Principal examiner reports for teachers

Principal examiner reports for teachers summarise what candidates did well and what candidates needed to improve for this examination series only.

This report is to be used in conjunction with the question paper and mark scheme.

For guidance on teaching and learning we provide resources for many of our syllabuses.

Resource	Where to find it
Grade descriptions – Grade descriptions describe the level of performance typically demonstrated by candidates achieving the different grades awarded for a qualification.	School support hub Select: Subject > Resource finder > Syllabus and specimen materials
Schemes of work – Schemes of work are designed to support you in your teaching and lesson planning.	School support hub Select: Subject > Resource finder > Teaching and learning
Lesson planning – Guidance on how to plan a lesson.	Lesson planning
Resource plus – There may be additional resources such as teaching packs containing lesson plans, resources and worksheets and videos for aspects of your syllabus.	School support hub Select: Subject > Resource finder > Teaching and learning
Teaching tools	Teaching Tools
Exemplar candidate responses	School support hub Select: Subject > Resource finder > Teaching and learning
Learner guide – A guide for students to help them understand what the course involves.	School support hub Select: Subject > Resource finder > Teaching and learning
Community forums – Do you have a question or something to share? Our online forums are great way to keep up to date with your subject and the global Cambridge community.	Community forum on the school support hub
Access to scripts for this series.	Access to scripts service
Results analysis is available for some syllabuses.	Results analysis
Test maker is available for some subjects.	Test maker

Other services from Cambridge International Education

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ADDITIONAL MATHEMATICS

Paper 0606/11
Non-calculator

Key messages

What candidates did well

- Many candidates showed secure procedural fluency across a range of topics.
- Core methods were generally applied accurately, including expanding brackets, using trigonometric identities, applying the quotient rule and carrying out initial integration steps.
- Algebraic manipulation was generally accurate when candidates used the factor theorem, discriminants, geometric series and polynomial division.
- Candidates often presented clear working when they selected a suitable method and maintained consistent notation throughout their solution.

What candidates needed to improve

- Some candidates would benefit from carefully checking substitutions, expansions and signs, particularly when working with coordinates and algebraic expressions.
- Some responses would benefit from closer attention to the precise requirement of the question. This included considering all cases, stating the complete domain and giving a conclusion supported by appropriate reasoning.
- Some solutions would benefit from more complete reasoning and consistent notation, particularly when simplifying logarithmic expressions, identifying valid solutions and forming vector equations.

Comments on specific questions

Question 1

Comprehensive responses

- Many candidates made clear progress with this question and approached the modulus in a structured way, using either of the standard methods to form the two required cases.
- Candidates who set out their working carefully generally handled the manipulation accurately and reached the two valid solutions.

Limited responses

- When using the method of squaring both sides, some candidates formed the middle term in a way that led to an unintended expression, such as producing $28x$, which resulted in solutions outside the required pair.
- Some candidates wrote equations that represented the same case, for example both $5x+4=3x-2$ and $-5x-4=-3x+2$, so the two distinct cases were not established.
- In these repeated equations, further manipulation occasionally introduced additional unintended solutions.
- A number of candidates considered only one case of the modulus, so the final response did not include both required outcomes.

Question 2

(a) **Comprehensive responses**

- Many candidates identified the centre of the circle correctly as (3, 4).

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Limited responses

- Some candidates reversed the signs when identifying the centre, giving the coordinates as $(-,3,-4)$.

(b) Comprehensive responses

- Many candidates stated the radius correctly as $\sqrt{20}$ or $2\sqrt{5}$.

Limited responses

- Some candidates gave the radius as 20. The square root needs to be applied when comparing the equation of a circle with the standard form.

(c) Comprehensive responses

- Some candidates determined the coordinates of point B correctly and used the required geometric relationship appropriately.

Limited responses

- Some candidates would benefit from setting out the geometric relationships before beginning the coordinate calculations.
- Solutions were sometimes made unnecessarily long. *A* direct use of the relevant geometric relationship provided a clearer route to the coordinates of *B*.

Question 3

Comprehensive responses

- Many candidates recognised that the brackets needed to be expanded before applying the identity $\cot^2\theta - \operatorname{cosec}^2\theta = -1$.
- The majority of those who expanded the brackets correctly applied the identity accurately to reach the correct simplified form.
- A small number of candidates chose to convert the trigonometric functions to sine and cosine; some of these attempts were successful.

Limited responses

- A small number of candidates did not expand the brackets successfully, giving an incorrect expansion such as $9 + 25\cot^2\theta$.
- Some candidates could improve their responses by ensuring the coefficient of 50 is included after applying the identity. Careful checking of each step can help maintain accuracy and lead to a correct final expression.
- A few candidates gave the final answer as 32, showing a misunderstanding of the simplification process.

Question 4

Comprehensive responses

- Candidates who recognised that integrating the relevant expression leads to a natural logarithm generally made good progress.
- Those who handled the logarithmic manipulation accurately were able to progress to finding the constant a.

Limited responses

- Some candidates were unable to make a successful start, often not recognising that the integral of $\frac{1}{(3x+2)}$ produces a logarithmic function.
- The most common error occurred in the final manipulation of the logarithmic equation, with many unable to simplify sufficiently to solve for a.
- Errors were also seen when substituting the limits into the integrated expression, leading to incorrect evaluations.

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Question 5

(a) **Comprehensive responses**

- The majority of candidates used the factor theorem correctly to form the equation $a^4 + 3a^2 – 28 = 0$.
- Many candidates then factorised the equation successfully and identified the unique solution a = 2, correctly recognising that a must be positive.
- A significant number of candidates who reached the correct equation also used trial and improvement effectively to confirm the solution.

Limited responses

- A very small number of candidates substituted –a instead of a, leading to an incorrect starting point.
- Some candidates attempted to solve the equation by rewriting it as $a^2(a^2 + 3) = 28$, which often led to confusion.
- Few candidates tried to solve the equation by setting each factor equal to 28, resulting in incorrect solutions.

(b) **Comprehensive responses**

- A significant number of candidates used polynomial division successfully and obtained the correct quadratic factor.
- Those who carried out the division accurately were able to progress into the next part of the question.

Limited responses

- Some candidates could improve their responses by carefully checking the signs during the division process, as sign slips were a common issue.
- Some candidates carried forward an incorrect initial factor from **part (a)** into **part (b)**, as they were working from an incorrect initial factor.

(c) **Comprehensive responses**

- The majority of candidates recognised that the discriminant was the key feature to consider and were able to calculate it correctly.
- Many candidates identified the correct reasoning behind the result, explaining clearly that a negative discriminant means the quadratic factor has no roots, which was the required conclusion.

Limited responses

- Some candidates gave only a partial solution, stating simply that the discriminant was negative or restating the wording of the question without explaining its significance.
- A small number of candidates incorrectly stated that $(x – 2)$ is a root, showing a misunderstanding of the role of the discriminant.

Question 6

(a) **Comprehensive responses**

- Candidates who read the question carefully recognised that they were required to find the stationary point, and therefore either differentiated the expression or completed the square.
- Those who selected an appropriate method generally progressed well and produced correct working.

Limited responses

- Many candidates misunderstood what was being asked, often equating the original expression to 0 and solving for x, which did not address the demand of the question.
- A common issue was not identifying that the stationary point required differentiation or completing the square, leading to incomplete or incorrect solutions.

(b) **Comprehensive responses**

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- Candidates who found the correct value of k in **part (a)** were generally able to determine the correct range in **part (b)**.
- Those who understood the structure of the range typically produced values that were mathematically sound.

Limited responses

- Some candidates identified the correct set of values for the range did not always use appropriate notation, which limited the completeness of their answer.

(c) Comprehensive responses

- Candidates who used completing the square generally showed clear understanding of how to proceed.
- Those who completed the square correctly typically identified the correct positive value, rejecting the negative result as required.

Limited responses

- Some candidates did not reject the negative answer, giving both values instead of the required positive one.
- A significant proportion of candidates did not progressed further than rearranging the equation by swapping x and y, and were then unable to complete the process from that point.

(d)(i) Comprehensive responses

- A small number of candidates correctly identified the domain of the combined function and stated it using appropriate notation.
- Those who used their correct value of k from **part (a)** were generally able to determine that the domain should exclude $-\frac{4}{3}$.

Limited responses

- Few candidates found the correct domain, even when they had obtained the correct value of k earlier in the question.
- Some candidates recognised that $-\frac{4}{3}$ was the critical value but could improve by using the correct notation such as x instead of y.

(ii) Comprehensive responses

- Most candidates identified the correct order of the numbers, equated the indices appropriately, and solved for × successfully.
- Those who completed the final step accurately rejected the invalid value and stated the correct solution.

Limited responses

- Many candidates did not reject the value $x = -3$ despite otherwise correct working.

Question 7

(a) Comprehensive responses

- The majority of candidates used the quotient rule successfully and were able to structure the derivative correctly.
- Many candidates appreciated that the solution required equating the numerator to zero, and those who showed all steps—including factoring out e^x or explicitly demonstrating the division by e^x—met the full demand of the 'Show that…' instruction.

Limited responses

- A significant number of candidates could improve their responses by ensuring brackets are used correctly throughout their calculations. Consistent and accurate use of brackets helps to maintain the correct structure of statements and supports the correct application of subsequent steps.

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- Sign errors were common, particularly in the final term, where + e^{3x} frequently appeared.
- A minority of candidates attempted to use the product rule, which often complicated the working unnecessarily.
- A common manipulation error was the appearance of e^{2x^2} in the numerator, indicating confusion in expanding and simplifying.
- A notable number of candidates omitted the required step of showing e^x as a factor or demonstrating the division by e^x, moving directly from the expanded numerator to the final given answer and therefore not meeting the full 'Show that…' requirement.

(b) **Comprehensive responses**

- This question was frequently attempted successfully. The majority of candidates worked with the given equation and solved it correctly, either by using the quadratic formula or by completing the square.
- Most candidates were able to take the logarithm of their solution appropriately and then simplify their final expression to obtain integer coefficients.

Limited responses

- Some candidates could improve their responses by carefully simplifying solutions from the quadratic formula, for example rewriting $\frac{\left(-4 \pm \sqrt{32}\right)}{2}$ as $-2 \pm \sqrt{32}$, which is incorrect.
- A small number of candidates gave both the positive and negative solutions inside the logarithm, not recognising that only the valid domain value should be used.
- A notable number of candidates omitted brackets in their final expressions, leading to ambiguity or incorrect notation.

Question 8

(a) **Comprehensive responses**

- A number of candidates solved the equation correctly and identified the required value of 4.
- Those who handled the removal of logarithms accurately were able to progress cleanly to the correct numerical solution.

Limited responses

- Most candidates did not reach the correct answer, often giving $x = 3$ instead of $x = 4$.
- Another common error occurred when removing logarithms: candidates incorrectly wrote $x = 4^3$ instead of $x = 3^4$, leading to 81 rather than the required value.

(b) **Comprehensive responses**

- Candidates who dealt correctly with the index of 4 early in their working were generally successful, recognising that both the positive and negative roots of ½ needed to be considered. (Click here and type comments).
- Those who handled the indices accurately were able to state the correct pair of solutions.

Limited responses

- A common error was to give only a single answer, $x = \sqrt{5}$, arising from using only the positive root of $\frac{1}{2}$
- Candidates who did obtain both $+\frac{1}{2}$ and $-\frac{1}{2}$ sometimes then gave their answers as $x = \sqrt{5}$ and $x = -\sqrt{5}$, showing that they had not dealt correctly with the negative index of $\frac{1}{2}$.

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Question 9

(a) (i) Comprehensive responses

- This part was generally well answered, with most candidates recognising the relationship between the fourth and seventh terms of the geometric sequence and using it correctly to determine the common ratio.
- Candidates who set up the ratio in the correct order typically reached the correct value with clear, accurate working.

