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

- **Digital mocks service**
- **Insight assessments**
- **Professional development**
  - Focus on assessment
  - Online marking workshops

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MATHEMATICS

Paper 9709/11
Pure Mathematics 1

Key messages

What candidates did well
- Many candidates presented their solutions well.
- Candidates demonstrated an understanding of when to apply calculus.
- Candidates were able to solve quadratic equations using a variety of methods.

What candidates needed to improve
- Candidates should ensure that brackets are expanded correctly.
- Candidates should check that their solution satisfies the requirements of the original question.
- Candidates should show their method clearly when solving quadratic equations.

Comments on specific questions

Question 1

Comprehensive responses
- Most candidates found the correct values of *r* and *a* and then found the correct sum to infinity.

Limited responses
- A few candidates found r to be outside the range $|r| < 1$.

Question 2

(a) (i) Comprehensive responses
- Most candidates used the binomial expansion or Pascal's triangle to find the correct first three terms of the expansion.

Limited responses
- A few candidates gave an incorrect value for the coefficient of x^2.

(ii) Comprehensive responses
- Most candidates gave the correct answer.

Limited responses
- A few candidates gave an incorrect answer.

(b) Comprehensive responses
- Most candidates used the previous parts of the question to find the coefficient of x^2.

Limited responses
- A few candidates gave a full expansion using their answers to the first two parts of the question.

Question 3

Comprehensive responses
- A few candidates gave a correct answer in a variety of forms.

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Limited responses
- The most common incorrect responses applied the three operations in the wrong order.

Question 4

Comprehensive responses
- A few candidates used the correct substitution, factorised successfully, and found all four angles.

Limited responses
- Some candidates found the positive value of sin θ and two correct values of θ.

Question 5

Comprehensive responses
- A few candidates differentiated correctly and gave the equation of the tangent in the required form.
- Most candidates correctly found the negative reciprocal of their value of $\frac{\mathrm{d}y}{\mathrm{d}x}$.

Limited responses
- Some responses showed a correct method with algebraic mistakes.
- A few final answers were not given in the form required by the question.

Question 6

Comprehensive responses
- Some candidates set up a correct quadratic in p by equating the difference between consecutive terms.
- Some candidates found the correct values of a and d for both sequences and hence the correct difference between the 20th terms.

Limited responses
- Some candidates made sign errors when equating the difference between consecutive terms.
- Some candidates found the correct values of a and d for one of the sequences.

Question 7

(a) **Comprehensive responses**
- Few candidates used the cosine rule correctly to find angle BCD.
- Some candidates correctly used $2r$ in the formula S = Rθ to find the length of the arc.

Limited responses
- The most common incorrect answers included using the radius of the sector as r rather than 2r.
- Some candidates gave the angle BCD in terms of r.

(b) **Comprehensive responses**
- Few candidates correctly found the areas of the sector and triangle.

Limited responses
- The most common incorrect answers included using the radius of the sector as r rather than 2r.
- A few candidates gave the area of the triangle as $\frac{1}{2} \times r \times r \times \sin 120$.
- A few candidates gave the area of the triangle as $\frac{1}{2} \times 2r \times 2r \times \sin 120$.

Question 8

Comprehensive responses
- Most candidates equated the two functions and solved a quadratic to find the two values of x.
- Some candidates understood the need to subtract the integrals of the squares of the two functions.

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- A few candidates completed the whole question correctly.
- A few candidates correctly found the volume of revolution of the straight line using the volume of a frustum of a cone.

Limited responses

- A few candidates subtracted the two functions before squaring.
- A few candidates gave the integral of $\left(\frac{5}{2x-1}\right)^2$ in terms of logarithms.
- Some candidates made arithmetic or algebraic slips when integrating and substituting.

Question 9

(a) Comprehensive responses

- Most candidates gave the correct inverse function.

Limited responses

- A few candidates used the square root rather than the cube root.

(b)(i) Comprehensive responses

- Most candidates found the correct value of *a*.
- Most candidates showed a complete method for solving a quadratic equation.

Limited responses

- Some candidates did not show a complete method for solving a quadratic equation.
- A few candidates made sign errors when evaluation f (–1).

(ii) Comprehensive responses

- Few candidates gave a fully correct solution.
- Many candidates expanded $(x-3)^3$ correctly.
- Most candidates stated $\mathrm{gf}(x)$ or $\mathrm{fg}(x)$ correctly.
- Many candidates correctly used b^2-4ac from a quadratic equation.

Limited responses

- A few candidates omitted the 16 from their full expansion of $(x-3)^3-16$.
- Some candidates made algebraic or sign errors when expanding and simplifying.
- Some candidates made sign errors when solving an inequality.

