to its starting point. A common error was to find the displacement from *A* at $t = 30$.

(ii) Again, few correct answers were seen. Candidates who set up the correct equation by equating the displacement to 10, were generally able to solve it correctly to give $T = 20$.

Question 11

This proved to be a challenging question for most candidates. Only the highest attaining candidates earned full marks, but a good number of candidates earned partial credit. Many candidates realised that the radius of the second circle was 5 but were unable to locate the centre of the circle. Candidates who were more successful, drew a sketch of the two circles. They then used Pythagoras' theorem to establish that the distance from the common chord to each centre was 4 units. This led to the deduction that the centre they needed was 8 units from the origin and a second application of Pythagoras' theorem to find this point. A very common error was to assume the centre was at either (5, 5) or (6, 6).

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