Limited responses

- A common error was to set up the equation the wrong way round, which led directly to an incorrect value for the common ratio.

(ii) Comprehensive responses

- Candidates who obtained the correct common ratio in **part (i)** were generally able to substitute it accurately into the sum formula, showing clear understanding of how the geometric series progressed.
- Those who handled the negative ratio carefully typically produced fully correct and well-simplified expressions.

Limited responses

- Many candidates could improve their response when simplifying expressions involving the negative common ratio by correctly handling signs and powers.
- These simplification slips meant that even correct substitution into the sum formula did not lead to a correct final answer.

(b) Comprehensive responses

- Many candidates answered this part well, efficiently identifying the common ratio using appropriate trigonometric identities then manipulated the resulting expression accurately and demonstrated that the sum to infinity simplifies to $\tan\theta$, meeting the full demand of the question.
- Candidates who maintained correct angle notation throughout showed accuracy in their response.

Limited responses

- Some candidates omitted angle notation in their working despite otherwise correct reasoning.

Question 10

Comprehensive responses

- Few candidates made a good start on this demanding question by integrating $f'(x)$ correctly and introducing the necessary constants of integration.
- Candidates who correctly recognised that a stationary point requires $f'(3) = 0$ were able to determine the first constant accurately.
- Those who established the correct derivative generally completed the remainder of the question well, with clear integration and appropriate substitution.

Limited responses

- Many candidates needed to take greater care when substituting the coordinates of the stationary point: many candidates used $y = \frac{36}{4}$ instead of recognising that the stationary point condition applies to the derivative, not the original function.
- Some candidates who integrated successfully then made sign errors when determining the second constant.
- These slips meant that otherwise promising solutions did not reach the fully correct final answer.

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Question 11

Comprehensive responses

- Many candidates made a solid start by correctly expressing the vectors OX, XB, XY, and OZ.
- Candidates with secure vector algebra were generally able to combine the vectors accurately to form an equation involving both a and b, and then solve successfully for m and n.

Limited responses

- Relatively few candidates were able to complete the full solution, with many struggling to combine the vectors into a single equation containing both a and b.
- Common errors included incorrect vector directions, sign slips when forming ZY, and equating coefficients of a and b to solve the simultaneous equations.
- These issues meant that even candidates who began well were often unable to reach the final correct values of *m* and *n*.

Question 12

Comprehensive responses

- Candidates who started by setting out the factorials clearly were generally successful. Those who simplified efficiently to obtain $(n-3)!$ in both denominators typically progressed well.
- Candidates with strong responses avoided unnecessary expansion and instead rewrote the numerator of $(n+3)!$ as $(n+3)(n+2)!$ on the LHS, which led to clean simplification and secure a complete method.

Limited responses

- Candidates who expanded factorials too fully often became entangled in algebraic complexity and were less successful than those who used concise factorial manipulation.
- A common error was adding 3 to 72 instead of subtracting, leading to an incorrect final value.

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ADDITIONAL MATHEMATICS

Paper 0606/12
Non-calculator

Key messages

What candidates did well
- Applying problem solving skills to unstructured questions.
- Showing an understanding of which learning objectives were relevant to questions.

What candidates needed to improve
- Candidates should read the question carefully to ensure they are not interpreting it incorrectly.
- Appreciation of the use of the word 'Hence' in the later part of a question.

Comments on specific questions

Question 1

(a) **Comprehensive responses**
- Many candidates produced a fully correct sketch with correctly shaped end points and passing through the points with coordinates $(-270°,-2)$, $(-90°,-2)$, $(90°,-2)$, $(270°,-2)$.

Limited responses
- Candidates did not have the correct curvature at the end points.
- The sketch did not pass through the points with coordinates $(-270°,-2)$, $(-90°,-2)$, $(90°,-2)$, $(270°,-2)$.**Error! Bookmark not defined.**

(b) **Comprehensive responses**
- Most candidates wrote down the correct amplitude.[Click here and type comments]

Limited responses
- An incorrect amplitude, usually 8, was written down.

(c) **Comprehensive responses**
- Most candidates wrote down the correct period, either in degrees or radians.

Limited responses
- An incorrect period was written down.

(d) **Comprehensive responses**
- Many candidates wrote down the correct set of values for k,

Limited responses
- Some candidates used incorrect inequalities in their solutions, although they had the correct critical values.

Question 2

(a) **Comprehensive responses**
- Many candidates found the correct gradient of the line perpendicular to AB and the midpoint of the line AB.

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- Most candidates formed the correct equation for the perpendicular bisector of AB and found the correct value of c.

Limited responses
- Some candidates did not use the perpendicular gradient.
- Some candidates needed to apply the correct method when calculating the midpoint of AB.

(b) Comprehensive responses
- Many fully correct responses were seen.
- Most candidates found the correct lengths of the lines AD and AB,
- Most candidates used their lengths for AD and BD in the given equation.

Limited responses
- Some candidates needed to apply the correct method when calculating the lengths of AB and BD.
- Some candidates made substitution errors using the given equation.
- There were arithmetic slips in some solutions.

Question 3

(a) Comprehensive responses
- Many candidates substituted in the value $x = -2$ into $f(x)$, and obtained the value of – 40.
- Some candidates used algebraic long division to obtain the remainder,

Limited responses
- Some candidates made arithmetic slips in their calculation.
- An incorrect substitution of $x = 2$ was made.
- Some candidates needed to apply the correct steps for algebraic long division.

(b) Comprehensive responses
- Many correct solutions were seen.
- Many candidates found a factor of $f(x)$ by inspection.
- Division of $f(x)$ by this factor lead to a quadratic quotient which could be factorised.

Limited responses
- Some candidates were unable to find a factor $f(x)$ of and were unable to progress.
- Some candidates, with a correct factor, made slips when finding the quotient by algebraic long division.

(c) Comprehensive responses
- Most candidates appreciated the meaning of the word ‘Hence’ and made use of their answers to **part (b)**.
- Most of these candidates were able to obtain at least one pair of solutions using their answers to **part (a)**.

Limited responses
- Many candidates only gave one pair of solutions, not recognising that the negative values were also solutions.
- Some candidates did not take note of the word ‘Hence’ and attempted to solve the equation by other means.

Question 4

(a) Comprehensive responses
- Most candidates were able to find the correct terms.

Limited responses
- Some candidates made arithmetic slips of used an incorrect method.

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(b) **Comprehensive responses**

- Some candidates found the correct sum by making use of their answers to **part (a)**
- Many candidates found the correct sum by attempting to find the sum of 100 terms and then subtracting the sum of 80 terms.

Limited responses

- Some candidates attempted to find the sum of 100 terms and then subtracting the sum of 81 terms or 79 terms.

$$\log_5 4x^2,$$

Question 5

Comprehensive responses

- Many correct responses were seen.
- Most of the candidates found the correct value of $\frac{dy}{dx}$ by differentiating the log function correctly.
- Most candidates found the value of y when $x = 3$ and attempted the tangent equation.

Limited responses

- Some candidates were unable to differentiate the log function correctly, by either writing it as $5\ln(2x-4)$ or using the chain rule.

Question 6

(a) **Comprehensive responses**

- Many candidates found the correct minor arc length of AB and added the two radii, equating this to the major arc length of AB.
- Most of these candidates were able to solve the resulting equation and obtain the correct value of α.

Limited responses

- Some candidates were unable to find the reflex angle AOB in terms of π and α.
- Some candidates introduced degrees into their calculations involving radians.
- Some candidates omitted the 2 radii in their calculations#

(b) **Comprehensive responses**

- Many candidates were able to obtain an equation of the correct form using their numeric α or $\pi - 1$.
- Some candidates recognised that $\pi^2 - 1$ could be written as $(\pi-1)(\pi+1)$ and were able to obtain the correct simplified answer.

Limited responses

- Some candidates did not simplify their final answer correctly when taking the square root.
- Some candidates made arithmetic slips and algebraic errors when attempting to simplify their equation.

Question 7

Comprehensive responses

- Many completely correct solutions were seen.
- Most candidates showed each step clearly and correctly.

Limited responses

- Some candidates did not show sufficient detail in going from $\frac{\cos^2 x}{\sin x}$ to the final answer of $\frac{\cos x}{\tan x}$.

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Question 8

(a) **Comprehensive responses**

- Some candidates found the value of x when y = 4 and used it in a correct derivative the find $\frac{dy}{dx} = -\frac{1}{11}$.
- A few candidates found $\frac{dx}{dy}$ and hence a correct solution.
- Most of these candidates the used the small changes rule to obtain a correct answer.

Limited responses

- Most candidates used the quotient rule or equivalent product rule to obtain $\frac{dy}{dx} = \frac{5(x-2)-(5x+1)}{(x-2)^2}$ or equivalent.
- Many candidates used x = 4 rather than x = – 9, as they had not read the information given in the question carefully.

Question 9

(a) **Comprehensive responses**

- Many correct solutions were seen, with candidates using the change of base rule correctly together with the subtraction rule.

Limited responses

- Some candidates appeared not to realise that $\ln x$ is the same as $\log_e x$.

(b) **Comprehensive responses**

- Many fully correct solutions were seen,
- Most candidates were able to use the laws of logarithms correctly to obtain a quadratic equation in terms of x which was usually solved correctly.

Limited responses

- Some candidates wrote $2\log_5 2x$ as $\log_5 2x^2$ rather than $\log_5 4x^2$ and were then usually able to form a quadratic equation.
- Some candidates did not use the fact that 1 can be written as $\log_5 5$.

Question 10

(a) **Comprehensive responses**

- Candidates who eliminated the common ratio in the terms of the geometric progression, obtaining $\frac{11x-1}{x+5} = \frac{x+5}{x-1}$ usually continued to obtain a value for x,
- A few candidates eliminated x, obtaining $\frac{5+r}{11r-1} = \frac{-1-5r}{r-1}$ and usually went on to obtain the correct value of r.
- Candidates with a quadratic equation in terms of x usually obtained the correct value of r and the first term.

Limited responses

- Few candidates needed to apply algebraic and arithmetic methods accurately to reach the correct solution.

(b) **Comprehensive responses**

- Candidates with a correct **part (a)** usually applied their values obtained in **part (a)** to the correct sum to infinity formula.

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Limited responses

- Candidates who had not obtained the correct values in **part (a)** were able to apply their values, provided $|\text{their } r| < 1$, to the sum to infinity formula.

Question 11

(a) **Comprehensive responses**

- Many candidates showed a clear solution, finding the vector **AB**, then vector **OC** and hence the vector **OD**.
- Some candidates used slightly different and equally successful methods.

Limited responses

- Some candidates needed to apply algebraic and arithmetic methods accurately to reach the correct solution.

(b) **Comprehensive responses**

- A correct answer for **part (a)** produced the required answer of $\frac{3}{4}$.

Limited responses

- Incorrect answers for **part (a)**.

Question 12

Comprehensive responses

- Many candidates produced well thought out and clearly presented solutions to this unstructured question

Limited responses

- Most candidates recognised the need to find the coordinated of the points P and Q. This was usually done successfully.
- Coefficient errors in integration or completely incorrect integration caused errors in solutions.
- Some candidates treated the appropriate unshaded area under the straight line as a triangle rather then a trapezium.

Question 13

Comprehensive responses

- Many candidates were able to write down a correct initial expression for ${}^{n+2}C_3 - {}^{n}C_3$ in terms of factorials or as the equation $\frac{(n+2)(n+1)n}{3!} - \frac{n(n-1)(n-2)}{3!}$.
- These candidates often continued to simplify this expression correctly to obtain the given result.

Limited responses

- Some candidates initially obtained correct initial expression for ${}^{n+2}C_3 - {}^{n}C_3$ in terms of factorials or as the equation $\frac{(n+2)(n+1)n}{3!} - \frac{n(n-1)(n-2)}{3!}$, and then equated this to n^2 and treated the result as an equation.
- Some sign errors and algebraic slips were often the cause of incorrect solutions.