Question 10

(a) Comprehensive responses

- Most candidates gave the correct answer.

Limited responses

- A few candidates did not calculate the value of $\frac{\mathrm{d}^2y}{\mathrm{d}x^2}$.

(b) Comprehensive responses

- Many candidates integrated to find the correct expression for $\frac{\mathrm{d}y}{\mathrm{d}x}$.
- Some candidates found the correct expression for y.

Limited responses

- The most common incorrect answers included using $x = 2$, $\frac{\mathrm{d}y}{\mathrm{d}x} = 3$ instead of $x = 2$, $\frac{\mathrm{d}y}{\mathrm{d}x} = 0$ at the stationary point.
- Some candidates did not include a constant of integration when integrating $\frac{\mathrm{d}^2y}{\mathrm{d}x^2}$.

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- Some candidates made arithmetic or algebraic slips when integrating and substituting.

(c) (i) Comprehensive responses

- Few candidates used the hint given in the question to state $(x-2)\left(x^2+2x-2\right) = 0$.
- Few candidates gave the correct values of *x*.

Limited responses

- Most candidates did not use the hint given in the question.

(ii) Comprehensive responses

- Few candidates worked out the correct values of $\frac{\mathrm{d}^2y}{\mathrm{d}x^2}$ and drew the correct conclusions.

Limited responses

- Many candidates did not answer this question.

Question 11

Comprehensive responses

- Some candidates found the gradients of the radii using $\frac{y_2-y_1}{x_2-x_1}$ and hence the equations of the tangents.
- A few candidates used implicit differentiation to find the gradients of the tangents.
- Most candidates who found the gradients of the tangents were able to find the equations of the tangents and their point of intersection.
- A few candidates were able to find the correct area of quadrilateral OPQR using the area of a rectangle minus the area of two triangles, the area under line PQ minus the area under line RQ, or the sum of the areas of triangles OQR and OQP.

Limited responses

- A few responses showed a correct method for integration but contained errors in the limits.
- A few candidates assumed that triangle PQR is isosceles.
- Many candidates did not attempt to find the area of the quadrilateral OPQR.

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MATHEMATICS

Paper 9709/12
Pure Mathematics 1

Key messages

What candidates did well
- Good understanding of the questions was seen throughout the paper, with candidates often selecting efficient methods of solution.

What candidates needed to improve
- Candidates should ensure that all necessary working is shown clearly, especially when solving quadratic equations and using limits in definite integration.
- Candidates should use correct mathematical language, including vectors notation, when describing transformations.

Comments on specific questions

Question 1

Comprehensive responses
- Many candidates recognised that the equation could be rearranged into a quadratic form and solved successfully.
- Many candidates realised that no solutions were possible from $x^2 = -\frac{4}{3}$.

Limited responses
- Some candidates when solving, did not obtain both the positive and negative solutions.
- Some candidates used $x = x^2$ and this often led to incorrect final answers.

Question 2

(a) **Comprehensive responses**
- Many candidates used vector notation to describe the translation.
- Many candidates used the term factor when describing the stretch.
- Some candidates correctly identified when the vertical translation needed to be applied for the order of transformations to be correct.

Limited responses
- Some candidates used non-mathematical language such as ‘right’, ‘up’ or ‘move’.

(b) **Comprehensive responses**
- Most candidates gave the expression in the required form.

Limited responses
- Some candidates did not include f in their answer.

Question 3

Comprehensive responses
- Many candidates found the midpoint and the perpendicular gradient to determine the equation of the perpendicular bisector.

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- Most candidates recognised the need to form and solve an equation in one variable when the two lines met.

Limited responses

Common errors were:

- Using the gradient of the line joining the two points rather than the perpendicular gradient.
- Using one of the given points instead of the mid-point.
- Subtracting the coordinates when finding the mid-point, rather than adding them.

Question 4

(a) (i) Comprehensive responses

- The binomial expansion was usually completed correctly.

Limited responses

- Some candidates did not simplify the required terms.
- Some candidates made errors with the signs of the terms.

(ii) Comprehensive responses

- The binomial expansion was usually completed correctly.

Limited responses

- Some candidates did not square *a* when expanding $(ax)^2$.

(b) Comprehensive responses

- Many candidates selected the appropriate three products correctly.

Limited responses

- Some candidates used the original terms rather than the required products.

Question 5

(a) Comprehensive responses

- Many candidates integrated correctly and included a constant of integration.
- Most candidates then recognised that the gradient was equal to 0 at the minimum points and correctly solved the resulting equations.
- Many candidates found that the x-coordinate of the other stationary point was 0.

Limited responses

- Some candidates forgot about the constant of integration.
- A common error was setting $\frac{dy}{dx} = 3$ rather than 0.
- A few candidates integrated the constant p to $\frac{p^2}{2}$.

Question 6

Comprehensive responses

- Many candidates transformed the given equation into a solvable form.
- Most candidates recognised that the required solutions were in the third and fourth quadrants.

Limited responses

- Answers where $\sin x = +\frac{1}{2}$ were sometimes given rather than when $\sin x = -\frac{1}{2}$.

Question 7

(a) Comprehensive responses

- Many candidates understood the question and were able to apply first the nth-term formula and then the sum-to-n formula.

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Limited responses

- Some candidates obtained fractional or negative values for the number of terms in the progression.
- Other candidates were effectively using $a + nd$ rather than $a + (n-1)d$ to find the number of terms.

(b) (i) Comprehensive responses

- Many candidates correctly used $\frac{k+4}{9} = \frac{k^2}{k+4}$ and were then able to form and solve a quadratic equation.
- Most candidates read the question correctly and chose the negative solution.

Limited responses

- Some candidates were unable to form an equation in only one variable.

(ii) Comprehensive responses

- Many candidates used their value of k to find the common ratio, the first term and the sum to infinity correctly.

Limited responses

- Some candidates incorrectly assumed that the first term of the progression was 9.
- Some candidates found a value of r greater than 1 and used it in the sum to infinity formula rather than recognising that there was an error in their working.

Question 8

(a) Comprehensive responses

- Many candidates used the given points to find the centre and radius of the circle correctly and then substituted these into the equation of a circle.

Limited responses

- Some candidates found the distance between the two given points but did not realise that this length was the diameter.
- Some candidates did not demonstrate a secure understanding of the equation of a circle.

(b) Comprehensive responses

- Many candidates found the points of intersection of the line and circle and then calculated the distance between these points in the required surd form.

Limited responses

- Some candidates' working was more complicated because they thought that the equation of the circle was $(x-3)^2 + (y-6)^2 = \sqrt{29}$ rather than 29.

Question 9

(a) Comprehensive responses

- Many candidates realised that integration was required to find the area of the shaded region.
- Most candidates realised that the limits were 0 and 4 and showed sufficient working.

Limited responses

- Some candidates did not show clear substitution of the limits or assumed that substituting 0 as the second limit would give a value of 0.

(b) Comprehensive responses

- Many candidates differentiated the given function correctly and used this to find the equation of the normal.
- Fewer candidates were able to find the area of the required triangle and equate this to their answer from **part (a)**.

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Limited responses

- Some candidates did not multiply the derivative by 2 when applying the chain rule.

Question 10

(a) Comprehensive responses

- Many candidates recognised that the discriminant was equal to 0 when the function had repeated roots.
- Most candidates gave their answers as exact values.

Limited responses

- Some candidates gave their final answers as inequalities.

(b) (i) Comprehensive responses

- Some candidates recognised that, for the inverse function to exist, the function needed to be one-to-one.
- Candidates used a variety of methods including completing the square, differentiating, or using the formula $\frac{-b}{2a}$ to find the vertex and therefore show the given answer.

Limited responses

- Many candidates were unsure how to establish the given result.

(ii) Comprehensive responses

- Many candidates completed the square correctly and then found the required inverse function.

Limited responses

- Some candidates divided the function by 2 or were unable to complete the square correctly.
- Some candidates completed the required working correctly but left ± in their final answer.

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MATHEMATICS

Paper 9709/13
Pure Mathematics 1

Key messages

What candidates did well

- Candidates used the correct approach when the question required the solution of simultaneous equations.
- Candidates correctly used the binomial expansion.
- Many candidates demonstrated a good understanding of questions involving calculus.
- Candidates correctly determined the equation of a circle from its centre and radius.
- Candidates correctly equated the discriminant of a quadratic equation to zero where appropriate.

What candidates needed to improve

- Greater care in reading questions would benefit candidates of all abilities.
- Candidates would benefit from greater accuracy in basic algebraic manipulation.
- Candidates should show sufficient working when solving quadratic equations.
- When a question includes 'show that', candidates should ensure that each step in their argument is clear.
- When solving trigonometric equations, candidates should ensure that all possible solutions are included in their answers.

Comments on specific questions

Question 1

(a) **Comprehensive responses**

- Most candidates correctly equated the two equations to form a three-term quadratic equation.
- Candidates used an appropriate method to solve the quadratic equation.

Limited responses

- Some candidates did not determine the *y*-coordinates of the intersection points.
- Candidates attempted to factorise a reduced form of the equation without first simplifying the original equation.

(b) **Comprehensive responses**

- Candidates recognised the connection between parts **(a)** and **(b)** and stated the solution using the values obtained in part **(a).**

Limited responses

- Some candidates did not recognise the connection between parts **(a)** and **(b)** and repeated the work from part **(a).**
- Some candidates selected the two outer ranges rather than the single range between *x=1* and *x=5*.