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ADDITIONAL MATHEMATICS

Paper 0606/13
Non-calculator

Key messages

What candidates did well
- Most candidates attempted to apply the relevant methods to solve the questions.

What candidates needed to improve
- Candidates should ensure that they write down sufficient detail, each step required in a 'Show that' question.
- Candidates should recognise that when the word 'Hence' appears in a later part of a question, then work in the previous part or parts needs to be used.
- Some candidates need to practice their algebraic skills.

Comments on specific questions

Question 1

(a) **Comprehensive responses**
- Many candidates completed the square correctly, using the given expression.

Limited responses
- Candidates were able to obtain $2\left(x-\frac{3}{2}\right)^2$ and made calculation errors with the constant c.

(b) **Comprehensive responses**
- Candidates tended to opt for the 'otherwise; option, obtaining the critical values by factorisation of $2x^2-6x+5$.

Limited responses
- Sign errors when using the critical value resulted in incorrect solutions.

Question 2

Comprehensive responses
- Many candidates attempted to form two equations using the given information.
- These candidates usually attempted to solve their equations and find the first term and the common difference.

Limited responses
- Some candidates needed to apply the correct arithmetic steps when forming and solving the two equations.

Question 3

(a) **Comprehensive responses**
- Candidates formed a two term quadratic equation after a correct change of base.

Limited responses

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- Candidates correctly changed the base of a term and used an incorrect method involving the power rule to solve the equation.

(b) **Comprehensive responses**

- Some candidates formed a quadratic equation in terms of 2^x.
- These candidates solved this quadratic equation and then found the only valid solution.

Limited responses

- Some candidates needed to apply the correct arithmetic steps when forming the quadratic equation.
- Some candidates attempted to give two solutions.

(c) **Comprehensive responses**

- Many candidates formed the quadratic equations $x^2 + 3x - 10 = 0$ and $x^2 + 3x + 2 = 0$.
- Most of these candidates solved these equations correctly and obtained all 4 correct solutions.

Limited responses

- Some candidates attempted a method of squaring which resulted in a quartic equation.

Question 4

(a) **Comprehensive responses**

- Most candidates found $\mathrm{p}(2)$ and showed the value of each term so that a sum of zero could be seen clearly.

Limited responses

- Some candidates did not show the value of each term.

(b) **Comprehensive responses**

- Most candidates used the factor given in part **(a)** to find $\mathrm{p}(x)$ as a product of this linear factor and a quotient.
- Many of these candidates were then able to factorise the quotient and write $\mathrm{p}(x)$ as a product of linear factors.

Limited responses

- Some candidates made arithmetic slips in the algebraic long division.

(c) **Comprehensive responses**

- Candidates appreciated the use of the word 'Hence' and attempted to use their solutions for part **(b)** to solve the quadratic equation in u^2.

Limited responses

- Some candidates only gave the positive solutions using their results from part **(a)**.

Question 5

(a) **Comprehensive responses**

- Some candidates were able to produce a correct sketch of the graph.

Limited responses

- Incorrect sketches usually included incorrect positioning, incorrect amplitude or an incorrect period.

(b) **Comprehensive responses**

- Candidates produced a correct sketch of the graph.

Limited responses

- Some candidates attempted a sine curve passing through the origin with an amplitude of 4 or a sine curve with period 180° with the correct endpoints.

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Question 6

(a) **Comprehensive responses**

- Candidates obtained the relationship $r = \frac{h}{\sqrt{3}}$ from the given diagram and substituted this into the formula for the volume of a cone.

Limited responses

- Some candidates needed to apply the correct steps when obtaining the relationship between h and r.

(b) **Comprehensive responses**

- Few correct solutions were seen.
- Candidates found $\frac{\mathrm{d}V}{\mathrm{d}h}$ and attempted to use the rates of change formula $\frac{\mathrm{d}V}{\mathrm{d}h} \times \frac{\mathrm{d}h}{\mathrm{d}t} = \frac{\mathrm{d}V}{\mathrm{d}t}$, using $\frac{\mathrm{d}V}{\mathrm{d}t} = 50$.

Limited responses

- Candidates needed to apply the correct steps in the differentiation of $V = \frac{1}{9}\pi h^3$, with respect to h.
- Candidates needed to apply the correct steps in the application of rates of change.

Question 7

Comprehensive responses

- Candidates formed the equation ${}^{20}C_r = \frac{4}{3} \times {}^{20}C_{r+1}$.
- Using this equation, candidates formed another equation in terms of factorials.
- The factorial terms were simplified leading to the equation $\frac{1}{20-r} = \frac{4}{3} \times \frac{1}{r+1}$, which leads to the correct solution of $r = 11$.

Limited responses

- Many candidates need to apply the correct steps when dealing with the simplification of the first equation.
- Many candidates wrote $\left(20-\left(r+1\right)\right)$ as $\left(21-r\right)$ instead of the correct $\left(19-r\right)$.

Question 8

(a) **Comprehensive responses**

- Candidates obtained the correct answer.

Limited responses

- Incorrect notation was used or an incorrect range was given.

(b) **Comprehensive responses**

- Candidates gave the correct answer.

Limited responses

- Incorrect notation was used or an incorrect domain was given.

(c) **Comprehensive responses**

- Many candidates used a completely correct method to find the inverse function.

Limited responses

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- Some candidates made arithmetic slips or had notation errors.

(d) **Comprehensive responses**

- Candidates produced 2 correct graphs and stated the exact coordinates of the intercepts with the axes.

Limited responses

- Some candidates sketched one correct curve.
- Some candidates omitted the exact coordinates of the intercepts with the axes.

Question 9

(a) **Comprehensive responses**

- Candidates were able to write down the equation of the circle and substitute in for either x or y using the line equation.
- The discriminant of the resulting quadratic equation was equated to zero and the resulting quadratic equation solved.

Limited responses

- Most candidates were able to write down the equation of the circle.
- Many candidates needed to apply the correct steps when substituting in for either x or y and when finding the discriminant.

(b) **Comprehensive responses**

- Candidates gave the correct answer.

Limited responses

- Candidates were unable to give a correct answer.

Question 10

Comprehensive responses

- Candidates drew a correct diagram to represent the parallelogram.
- Candidates used a correct method by finding, for example, vectors $\overrightarrow{OD}, \overrightarrow{OE}$ and $\overrightarrow{DE}$.

Limited responses

- Candidates mislabelled their parallelogram.
- Candidates attempted the question without drawing a diagram.

Question 11

Comprehensive responses

- Candidates used their problem-solving skills to obtain a plan of action for the solution of this unstructured question.
- Candidates first found the coordinates of the points of intersection between the line and the curve.
- The area under the curve between these two points was then found using integration.
- This area was the subtracted from the area of the trapezium formed under the straight line.

Limited responses

- Most candidates attempted to fine the coordinates of the points of intersection of the line and the curve.
- Some candidates needed to apply integration techniques accurately when finding the area under the curve.
- Some candidates made arithmetic slips.

Question 12

(a) **Comprehensive responses**

- Candidates obtained a derivative of the correct form using the chain rule.

Limited responses

- Candidates needed to apply the correct application of the chain rule.

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(b) **Comprehensive responses**

- Candidates used their answer to part **(a)** to find $\frac{dy}{dx}$ at the point where $x = a$.
- Candidates then found the gradient of the normal at this point and found the equation of the normal.
- The values $x = 0$ and $y = 0$ were substituted into this normal equation to find the exact value of a.

Limited responses

- Candidates used a correct method to find the equation of the normal using their answer to part **(a)**.

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ADDITIONAL MATHEMATICS

Paper 0606/21
Calculator

Key messages

What candidates did well
- Many candidates produced work that was well-structured, logically set out and easy to follow.
- Many candidates showed sufficient working to communicate their method clearly.
- Many candidates made sensible use of the formula page to ensure the formulas they used were correct.
- Many candidates gave their solutions to a suitable degree of accuracy.

What candidates needed to improve
- When an answer is required correct to 3 significant figures, candidates should ensure they show at least 4 significant figures for all intermediate values.
- Some candidates did not show sufficient working. When values have been found using incorrect expressions or values, for example, the method used to find them must be shown.
- Some candidates overwrote an error and then corrected it by writing on top of the original work instead of rewriting it. This sometimes resulted in work that was ambiguous. Candidates should cross out incorrect work and rewrite it.
- Some candidates used their calculators to evaluate definite integrals rather than showing their method.
- When candidates have been asked to show that a result is true, they need to understand that it is acceptable to use that result in further parts of the question, if needed, even if they have been unable to generate a correct argument to show the result is valid.

Comments on specific questions

Question 1

(a) Comprehensive responses
- Many candidates correctly sketched the graph of the cubic polynomial, with the maximum in the second quadrant and the minimum in the third quadrant, along with the correct *x*– and *y*–intercepts.

Limited responses
- Some candidates placed the minimum point on the *y*-axis.
- Some candidates did not label the *y*-intercept or incorrectly thought it was –15.
- Some candidates drew a negative cubic graph.
- A few candidates drew the graph of a quadratic function.

(b)(i) Comprehensive responses
- Candidates with a correct curve generally used their curve to give both inequalities correctly.

Limited responses
- Some candidates gave the regions where the curve was below the x-axis, instead of above the axis.
- Some candidates only obtained only one of the inequalities correctly – usually $x > \frac{1}{2}$.
- Some candidates needed to relate the curve to the inequality, ensuring they used information from both parts of the question when solving algebraically.

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Question 2

(a) **Comprehensive responses**

- Nearly all candidates correctly stated the amplitude.

Limited responses

- A few candidates thought the amplitude was 6 or 8.

(b) **Comprehensive responses**

- Most candidates knew the period of $y = \cos x$ is 360 and correctly multiplied this period by 8 to give the period as 2880.

Limited responses

- A few candidates thought the period of $y = \cos x$ was 180 and so found half of the total period.
- A few candidates worked in radians rather than degrees.

(c) **Comprehensive responses**

- Many candidates successfully rearranged $4\cos\left(\frac{x}{8}\right)+2=0$ to $\cos\left(\frac{x}{8}\right)=-\frac{1}{2}$ and then correctly found that $\frac{x}{8}=\pm 120$ leading to $x = –960$ and 960.

Limited responses

- Some candidates omitted to find the solution $x = –960$ after finding $x = 960$.
- Some candidates were unsure how to proceed after finding $\cos^{-1}(-\frac{1}{2})=120$.
- A few candidates listed 120 as a solution.
- A few candidates worked in radians.
- A few candidates made a sign error when rearranging the trigonometric equation.

(d) **Comprehensive responses**

- Many candidates drew a correctly shaped cosine graph with amplitude 4, maximum at (0, 6), and correctly placed x-intercepts.

Limited responses

- Some candidates did not take care to ensure the x-intercepts were in the correct positions.
- Some candidates did not relate the curve to answers in the previous parts of the question and so did not draw a cosine graph with correct period or amplitude even when they had answered **part (a)** and **part (b)** correctly.

Question 3

(a) **Comprehensive responses**

- Most candidates formed both equations correctly from the information given.
- Most candidates correctly simplified and then solved the simultaneous equations accurately, either by substitution or elimination.

Limited responses

- Some candidates needed to correctly translate the problem into algebraic equations.
- A common mistake amongst these candidates was to multiply the expression for the 6th term by 1.5 instead of the 3rd term.
- Some candidates used an incorrect formula for finding the sum of terms. Candidates are advised to refer to the formula page during the examination.
- Some candidates made algebraic slips when simplifying or solving the simultaneous equations. It is sensible to check that answers fit the information given in the question.
- Several candidates misread the sum of the first 10 terms as 225 rather than 255.

(b) **Comprehensive responses**

- Most candidates correctly substituted the values of a and d into the arithmetic series sum formula and formed a correct inequality involving 40 000.

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- Many candidates simplified their expression to obtain a quadratic inequality in solvable form.
- Many candidates then showed their solution of the quadratic inequality and correctly rejected the negative solution. They then correctly interpreted the positive solution and rounded it to the next whole number.
- Some candidates did not obtain the correct values in **part (a)** and did not show clear working for solving their quadratic inequality.

Limited responses

- Some candidates did not obtain the correct values in **part (a)** and did not show sufficient working here. Candidates should ensure they express any quadratic inequalities in solvable form and show the method of solution.
- Some candidates omitted to interpret their solution to the inequality, giving a non-integer value or rounding down rather than up to the nearest integer.
- A few candidates incorrectly expanded their brackets and obtained a linear equation instead of a quadratic or made other algebraic slips.
- A few candidates relied solely on trial and improvement without sufficient justification or did not clearly identify the least integer satisfying the condition. Candidates should use algebraic methods to solve problems in this paper.
- A few candidates incorrectly expressed their answer as $n > 160$.

Question 4

(a) **Comprehensive responses**

- Many candidates found the gradient and equation of the straight line using the given coordinates.
- Some candidates correctly rearranged the equation of the straight line to the required form.

Limited responses

- Some candidates did not complete the rearrangement to the required form and left their final answer as $y = \frac{1}{3}e^{-1.5x^2+19.2}$.
- Some candidates did not transform their linear equation to the exponential form.
- A few candidates incorrectly expressed $e^{-1.5x^2+19.2}$ as $e^{-1.5x^2} + e^{19.2}$.
- A few candidates incorrectly treated the coordinates (4.64, 12.24) as (12.24, 4.64), leading to an incorrect method for determining the constant c.
- A few candidates used the midpoint of the given coordinates. While not incorrect, this was not a necessary step.

(b) **Comprehensive responses**

- Most candidates substituted $x = 3$ correctly into the equation obtained in **part (a)** and evaluated the exponential expression accurately.

Limited responses

- Some candidates substituted into an incorrect equation obtained in **part (a)**.

(c) **Comprehensive responses**

- Some candidates used logarithms correctly to rearrange their equation to make x^2 the subject and then obtained both values of x.
- A few candidates worked with the equivalent exponential equation $y = \frac{1}{3}e^{(-1.5x^2+19.2)}$

Limited responses

- Some candidates found x^2 correctly and then omitted the negative solution when finding the square root.
- A few candidates truncated values of x to ±3.24 instead of rounding to 3 significant figures.
- Many candidates made algebraic errors when rearranging the equation to make x^2 the subject. Those starting from $y = \frac{1}{3}e^{-1.5x^2+19.2}$ generally made more algebraic slips.
- Most candidates with an incorrect equation in **part (a)** were unable to express their working correctly in the required square root form.

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Question 5

(a) **Comprehensive responses**

- Many candidates used the chain rule to correctly differentiate $y = \tan^3 5x$ to reach $3\tan^2(5x) \times 5\sec^2(5x)$ and then used $\sec^2 5x = 1 + \tan^2 5x$ to correctly write their derivative in terms of $\tan 5x$.
- A few candidates took a less efficient route and used the product rule on $y = \tan 5x \tan^2 5x$.

Limited responses

- Some candidates got as far as $15\tan^2 5x \sec^2 5x$ and did not complete their answer by writing the derivative in terms of $\tan 5x$ only.
- Some candidates omitted the chain rule factor of 5.
- Some candidates differentiated $\tan^3 5x$ incorrectly as either $3\tan^3 5x$ or $15\left(\sec^2(5x)\right)^2$.
- Some candidates used an argument of x rather than $5x$.

(b) **Comprehensive responses**

- Many candidates correctly solved $\tan^2 5x = 0$ and gave all solutions within the given interval.

Limited responses

- Some candidates found only one or two solutions, usually $x = 0$ and/or $x = \frac{\pi}{5}$, instead of all the required solutions.
- A few candidates did not consider that $\sec^2 5x \neq 0$ and $\tan^2 5x \geqslant 0$ and incorrectly obtained values from $\sec^2 5x = 0$ or from $1 + \tan^2 5x = 0$.
- Some candidates were unable to obtain a suitable form for the derivative and so were unable to solve the equation.

Question 6

Comprehensive responses

- Many candidates identified that there were 6 choices for the leading digit when the number started with four or more and ended in a zero, and 5 choices when the number ended in a five.
- Many candidates then correctly evaluated the required permutations.

Limited responses

- Some candidates only considered some of the possible cases – without considering both ways of meeting the required number.
- Some candidates did not consider that when the number ended in 5, it could not then start with a 5 so over counted the possibilities.
- Some candidates attempted to use combinations rather than permutations.

Question 7

Comprehensive responses

- Most candidates correctly expanded $\left(1 + \frac{1}{4x}\right)^2$ and found the first 3 terms in the expansion of $(2 - 3x)^6$.
- Many candidates then correctly identified the correct 3 products that were independent of x and summed them to find the coefficient of the term independent of x.

Limited responses

- Some candidates were unable to expand $\left(1 + \frac{1}{4x}\right)^2$ correctly.

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- Some candidates correctly expanded both $(2-3x)^6$ and $\left(1+\frac{1}{4x}\right)^2$. They were then unable to identify the correct 3 products.
- Some candidates fully expanded $(2-3x)^6$ which was not necessary.

Question 8

(a) **Comprehensive responses**

- Many candidates correctly found and expression, in terms of x, for AP, either using Pythagoras' theorem or the perimeter and then used it to form a valid equation in x.
- Some candidates then solved their equation accurately to obtain $x = \frac{81}{14}$ and used x in a correct trigonometric ratio to give θ correct to 4 decimal places.

Limited responses

- A few candidates needed to correctly solve their equation in x.
- Some candidates just stated the value of θ as the given value of 0.885 without first showing a more accurate value.
- A few candidates lost accurately through rounding prematurely.
- A few candidates formed an incorrect equation for the perimeter of triangle APC.
- A few candidates used the given value of θ to show the perimeter of the triangle was 18 cm. Candidates should not assume the validity of a result they are trying to show is true by using it in a solution which works back to another value given in the question.

(b) **Comprehensive responses**

- Nearly all candidates used the formula $s = r\theta$ correctly to find the length of arc AB.

Limited responses

- A few candidates used the formula for area of a sector.
- A few candidates found the length of the chord AB.
- A few candidates did not attempt this part despite being given the correct angle to use in the previous part of the question.

(c) **Comprehensive responses**

- Most candidates correctly calculated the area of the sector.

Limited responses

- A few candidates did not include $\frac{1}{2}$ in the area formula.
- A few candidates found the arc length instead of the area.
- A few candidates did not attempt this part.

Question 9

Comprehensive responses

- Most candidates rearranged the trigonometric equation correctly to $\sin(\theta - 0.5) = \frac{2}{5}$.

  They then found all three angles in the interval $-3.5 \leqslant \theta \leqslant 3.5$ and then added 0.5 to each of these to obtain the correct three values of θ.

Limited responses

- Many candidates obtained only the base angle $\sin^{-1}\frac{2}{5}$ and went on to get just one solution for $\sin(\theta - 0.5)$.
- Some candidates only found one futher solution by subtracting the base angle from π.
- Some candidates lost accuracy either through premature approximation or else not giving their values correct to 3 significant figures.
- A few candidates found the solutions of $\sin(\theta - 0.5) = \pm\frac{2}{5}$.

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- A few candidates incorrectly gave the second solution as $\theta = \pi - 0.912$.
- Some candidates could not rearrange the equation into solvable form.

Question 10

Comprehensive responses
- Many candidates differentiated the function correctly, determined the gradient of the normal and formed the correct equation of the normal.
- Some candidates found both intercepts accurately and used them to calculate the area of triangle *OPQ*, giving the final answer correct to 3 significant figures.
- Many candidates showed clear and logically thought out working.

Limited responses
- Some candidates found the equation of the tangent instead of the normal.
- Some candidates needed to apply appropriate methods when differentiating $\ln(3x^2 + 5)$ or when applying the product rule.
- A few candidates rounded intermediate values, leading to a loss of accuracy in the final answer.
- Most candidates were unable to differentiate correctly, particularly the term $\frac{6x}{3x^2 + 5}$.
- Some candidates needed to apply appropriate methods when finding the gradient or equation of the normal, leading to incorrect subsequent answers.
- A few candidates did not give their final answer to 3 significant figures as required in the question.

Question 11

Comprehensive responses
- A few candidates made a correct plan for finding the shaded region and correctly found the coordinates of B and C before setting up a correct integration.
- A few candidates then went on to obtain both of the correct antiderivatives $3x + \ln(1 + x)$ and $4x + \frac{12}{1 + x}$, substituted the correct limits, and gave the exact area of the shaded region.

Limited responses
- Many candidates did not formulate a correct plan for finding the area after correctly finding the coordinates of the points B and C.
- Many candidates were able to find one of the correct antiderivatives – usually $3x + \ln(1 + x)$.
- Many candidates did not work with exact values or used the integration function on their calculator.

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ADDITIONAL MATHEMATICS

Paper 0606/22
Calculator

Key messages

What candidates did well

- Many candidates offered well-thought-out solutions and stated their results clearly, taking care to use correct mathematical form, for example using brackets where necessary.
- Some candidates demonstrated strong analytical skills by breaking down problems problems and identify a suitable sequence of steps to solve them.
- A good number of candidates seemed to have read each question carefully and offered complete attempts at solutions using all the information given.

What candidates needed to improve

- Some candidates needed to refer to the List of formulas given on page 2 of the examination paper. This would have helped them to avoid incorrectly recalling formulas and equations that are given to them.
- A few candidates needed to read each question a little more carefully to interpret and use all key statements and information, such as whether they should be working in degrees or radians.
- A few candidates needed to make sure that numerical values were simplified as, for example, values which simplify to integers, such as $\frac{6}{2}$ and $16e^{4\ln 2} - 40e^{2\ln 2}$, should have been written as integers.
- Some candidates needed to take notice of the instructions regarding accuracy of answers given on the front page of the examination paper, particularly in relation to angles.
- The problems set were all solvable using algebraic strategies. Some candidates attempted to solve some of the problems using trials. Occasionally this produced a complete solution. Commonly, it produced an incomplete result or no result at all.
- Some candidates omitted key method steps when solving unsimplified equations or systems of equations, suggesting that these method steps had been carried out using a calculator. All necessary steps in a method, such as writing an equation or system of equations in a form that can be solved using simple algebraic processes without using the calculator, should be shown.
- Some candidates needed to organise and present their responses more clearly to help ensure their reasoning is easy to follow and prevent miscopying of their own work.
- Some candidates needed to take more care with correct mathematical form as, for example, some omitted brackets from the arguments of trigonometric functions and/or logarithms and some wrote vectors in the incorrect form $\begin{pmatrix} a\mathbf{i} \\ b\mathbf{j} \end{pmatrix}$.
- For the graph of the function in **Question 8(b)(iii)**, some candidates did not appreciate that the domain was an important feature of the graph that should have been indicated or, at least, very clearly implied.
- For example, some candidates used a starting point for $y = f(x)$ that was closer to $x = -2$ than $x = -1$.

Comments on specific questions

Question 1

(a) Comprehensive responses

- Many candidates successfully used the method of completing the square, as required, to answer this part of the question.

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Limited responses

- Some candidates made slips when completing the square, such as omitting the power 2 or equating the expression to 0.
- Some candidates did not evaluate $\frac{6}{2}$ as 3 and gave the answer $\left(\frac{6}{2}, 1\right)$.
- A few candidates stated $(x – 3)^2 + 1$ and then gave the answer (3, –1) or (3, –19).
- Some candidates found the correct point using an unacceptable method, such as calculus to find x and then $y = x^2 – 6x + 10$ to find y.

(b) Comprehensive responses

- Many candidates offered fully correct solutions.
- A good number of candidates gave the answer in the form $y – 7 = –3(x – 6)$ which was the simplest way to use all the information.

Limited responses

- A few candidates found the correct gradient of AC then went on to find the perpendicular gradient.
- A few candidates found the correct gradient, substituted this and (6, 7) into $y = mx + c$ and made an arithmetic slip when evaluating c.
- A few candidates stated a correct gradient calculation for their AC then made an arithmetic error when evaluating it.
- A few candidates omitted to include y in their answer and offered, for example, equation = $–3x + 25$.

Question 2

Comprehensive responses

- Some candidates offered accurate, complete and fully justified solutions, including the use of the discriminant equal to zero in their final argument.
- Most candidates wrote a correct unsimplified form of the discriminant and offered well-thought-out, step by step solutions.
- Many candidates were able to simplify their correct unsimplified form to $4k^2 + 33$.

Limited responses

- Some candidates did not use $4k^2 + 33 = 0$ in their conclusion.
- A few candidates needed to pay closer attention in their concluding step, such as writing $k^2 = \sqrt{\frac{-33}{4}}$ or making a statement such as ‘you cannot have a negative square root’.
- A few candidates were unable to simplify their correct unsimplified form with common errors being an incorrect constant, the inclusion of a term in k or $2k^2$ rather than $4k^2$.
- A small number of candidates needed to refer to the List of formulas on page 2 of the examination paper, as they were unable to recall that the discriminant is $b^2 – 4ac$.

Question 3

(a) Comprehensive responses

- Many candidates stated a fully correct derivative.

Limited responses

- Some candidates correctly differentiated $\cos(5x+ 3)$ and incorrectly differentiated $\sqrt{x+1}$, for example stating $\frac{1}{2}(x+1)-5\sin(5x+3)$.
- Some candidates differentiated $\sqrt{x+1}$ correctly and offered a partially correct derivative for $\cos(5x + 3)$, for example $\frac{1}{2}(x+1)^{-\frac{1}{2}}+5\sin(5x+3)$ or $\frac{1}{2}(x+1)^{-\frac{1}{2}}-\frac{1}{5}\sin(5x+3)$.
- A few candidates were able to correctly differentiate both $\sqrt{x+1}$ and $\cos(5x + 3)$ and then went on to use them in an attempt at the product rule.

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- A small number of candidates rewrote $\cos(5x + 3)$ as $\cos 5x + \cos 3$ and attempted to differentiate.
- A few candidates differentiated $\cos(5x + 3)$ as $\cos 5$ or $-5\sin(5x + 3)\cos(5x + 3)$.
- A small number of candidates omitted brackets around $5x + 3$ or included '$+ c$' in their answer.

(b) **Comprehensive responses**

- A good number of candidates offered a fully correct, simplified solution, including a constant of integration.
- Some candidates correctly stated $3\tan\frac{x}{3}$ then omitted the constant of integration.
- A few candidates correctly stated $\frac{1}{\frac{1}{3}}\tan\frac{x}{3}+c$ then made an error when simplifying.

Limited responses

- Some candidates offered the answer $\frac{1}{3}\tan\frac{x}{3}+c$ or $\frac{1}{3}\tan\frac{x}{3}$.
- Some candidates rewrote $\sec^2\frac{x}{3}$ as $\frac{1}{\cos^2\frac{x}{3}}$ or $1 + \tan^2\frac{x}{3}$ and made no progress.
- A few candidates treated $\sec^2\frac{x}{3}$ as a product of $\sec^2$ and $\frac{x}{3}$, showing a misunderstanding of the trigonometric function.
- A few candidates treated $\sec^2\frac{x}{3}$ as if it were a power of x in some way, for example raising the power by 1.

Question 4

(a) **Comprehensive responses**

- Many candidates attempted to draw a smooth curve, with no ruled sections, that was clearly an attempt at the graph of the modulus of a quadratic function.
- Most candidates indicated the correct y-intercept and many drew the maximum point on the y- axis.
- Candidates usually indicated the correct x-intercepts either in exact form or as decimals accurate to 3, or more, significant figures.
- A good number of candidates attempted to draw cusps.

Limited responses

- Some candidates drew graphs that clearly had ruled sections.
- Some candidates drew graphs that had incorrect curvature for one or more sections.
- A few candidates stated incorrect, or insufficiently accurate, x-intercepts.
- A few candidates omitted to state some or all of the intercepts.
- Some candidates drew their local maximum in the first or second quadrant.
- Candidates who plotted and joined points could benefit from practicing drawing smooth shape, for example curves which had minimum points at $(\pm 2, 1)$ or graphs with incorrect curvature.
- Some responses bore no resemblance to the graph of the modulus of a quadratic function, for example a ruled, V-shaped graph with x-intercept at $\sqrt{5}$.

(b) **Comprehensive responses**

- Some candidates offered fully correct solutions, often by forming and solving simple pairs of linear simultaneous equations, for example $2.5a + b = 4$ and $-1.5a + b = -4$.
- A few candidates offered fully correct solutions using the, more complex, method of forming and solving quadratic simultaneous equations.
- Some candidates offered fully correct solutions using the gradients of appropriate line segments, for example those joining $(0.5, 0)$ and $(2.5, 4)$ or $(-1.5, -4)$ and $(2.5, 4)$.

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Limited responses

- Some candidates found one correct expression, often $2x - 1$, and made no attempt to state or find the other expression.
- A reasonable number of candidates found one correct expression, again often $2x - 1$, then attempted to use a full method to find the other expression and made an arithmetic slip.
- A few candidates found one correct expression and then stated the answer in an incorrect form, for example $\pm 2x - 1$ or $\pm 2x \pm 1$ or $\pm (2x - 1) = 4$ or $f(x) = |-2x + 1|$, $f(x) = |2x - 1|$.
- Some candidates used a correct pair of linear equations to eliminate one unknown then made a slip when solving to find the value of at least one of the unknowns.
- Some candidates listed the four possible linear equations in a and b and made no further progress or combined them so that the only solutions found were $a = 0$ and $b = 4$.
- Some candidates formed a quadratic in a and b such as $(2.5a + b)^2 = 16$ and either expanded incorrectly or made no further progress.
- Some candidates working with quadratic forms made slips in simplifying to find $a = -2b$, or similar. Other candidates found this relationship and did not use it in any productive way.
- A few candidates attempted to form an expression using the product $(2x - 5)(2x + 3)$ in some way.
- Candidates who used trials or inspection often did not find both expressions.
- A few candidates made no correct interpretation of the modulus and stated, for example, $2.5a + b = 4$ and $-1.5a + b = 4$ only or $(2.5a + b)^2 = 4$.

Question 5

(a) **Comprehensive responses**

- Some candidates gave fully correct responses.
- A good number of candidates understood the need to separate the problem into two sets such as
  - 'the numbers that ended with 2, 4, 6, or 8' plus 'the numbers that ended with 0'.
  - 'the numbers that started with 2, 4, 6, or 8' plus 'the numbers that started with 1, 3, 5, 7 or 9'.
  - 'all possible arrangements of 0 to 9' less 'the arrangements of 0 to 9 that started with 0 plus the odd numbers'.

Limited responses

- A few candidates offered a fully correct sum or difference then evaluated it incorrectly.
- Many candidates offered a single calculation or value that was part of a correct method.
- A few candidates did not separate the problem into distinct, mutually exclusive cases. Commonly these candidates evaluated $8 \times {}^8P_4 \times 5 = 67200$.
- Some candidates incorrectly used combinations.
- A few candidates offered answers that were larger than the number of all possible arrangements of the digits from 0 to 9.

(b) **Comprehensive responses**

- Many candidates gave fully correct responses.
- A good number of candidates made a list or table, showing they had interpreted the information given correctly and separated it into three possible cases, from which they derived the products needed for the correct solution.

Limited responses

- Some candidates omitted one of the products from their sum, or repeated a product they had already included.
- Some candidates included cases such as 4 teachers, 4 students, 2 others.
- A few candidates interpreted the information given correctly, then formed a sum of three sums instead of three products.
- Candidates who attempted to subtract the cases to be discarded from all possible cases sometimes omitted one or more of the cases to be discarded.
- Some candidates incorrectly used permutations.
- A few candidates simply evaluated ${}^9C_4 + {}^7C_4$ or ${}^{10}C_4 \times {}^{10}C_6 + {}^{10}C_5 \times {}^{10}C_5 + {}^{10}C_6 \times {}^{10}C_4$.

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Question 6

Comprehensive responses
- A few candidates offered a fully correct response.
- A good number of candidates stated and simplified the first three terms of each expansion at or near the start of their solution, helping them to deduce the correct strategy.

Limited responses
- Some candidates offered only positive values for a and b in an otherwise correct solution.
- A few candidates rejected or did not use the negative value for a.
- A few candidates omitted one of the terms needed to find the value of c, often this was $20a^4$.
- A few candidates made a slip when simplifying ${}^5C_2(ax)^2$, offering $10ax^2$ for that term.
- Some candidates did not state the expansions they were using and then chose incorrect
- strategies, such as $a = u_1t_1$, $b = u_2t_2$ and $c = u_3t_3$, where u_n were terms of $(a + x)^n$ and t_n were terms of $(1 + ax)^5$, leading to the values $a = 2$, $b = 320$ and $c = 960$.
- A few candidates omitted to explicitly state the values of b and c.
- A small number of candidates reversed the values of b and c.
- A few candidates found $a = \pm 2$ then miscalculated b and/or c when substituting $a = -2$.
- A few candidates tried to find the expansion of $(a + x)^4$ by multiplying out
- $(a + x)(a + x)(a + x)(a + x)$ and similarly for $(1 + ax)^5$.

Question 7

(a) **Comprehensive responses**
- Many candidates stated the correct position vector of A, either in unsimplified or simplified form.
- Some candidates used **i-j** form and others used a correct column vector.

Limited responses
- Some candidates added or subtracted the initial position vector and the velocity vector of A. Some of these candidates also multiplied by 2.
- A few candidates confused the initial position vector and the velocity vector of A and offered
- $2(2\mathbf{i} + 5\mathbf{j}) + (8\mathbf{i} + 8\mathbf{j})$ or equivalent.
- A few candidates offered $2(8\mathbf{i} + 8\mathbf{j})$ or $2(2\mathbf{i} + 5\mathbf{j})$, or equivalent.
- Some candidates wrote their vectors in an incorrect form, for example $\begin{pmatrix} 18 \\ 21 \end{pmatrix}$ or $\begin{pmatrix} 18\mathbf{i} \\ 21\mathbf{j} \end{pmatrix}$.

(b) **Comprehensive responses**
- Many candidates stated the correct position vector in t, either in unsimplified or simplified form.
- Some candidates used **i-j** form and others used correct column vectors.

Limited responses
- Many of the candidates who had an error in their vector in part **(a)**, repeated a similar error in this part.
- A few candidates found the magnitude of their answer to part **(a)** in this part.
- Some candidates offered a vector which did not include t.
- Some candidates wrote their vectors in an incorrect form, for example $\begin{pmatrix} 2 \\ 5 \end{pmatrix} + t\begin{pmatrix} 8 \\ 8 \end{pmatrix}$ or $\begin{pmatrix} 2\mathbf{i} \\ 5\mathbf{j} \end{pmatrix} + t\begin{pmatrix} 8\mathbf{i} \\ 8\mathbf{j} \end{pmatrix}$.
- A few candidates, perhaps, needed to read the question more carefully as the answer $(18\mathbf{i} + 21\mathbf{j}) + t(8\mathbf{i} + 8\mathbf{j})$ was sometimes offered.

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(c) **Comprehensive responses**

- A few candidates stated the correct position vector of *B*, either in unsimplified or simplified form.
- Some candidates used **i-j** form and others used a correct column vector.
- Many candidates drew a sketch, either indicating north with the bearing and speed marked, or a set of axes with a ray drawn in the second quadrant and the speed marked. They then used this to help them determine the signs of the components of the velocity vector.
- A good number of candidates used surds in their work, maintaining accuracy.

Limited responses

- A small number of candidates found the correct velocity vector, doubled it then omitted to add it to 20**i** + 8**j**.
- Many candidates omitted to negate the *x*-component of the velocity vector.
- A few candidates converted the surds to decimals and harshly rounded the *y*-component of the velocity vector.
- As with previous parts of the question, some candidates wrote their answers in an incorrect form.
- A few candidates did not understand that the speed was the magnitude of the velocity vector. These candidates found a velocity vector then found its magnitude. They then divided by the magnitude, which they had often decimalised, then multiplied by the speed. This unnecessary step introduced the possibility of rounding errors.
- Some candidates found a velocity vector and then spoiled it by multiplying it by the speed.
- Some candidates found the magnitude of 20**i** + 8**j** then spoiled their velocity vector by dividing it by this and multiplying by the speed.
- Some candidates reversed the components of the velocity vector.
- Some candidates drew diagrams which indicated that they were working in an incorrect quadrant.
- Some candidates made no attempt to answer.

(d) **Comprehensive responses**

- A few candidates formed and carried out a correct and complete plan. These candidates found the difference of the correct position vector of *A* at 17 00 and the correct answer to part **(c)**, then used this difference in a distance calculation.
- Most of these candidates stated a distance calculation for the difference of two vectors, such as $\sqrt{(34-5)^2+\left(37-\left(8+5\sqrt{3}\right)\right)^2}$. Fewer candidates chose to find the magnitude of the vector $29\mathbf{i} + (29-5\sqrt{3})\mathbf{j}$, or equivalent.

Limited responses

- Many candidates stated a position vector for *A* at 17 00 and used it with their answer to part **(c)** in a correct plan for their vectors.
- Some candidates omitted to state the position vector of *A* they had used in their distance calculation.
- Some candidates found the magnitude of $\overrightarrow{OA}$ and the magnitude of $\overrightarrow{OB}$ and subtracted them.
- Some candidates offered a vector as their answer, usually labelling it as the distance.
- A good number of candidates made no attempt to answer.

Question 8

(a) **Comprehensive responses**

- Many candidates stated the correct range, using correct notation.

Limited responses

- A few candidates used an incorrect inequality sign and offered f(x) > 1.5.
- Some candidates omitted to take note of the domain of f and stated the range as f(x) > 1.
- Some candidates used incorrect notation such as '$x \geqslant 1.5$' or 'range $\geqslant 1.5$' or simply stated 1.5.
- Some candidates offered an answer unrelated to the function, such as f(x)$\in$ □ .

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(b) (i) Comprehensive responses

- Some candidates stated the correct domain, using correct notation.
- A few candidates were able to correctly follow through with the value of 1.5 they had stated in part **(a)**.

Limited responses

- A few candidates used an incorrect inequality sign.
- Some candidates used incorrect notation such as 'f $^{-1}(x) \geqslant 1.5$' or 'domain $\geqslant 1.5$' or simply stated 1.5.
- Some candidates stated the domain of f, $x \geqslant -1$, when the use of '–1' did not follow their part **(a)**.

(ii) Comprehensive responses

- Many candidates offered a fully correct response.
- Candidates who were the most successful, inverted the function using a series of steps, each of which changed a single operation.
- Many candidates stated their answer using a logarithm to base 2. Some other candidates correctly used other consistent bases such as e or 10.

Limited responses

- Some candidates started with $2^y = x - 1$ then omitted brackets around the argument of the logarithm in their answer, stating $y = \log_2 x - 1$.
- Some candidates combined method steps and sometimes made a sign or arithmetic error in their solution, offering for example $y = \log_2(x+1)$ or $y = \log_2(1-x)$.
- A few candidates used either an incorrect order of operations such as $x = 1 + 2^y$ then $y = \log_2 x - 1$. Other candidates used a completely incorrect operation such as $x = 1 + 2^y$ then $y = 2^{x-1}$.
- Some candidates stated a correct answer in base e or base 10 and then spoiled it by 'cancelling' the logarithms and stating the answer as $y = \frac{x-1}{2}$.
- Some candidates used logarithms in an invalid way early in their solution, for example stating $\lg x = \lg 1 + \lg 2^y$.
- A few candidates offered an incomplete method as they omitted to swop the variables and gave their final answer as an expression in y rather than x.

(iii) Comprehensive responses

- A good number of candidates drew a pair of correct smooth curves, over the correct domains and showed all intercepts.
- Candidates who used matching scales for each axis were able to reflect $y = f(x)$ in the line $y = x$ more easily.

Limited responses

- Some candidates drew a correct smooth curve for $y = f(x)$, with intercepts marked and asymptotic behaviour.
- Some candidates whose graphs did not have asymptotic behaviour, did not indicate that the graph of $y = f(x)$ started at $x = -1$.
- Some candidates drew an acceptable graph for $y = f(x)$ which intersected with $y = x$. This resulted in an error as their graphs of $y = f(x)$ and $y = f^{-1}(x)$ intersected once or twice.
- A few candidates drew an acceptable graph for $y = f(x)$, then were unable to use it to correctly draw the graph of the inverse function. Some attempts at the graph of $y = f^{-1}(x)$ were the result of reflecting $y = f(x)$ in the x-axis or rotating $y = f(x)$ about the origin, for example. Other candidates had a reasonably reflected shape that was marked with inconsistent intercepts.
- For $y = f(x)$, a few candidates, drew graphs of exponential shape that intersected with the x- axis or that had incorrect curvature.
- Some candidates plotted and joined points and would benefit from practicing drawing smooth curves of shapes.
- Some candidates drew graphs for $y = f(x)$ which were unrelated to the function. For example, some drew straight lines or parabolas.
- Some candidates made no real attempt to answer.

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(c) (i) Comprehensive responses

- A few candidates offered a correct explanation, indicating clearly that the range of f was a subset of the domain of g.

Limited responses

- Some candidates did not clearly indicate that the range of f was completely within the domain of g and used language such as 'the range of f overlaps the domain of g' or 'the range of f is larger than the domain of g' or ' f $\geqslant$ 1.5 fits $x \geqslant -1$'.
- Many candidates offered explanations such as 'it is one to one' or 'they have the same domain'.

(ii) Comprehensive responses

- Many candidates stated the correct composite function either as a product or in expanded form.

Limited responses

- Some candidates who attempted a product omitted brackets and offered $1 + 2^x(1 + 2^x + k)$.
- A few candidates offered $g(x) \times f(x)$ or formed $fg(x)$.

(iii) Comprehensive responses

- Some candidates found f(3) = 9 and then solved g(9) = 126 correctly. This was the simplest approach.
- Some candidates substituted $x = 3$ into the correct expression for $gf(x)$ and correctly formed and solved the resulting equation.
- Some candidates who stated $1 + 2^x(1 + 2^x + k)$ in part **(c)(ii)**, recovered in this part and offered a correct solution.

Limited responses

- A few candidates made sign or arithmetic slips when solving a correct equation.
- Some candidates used an incorrect expression for $gf(x)$ which could have been avoided by finding f(3) = 9 and then g(9) = 126.

Question 9

(a) Comprehensive responses

- A few candidates offered a complete and correct solution, with all steps clearly shown.
- Some candidates offered a correct method and then harshly rounded their final answer.
- Most candidates who offered a correct solution used calculus to find $\frac{dv}{dt}$ with only a few candidates attempting to complete the square for v.

Limited responses

- A few candidates offered a correct solution for $\frac{dv}{dt} = 0$ and then went on to offer a solution from $e^{2t} = 0$.
- A few candidates found an expression for $\frac{dv}{dt}$ and then incorrectly applied laws of logarithms when attempting to solve $\frac{dv}{dt} = 0$.
- A very common error in this question was to find the value of t for which s has a stationary value.
- A small number of candidates did not differentiate correctly and offered, for example, $v = 4te^{4t-1} - 2te^{2t-1}$.
- A few candidates attempted to integrate the expression for s.

(b) Comprehensive responses

- Many candidates were able to use or find the correct expression for the acceleration in this part of the question and use it successfully to offer a correct answer.

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Limited responses

- A few candidates converted ln2 to a decimal and then offered an inexact answer.
- A few candidates did not complete the solution and offered only $16e^{4\ln 2} - 40e^{2\ln 2}$.
- A few candidates made no attempt to answer.

Question 10

Comprehensive responses

- Some candidates offered a fully correct solution. These candidates understood the need to factor out $\sin(3x + 1)$ to obtain all valid solutions.
- Many candidates offering correct solutions stated and used a substitution, such as $u = 3x + 1$, at an early stage in their working.
- Some candidates used one of the simplest approaches which were to write $\tan(3x + 1)$ as $\frac{\sin(3x+1)}{\cos(3x+1)}$ or to write $\sin(3x + 1)$ as $\tan(3x + 1)\cos(3x + 1)$. This resulted in an equation that could be rearranged and factorised quite easily.
- A few candidates were successful using more complex approaches, for example with an initial step of squaring both sides or multiplying both sides by $\sin(3x + 1)$.

Limited responses

- After an initial correct step of, for example, $\frac{\sin(3x+1)}{\cos(3x+1)} = 5\sin(3x + 1)$, many candidates divided by $\sin(3x + 1)$ and so lost some solutions.
- Candidates who used one of the more complex approaches were more likely to make an error or to not offer a full set of solutions.
- A few candidates worked in degrees not radians.
- A few candidates offered inaccurate answers. Often these were the result of using harshly rounded working values for $3x + 1$; sometimes they were the result of not applying the instruction to round to 3 significant figures, stated on the front page of the examination paper; sometimes they were the result of incorrect rounding.
- Some candidates needed to take more care with their interpretation of, $\tan(3x + 1)$ as a common error was to write $\frac{\sin(3x+1)}{\cos(3x+1)}$ as $\frac{\sin}{\cos}(3x+1)$ and a few candidates wrote, for example, $\frac{\sin x(3x+1)}{\cos x(3x+1)}$.
- Some candidates made a partial recovery from these errors and some did not. For example, a few candidates were unable to make any progress as they had formed $\cos x = \frac{1}{5}$ or $\cos = \frac{1}{5}$.

Question 11

Comprehensive responses

- Candidates used a variety of successful approaches to solve this problem.
- For example, many candidates used the efficient approach of finding the points of intersection of the two circles, by forming the equation of C_1 and using $y = 19 - 3x$ to eliminate y and solving, then finding the distance from (12, 8) to one of the points of intersection.
- Some candidates were successful with methods that involved forming and comparing equations of C_1 and C_2.
- Some candidates repeatedly applied Pythagoras' theorem.
- A few candidates made good use of a helpful sketch.

Limited responses

- Some candidates offered a correct solution as far as finding the two points of intersection of the two circles, and were then unable to complete the solution correctly. A simple sketch may have helped some of these candidates.
- A few candidates made arithmetic or sign slips in their algebra, for example when forming
- $10x^2 - 90x + 200 = 0$ or expanding $(x - 3)^2 + (y - 5)^2 = 5$.
- Some candidates omitted key steps in their solution. For example, some did not show the elimination of one unknown or did not write their equation in solvable form before solving it, suggesting over-use of the calculator.

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- Some candidates used trials. This was not an efficient method of solution and candidates using this approach generally omitted necessary method steps.
- Some candidates attempted to work with the equation of C_2 only, and did not use the information given for C_1.
- Some candidates would benefit from referring to the List of formulas on page 2 of the examination paper, as they were unable to recall the standard or general equation of a circle.

Question 12

Comprehensive responses

- Some candidates used the chain rule to deduce that $\frac{dV}{dr} = 9$, found $\frac{dV}{dr} = 4\pi r^2$, equated these, solved for r and then completed the solution.
- A few candidates made r the subject of $V = \frac{4}{3}\pi r^3$, found $\frac{dr}{dV}$ and used $\frac{dr}{dt} = \frac{dr}{dV} \times 9\frac{dr}{dt}$ to find V without needing to find r.
- A few candidates stated and used a substitution, such as $\frac{dr}{dt} = x$, in their solution.

Limited responses

- Some candidates round the correct value of r then did not go on and find the corresponding value of V.
- Some candidates offered both positive and negative values for r and did not always reject the negative value.
- Some candidates made premature rounding errors in their working values that resulted in an insufficiently accurate answer.
- A few candidates made slips with π when rearranging $4\pi r^2 = 9$. This usually resulted in $r = \frac{3}{2}\sqrt{\pi}$, or similar. Similar errors were sometimes seen when evaluating V.
- Some candidates were able to state a correct and valid chain rule, such as $\frac{dV}{dt} = \frac{dV}{dr} \times \frac{dr}{dt}$, then seemed unsure of how to proceed beyond that point.
- A few candidates incorrectly stated that $r = t$, $\frac{dr}{dt} = 1$, $\frac{dV}{dt} = 4\pi r^2$.
- A few candidates stated and used spurious expressions for $\frac{dr}{dt}$ such as $8\pi r$.
- A few candidates made no attempt to answer.

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ADDITIONAL MATHEMATICS

Paper 0606/23
Calculator

Key messages

What candidates did well

- Some candidates used all the information given, showing that they had read questions carefully.
- Some candidates were able to form a correct plan when solving a multi-step problem.
- Many candidates communicated their methods and results clearly, offering detailed, step-by-step solutions.

What candidates needed to improve

- Some candidates needed to refer to the List of formulas given on page 2 of the examination paper. This would have helped them to avoid incorrectly recalling formulas that are given to them.
- A few candidates needed to read each question more carefully to interpret all key statements and use all the information given.
- Some candidates sketched, rather than drawing accurately, the graph in **Question 1(a)**. When the command word in a question is draw and graph paper is given, the graph should be drawn accurately. Candidates should plot the vertex and endpoints to help them maintain accuracy.
- To be reasonably confident that a final answer is correct to 3 significant figures, candidates should make sure that their working values are accurate to 4, or preferably more, significant figures.
- When the question requires a result to be shown to 3 significant figures, a more accurate decimal should always be shown before rounding.
- Candidates should be aware that knowledge of *suvat* equations is not required for this syllabus and that all kinematics problems are solvable without using these equations.

Comments on specific questions

Question 1

(a) **Comprehensive responses**

- A good number of candidates drew an accurate, ruled graph.
- Candidates plotted at least the endpoints and vertex of the graph.
- Candidates took care to draw their graph for $-3 \leqslant x \leqslant 3$, as required.

Limited responses

- Some candidates drew a ruled V-shaped graph with correct vertex that did not extend across $-3 \leqslant x \leqslant 3$ or had insufficiently accurate endpoints.
- Some candidates sketched, instead of drawing accurately, a ruled V-shaped graph with correct vertex that had very inaccurate endpoints.
- A few candidates drew graphs that were not ruled.
- A few candidates drew a V-shaped graph with vertex on the y-axis.
- A few candidates drew the graph of $y = 2x + 1$ only.

(b) **Comprehensive responses**

- Some candidates offered fully correct solutions, drawing the line $y = x + 2$ of sufficient length to intersect with their accurate V-shaped graph twice, and finding the critical values from the graph in order to form their inequalities.

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Limited responses

- Some candidates drew a correct line, stated correct critical values and and needed to check their final answer for accuracy. For example, some candidates offered $x \leqslant -1$, $x \geqslant 1$ and some offered $-1 < x < 1$.
- A few candidates drew the correct line and then used algebra to find the critical values, which did not match the points of intersection of their graphs.
- A few candidates did not draw the correct straight line. For example, some candidates drew $y = 2$ while others found the critical values using algebra and then drew $x = -1$ and $x = 1$.
- Some candidates made no attempt to use the graph and just used algebra.

Question 2

(a) **Comprehensive responses**

- Candidates used a variety of successful trigonometric approaches to show the given result, taking care to show a value that was more accurate than 2.21 before rounding as required.
- Some candidates used $\theta = 2\tan^{-1}2$, which was the most reliable approach as it used values that were all very easy to determine from the diagram.

Limited responses

- Some candidates used a correct trigonometric approach then did not complete their argument. For example some omitted to show a value that was more accurate than 2.21 before rounding and others showed a more accurate decimal then did not conclude it was 2.21 to 3 significant figures.
- Some candidates who used methods that used the length of *AP*, sometimes used an incorrect form of Pythagoras' theorem to find it.
- A small number of candidates needed to referr to the List of formulas on page 2 of the examination paper, as they attempted to use an incorrect form of the cosine rule or sine rule.
- A small number of candidates found the area of triangle *APD* and then equated to $\frac{5}{2}\sin\theta$. The angle generated in this case was acute and needed to be subtracted from π. Candidates who chose this approach did not always complete the method.
- A few candidates worked in degrees and converted to radians. This introduced a greater likelihood of making an error.

(b) **Comprehensive responses**

- Some candidates offered a fully correct solution, either by finding the area of the segment and subtracting it from the area of the square, or by subtracting the area of the sector from the area of *ABCDP*.

Limited responses

- A few candidates used harshly rounded working values and stated inaccurate final answers.
- Some candidates stated or used the correct value of *AP*, then found some or all of the areas needed and combined them incorrectly resulting in an incorrect plan.
- For example, some candidates subtracted the area of the sector *APD* from the area of the square *ABCD* and did not then add the area of the triangle *APD*.
- Candidates who worked in degrees were more likely to make an error.
- Some candidates stated or used values for *AP* that were impossible for the question, such as 1 or 2 or 4 or 5.

Question 3

(a) **Comprehensive responses**

- Most candidates stated the correct, simplified expansion.

Limited responses

- A few candidates either miscopied the question or miscopied their own writing.
- A few candidates offered $1 - 2x^2$.
- A few candidates did not simplify their answer.

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(b) **Comprehensive responses**

- A few candidates used part **(a)** correctly in this part, rewriting the expansion given as $(1 - 4x^2)^{10}(1 - 2x)^2$, selecting the appropriate coefficients to multiply and complete the problem.

Limited responses

- A few candidates stated a partially correct solution and then did not state an answer that was free of x.
- Many candidates did not follow the instruction to use part **(a)**, indicated by the use of the key word 'Hence'. These candidates expanded both $(1 + 2x)^{10}$ and $(1 – 2x)^{12}$ and attempted to select appropriate coefficients to multiply. This was a much lengthier approach as there were many more terms to multiply and sum. Some of these candidates were successful and others omitted terms.
- A few candidates attempted to expand $(1 + 2x)^{10}$ or $(1 – 2x)^{12}$.
- A few candidates attempted to work with $(1 – 4x^2)^{22}$ or $(1 – 2x)^{22}$.
- A small number of candidates needed to refer to the List of formulas on page 2 of the examination paper, as they were unable to apply the binomial theorem correctly.
- Some candidates made no real attempt to answer.

Question 4

(a) **Comprehensive responses**

- Many candidates transformed the data and drew a sufficiently accurate, ruled, straight line.

Limited responses

- A few candidates plotted the correct points and joined them with a line drawn freehand.
- Some candidates made a slip or slips when plotting the transformed data and joined each point to the next using a series of straight lines, rather than a single straight line, or joined them with a curve.
- Some candidates did not transform the data and plotted the given points. Some of these candidates then attempted to draw a curve through, or a line of best fit for, their plots.

(b) **Comprehensive responses**

- Some candidates identified P as the gradient and Q as the y-intercept of the line they had drawn and were able to find these correctly.

Limited responses

- A few candidates stated only Q correctly.
- Some candidates used their gradient and a point in a calculation to find Q instead of reading the value directly from their graph. This approach was more likely to result in an error.
- A few candidates stated or found only P correctly.
- A few candidates used the given data, instead of the transformed data, in their gradient calculation to find P.
- A few candidates used $\frac{x_1 - x_2}{y_1 - y_2}$ in their gradient calculation to find P.
- Some candidates attempted to use logarithms in some way.
- A few candidates formed simultaneous equations in P and Q and were unable to solve them.

(c) **Comprehensive responses**

- Some candidates correctly evaluated $x^4 = 1.21$ and used the graph to find the corresponding value of y.

Limited responses

- Some candidates found the value of y for $x = 1.05$ or $\sqrt[4]{1.05}$.
- Some candidates made a slip when reading the scales on the axes.

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Question 5

(a) **Comprehensive responses**

- Many candidates drew a neat and correct velocity-time graph with all the key data marked.

Limited responses

- Some candidates drew graphs of correct shape then omitted to show at least one key piece of information on the graph. For example, V was often omitted on the vertical axis.
- Most candidates attempted to draw a graph with connected ruled sections.
- A few candidates drew two correct sections only. Some of these candidates omitted one part of the graph, for example the section where the particle was moving with constant acceleration or with constant velocity. A small number of candidates drew the first two sections correctly and needed to pay closer attention to the section where the particle was decelerating.

(b) **Comprehensive responses**

- A few candidates used the information given to form and solve a correct pair of simultaneous equations in V and T, commonly $\frac{V}{T} = 1.5$ and $\frac{1}{2}TV + 2TV + \frac{60-3T}{2} \times V = 1104$.

Limited responses

- A few candidates formed and solved a correct pair of simultaneous equations then omitted to discard the negative solutions for T and V.
- A few candidates formed a correct pair of equations and needed to pay close attention when attempting to solve them. For example, some slips were made when simplifying their equation in one unknown to a solvable form.
- A few candidates who had made a slip in forming the quadratic equation in one unknown omitted to show the method of solution for that equation.
- Some candidates incorrectly interpreted the information given about the acceleration, forming $\frac{T}{V} = 1.5$, for example.
- A few candidates incorrectly interpreted the information given about the total distance, forming $\frac{1}{2}TV = 1104$, for example.
- Candidates who attempted to use *suvat* equations often made little progress.
- Some candidates made no real attempt to answer.

Question 6

(a) **Comprehensive responses**

- Some candidates offered a fully correct response.
- A variety of approaches were seen and a common first step was to form a single fraction, or a pair of fractions with a common denominator, and then simplify.
- Another fairly common approach was to write $\sec\theta$ and $\tan\theta$ in terms of $\sin\theta$ and $\cos\theta$ and then simplify to a single fraction.
- Candidates worked to show that the left-hand side of the equation was equal to the right-hand side, detailing clear, logical and sufficient working to justify the given result, $2\tan\theta$.

Limited responses

- A few candidates needed to correctly simplify to a single fraction in terms of the given trigonometric functions. Sometimes candidates needed to combine steps correctly rather than taking a step-by-step approach to the simplification. For example, the denominator $(\sec\theta - \tan\theta)(\sec\theta + \tan\theta)$ was sometimes omitted and candidates wrote only $(\sec\theta - \tan\theta)^2$.
- A few candidates needed to simplify their fractions in terms of $\sin\theta$ and $\cos\theta$. Usually candidates needed to pay closer attention in the simplification of the fractions in the denominator.
- A small number of candidates did not show sufficient simplification of their expression on the left-hand side to justify their writing down of the final step.
- A small number of candidates used $\sec\theta = \frac{1}{\sin\theta}$.

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- Some candidates would benefit from presenting their solutions more clearly. For example, some candidates omitted some or all of the arguments of the trigonometric functions; other candidates made several attempts and needed to organise their work more clearly to ensure that each step followed logically from the previous one.

(b) **Comprehensive responses**

- A few candidates stated a fully correct response.
- Most of these candidates offered the simple solution of writing the equation as a quadratic equation in $\sin\theta$ and solving it using the quadratic formula.

Limited responses

- A small number of candidates prematurely approximated their values of $\sin\theta$, which resulted in inaccurate final solutions, or found angles from $\sin\theta = -1 - \sqrt{2}$.
- A small number of candidates found the correct quadratic in $\sin\theta$, in solvable form, then made a slip when solving it. A few of these candidates did not show any method of solution and stated only the incorrect values they had found.
- A few candidates found the correct quadratic in $\sin\theta$, in solvable form, then made no attempt to solve it, or were unable to solve it as it did not factorise.
- A few candidates stated $2\sin\theta + \sin^2\theta = 1$, then $\sin\theta(\sin\theta + 2) = 1$ and $\sin\theta = 1$ or $\sin\theta = -1$.
- A small number of candidates needed to refer to the List of formulas on page 2 of the examination paper, as they attempted to use an incorrect form of the quadratic formula.
- Some candidates stated a correct relationship such as $2\sin\theta = \cos^2\theta$ and made no further progress.
- A few candidates stated only $2\tan\theta = \cos\theta$.
- A few candidates needed to pay closer attention to the key word 'Hence' and attempted to work with the unsimplified form of the given equation.

Question 7

Comprehensive responses

- Some candidates offered two correct solutions.

Limited responses

- Some candidates chose the correct two graphs then offered only one correct solution for p and q.
- Common errors were to write
  - for graph A: $p = -2$ $q = 2$ or $p = 1$ $q = 2$ or $p = 0$ $q = 2$
  - for graph C: $p = 1$ $q = 2$ or $p = -2$ $q = 2$ or $p = 0$ $q = 2$.
- Some candidates chose graph D as one of their options and commonly this was paired with graph C. Graph B was rarely selected.

Question 8

(a) **Comprehensive responses**

- Some candidates found the correct number of arrangements.

Limited responses

- A small number of candidates either counted A or B twice or included E as the last letter, as their solution was $2 \times {}^3P_3 \times 4$.
- Some candidates offered answers that were greater than the number of all possible arrangements.
- A few candidates used combinations rather than permutations, or used factorials incorrectly and offered for example $2! \times {}^3P_3 \times 3!$ or $2 \times 5! \times 3$.

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(b) (i) There was an error in question 8(b)(i) relating to ambiguous wording. This has been corrected in the published version of the paper. This error was discussed at the examiners' meeting before marking began. The examiners considered the impact on candidates based on the answers they had seen. Changes to the marking approach for this question were agreed to make sure that no candidates were disadvantaged by the issue.

Comprehensive responses

- A few candidates stated the correct solution of one even and four odd or two even and 3 odd digits, stating for example ${}^4C_1 \times {}^5C_4 + {}^4C_2 \times {}^5C_3 = 80$.
- A limited number of candidates stated ${}^4C_1 \times {}^5C_4 = 20$, which was accepted due to the ambiguous wording of the question, but would not be accepted as a response to the corrected wording of the question paper, and therefore does not appear in the mark scheme.

Limited responses

- A few candidates offered a correct method and then did not evaluate it correctly.
- Some candidates miscounted the number of even digits as 5.
- Some candidates offered answers that were greater than the number of all possible selections.
- A few candidates used permutations rather than combinations.

(ii) Comprehensive responses

- A few candidates offered a fully correct solution to this part of the question. Candidates used one of two approaches.
- The most efficient method was to find all possible selections of five digits from nine, ${}^9C_5$, and to subtract the selections which contained none of the digits that were greater than 6, ${}^6C_5$.
- An alternative approach, which was reasonably efficient on this occasion, was to form a sum of three products, where each product represented selections with one, two or all three of the numbers greater than 6.

Limited responses

- Some candidates seemed to be finding the number of selections that contain at least one digit greater than or equal to 6, as ${}^9C_5 - {}^5C_5$ was fairly common.
- Some candidates miscounted the number of digits from 1 to 9 as 10 or miscounted the number of even digits as 5.

Question 9

(a) Comprehensive responses

- Candidates who were successful gave clear, step-by-step solutions, building up from the area of the cross-section to find the volume of the prism in terms of x and y, equating this to the given volume and then writing y as a function of x. They then used this correctly in an expression for the surface area to derive the given result.
- Some candidates found $y = \frac{250}{x^2}$ which produced a simple conclusion to the problem; other candidates found $y = \frac{1000 + 250\sqrt{3}}{x^2(4 + \sqrt{3})}$.
- Some candidates numbered their steps so that when a solution continued in a second column, for example, their solution maintained its logical progression.

Limited responses

- A few candidates found a correct expression for y in terms of x, stated a correct expression for the surface area in terms of y and x, then made a slip in the final step, such as miscopying their own work, or an arithmetic slip in the simplification to the given answer.
- A good number of candidates stated correct expressions in x and y for the volume and the surface area.
- A few candidates found a correct expression in x and y for the volume of the prism and equated to the given volume, then made a rearrangement or comparison error and stated
- $y = 250$.
- A few candidates offered the correct area of the triangle only.

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- A few candidates incorrectly stated the area of the triangle as $\frac{1}{2}\times\frac{x}{2}\times x$.
- A few candidates seemed to be working back from the given answer at some point in their solution as correct expressions followed incorrect working.
- Some candidates made no real attempt to answer.

(b) (i) Comprehensive responses

- A few candidates offered correct solutions.
- Most of these candidates used an accurate value for x in their working to find A. Some used a sufficiently accurate decimal value.

Limited responses

- Some candidates found a value for x, either in exact form or to 3 or more significant figures and then made no attempt to find A. These candidates may have continued the solution if they had reread the question at that point.
- A few candidates made slips when differentiating one or both terms of the expression given for A in part **(a)**, not seeing that both terms were simple multiples of powers of x.
- Some candidates applied the quotient rule to differentiate $\frac{1250}{x}$.
- Candidates who did not write $\frac{1250}{x}$ as $1250x^{-1}$ sometimes differentiated this as $\frac{1250}{x^2}$.
- A few candidates incorrectly applied the product rule to differentiate A.
- Some candidates set their derivative equal to 0 and found a value of x; other candidates were unable to carry out the algebraic steps needed to do this.
- A small number of candidates equated the second derivative to 0 and attempted to solve it.
- Some candidates were unable to form a correct plan to find the minimum value of A and made no use of calculus in their attempt.
- Some candidates made no attempt to answer.

(ii) Comprehensive responses

- A few candidates were able to form the correct second derivative and use it with an acceptable value of x to demonstrate that the value of the second derivative was positive, hence showing that the value of A was a minimum.

Limited responses

- Some candidates formed a correct second derivative and then made a slip when evaluating it for $x = 6.019$, or equivalent.
- A few candidates were able to follow through with their first derivative from part **(a)** to state their version of the second derivative correctly. This was permitted providing it was of equivalent form.
- Many candidates were unable to find a second derivative.
- Many candidates made no attempt to answer.

Question 10

(a) Comprehensive responses

- Some candidates offered fully correct solutions to this part of the question.

Limited responses

- Some candidates made an attempt at the product rule, with correct structure, and with at least one incorrect derivative of x or $\sin(2x - 3)$. For example $\sin(2x - 3)$ was sometimes differentiated as $2x\cos 2x - 3$.
- Some candidates did not see that the given function was a product and so did not apply the product rule. These candidates offered, for example, $2x\cos(2x - 3)$ or $-2x\cos(2x - 3)$, or applied the quotient rule.
- A few candidates treated $\sin(2x - 3)$ as if it were the product of sin and $2x - 3$ and had derivatives which included terms such as $(2x - 3) \times \cos$ and $2\sin$.

(b) Comprehensive responses

- A very small number of candidates offered a fully correct solution to this part of the question.

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Limited responses

- Some candidates omitted to show the substitution of the limits into the integral and stated only a decimal answer. The substitution of the limits into an integral is a necessary step in the method and should be shown.
- A few candidates made slips when integrating $\sin(2x - 3)$.
- Some of these candidates formed an expression of the form $\frac{1}{2}x\sin(2x-3)+k\cos(2x-3)$.
- Some of these candidates omitted to explicitly show the substitution of the limits into their expression, offering only decimal values. When an expression such as this is incorrect, evidence of the substitution of the limits must be seen, as it is not implied from decimals only.
- Some candidates combined steps and made slips that might have been avoided if they had carried out step-by-step solutions.
- Some candidates did not attempt to use the previous part of the question and offered expressions such as $-\frac{x^2}{2}\sin^2(2x-3)$ or $\frac{x}{2}\sin(2x-3)$.

Question 11

(a) Comprehensive responses

- Success in this part of the question relied upon candidates producing step-by-step solutions and considering how to derive the answer from the equation in r they had formed. For example, candidates who formed the cubic equation $r^3 - 7r + 6 = 0$ needed to factorise the cubic into a correct product of linear and quadratic factors to be able to complete the solution.

Limited responses

- Some candidates attempted to simplify $ar^n - ar^{n-1} = \frac{1}{6}(ar^{n+2} - ar^n)$.
- A few candidates divided by or factored out ar^n to find $r - 1 = \frac{1}{6}(r^3 - r)$.
- These candidates did not usually see that this could be factorised on the right-hand side to form $r - 1 = \frac{1}{6}r(r-1)(r+1)$, which resulted in a simple completion.
- A few candidates worked as far as $7 = r^2 + 6r^{-1}$ and then wrote down the given answer, omitting key steps in the solution.
- Some candidates divided through by a and then made no further progress as they did not see the common factor of r^n.
- A few candidates were unable to form a correct expression for u_{n+1}. For example, ar was sometimes stated for this term.
- Working was not always well-presented.
- Some candidates made no attempt to answer.

(b) Comprehensive responses

- Success in this part of the question depended on candidates making the link to part **(a)** in order to find the value of r using the given equation. Once this had been found, the correct solution reduced to solving an equation using powers of 2 or logarithms.
- A few candidates offered fully correct solutions.

Limited responses

- Some candidates were able to solve $r^2 + r - 1 = 0$ to find $r = 2$.
- Some of these candidates did not discard $r = -3$.
- Some of these candidates made no further progress.
- A few candidates formed $2^{k+1} - 2^{k-1} = 48$ and then attempted to use laws of indices in an invalid way, for example solving $2^{\frac{k+1}{k-1}} = 48$.
- Some candidates did not make the link to the previous part of the question.
- A few candidates attempted to take logarithms in an invalid way and offered, for example,
- $(k + 1)\log r - (k - 1)\log r = \log 48$.
- A few candidates were unable to form a correct expression for u_{k+2}.
- Many candidates made no attempt to answer.

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- Working was not always well-presented.

Question 12

Comprehensive responses

- Candidates who saw that the equation could be rewritten in terms of cot2x made the simplest start to solving the equation.
- Candidates who made a substitution such as y = cot2x were more likely to factorise correctly.

Limited responses

- A small number of candidates included extra values in $-\frac{\pi}{2} \leq x \leq \frac{\pi}{2}$, for example 0 was sometimes also stated.
- A few candidates were able to find cot2x = 0 and cot2x = –2, and only attempted to solve cot2x = –2, as the possibility of $\cot 2x = 0 \rightarrow \frac{\cos 2x}{\sin 2x} = 0 \rightarrow \cos 2x = 0$ was rejected or not considered.
- Some candidates worked in terms of tan2x and often lost some solutions when solving $\frac{1+2\tan 2x}{\tan^2 2x} = 0$, or equivalent, as the possibility of $\frac{1}{\tan^2 2x} = 0 \rightarrow \frac{\cos^2 2x}{\sin^2 2x} = 0 \rightarrow \cos 2x = 0$ was rejected or not considered.
- Some candidates rewrote the equation in terms of tan2x, or sin2x and cos2x. Some of these candidates made slips in their working when attempting to write their equation in a correct form ready to be factorised. Some of these candidates were unable to generate the algebra required to produce a solution.
- A few candidates used a trigonometric identity in an invalid way, for example some used sec2x –1 = tan2x and others replaced cosec^2 2x with 1 + cot2x.
- Working was not always well-presented.
- Some candidates made no attempt to answer.

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