Question 2

(a) **Comprehensive responses**

- Most candidates recognised that $\sqrt{x}$ was the same as $x^{\frac{1}{2}}$ and then correctly combined the powers.

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Limited responses
- Some candidates did not combine the powers correctly.

(b) **Comprehensive responses**
- Most candidates correctly formed a valid quadratic equation.

Limited responses
- Having solved for the substituted variable, some candidates did not determine the corresponding values of x.

Question 3

(a) **Comprehensive responses**
- Many candidates correctly used the required trigonometric identities to prove the given identity.

Limited responses
- Some candidates did not show sufficient steps in their working to provide a complete solution.

(b) **Comprehensive responses**
- Candidates who correctly used the identity from part **(a),** collected all the terms on one side and factorised were able to obtain all the required values.

Limited responses
- Some candidates omitted solutions arising from either $\sin\theta=0$ or $\tan\theta=0$ and therefore did not find all the required values of θ.

Question 4

(a) **Comprehensive responses**
- Candidates correctly differentiated and equated the resulting expression to the given gradient value to find the value of k.

Limited responses
- Some candidates equated their derivative to an incorrect gradient value or to 0.

(b) **Comprehensive responses**
- Candidates correctly equated their derivative, including their value of k, to the given numerical gradient.
- Candidates correctly used the negative solution of the resulting equation to find the y coordinate of Q.

Limited responses
- Some candidates equated their derivative to an incorrect gradient value or to 0.
- Some candidates included the coordinates of PPP in their final answer.

Question 5

(a) **Comprehensive responses**
- Candidates obtained four correct terms by using the binomial expansion correctly.

Limited responses
- Some candidates did not apply the appropriate power to the $3x$ term in the expansion.

(b) **Comprehensive responses**
- Candidates correctly multiplied their expression from part **(a)** by $(1 – 3x)$.
- Candidates collected terms correctly.

Limited responses
- Although the correct method was applied, sign errors resulted in an incorrect answer.
- Some candidates only evaluated the term in x^3.

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(c) Comprehensive responses

- Candidates correctly identified the value of x that they needed to use.

Limited responses

- Some candidates did not identify the correct value of x to use.

Question 6

(a) Comprehensive responses

- Most candidates recognised that solving the equation obtained by equating the derivative to 0 would give the required values of x.

Limited responses

- Some candidates did not recognise that $x^4 = 16$ has two solutions and therefore found only one stationary point.

(b) Comprehensive responses

- Most candidates correctly equated two algebraic expressions and arrived at the correct answer.

Limited responses

- Some candidates made errors in basic algebraic manipulation, resulting in incorrect answers.

Question 7

(a) Comprehensive responses

- Most candidates correctly identified the required angle in radians.

Limited responses

- Some candidates did not identify the correct value of the required angle in radians.

(b) Comprehensive responses

- Most candidates correctly used the given radius to calculate the areas of sectors and triangles and combined these appropriately to determine the composite area.

Limited responses

- Some candidates continued to use incorrect angle values, while others gave decimal answers despite the requirement for an exact answer.

Question 8

Comprehensive responses

- Candidates correctly isolated the x term from the fractional coefficient and arrived at the correct integral.

Limited responses

- Some candidates obtained incorrect results from integration, resulting in incorrect answers despite otherwise correct methods.

Question 9

(a) Comprehensive responses

- Most candidates correctly differentiated the given function.

Limited responses

- Some candidates did not convert the square root expression into the correct fractional power.

(b) Comprehensive responses

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- Most candidates correctly applied the process of related rates of change.

Limited responses
- Some candidates misinterpreted the information given in the question.

Question 10

(a) **Comprehensive responses**
- Candidates successfully eliminated either *a* or *d* as a first step.

Limited responses
- Candidates who eliminated *r* as a first step generally made little further progress.

(b) **Comprehensive responses**
- Candidates correctly obtained the value of r from the quadratic equation given in part **(a)**.
- Candidates correctly used the value of *r* to find *a* and then *d*.

Limited responses
- Some candidates used either incorrect value of *r* or an incorrect relationship from their working in part **(a)**.

Question 11

(a) **Comprehensive responses**
- Candidates clearly showed how they obtained the centre and radius.
- Candidates correctly used these values to obtain the required form of the equation of the circle.

Limited responses
- Candidates provided insufficient evidence of how they obtained their values for the centre and radius.
- Some candidates did not use the appropriate form of the equation of the circle.

(b) **Comprehensive responses**
- Candidates produced a quadratic equation by combining the given linear equation and the equation of the circle.
- Candidates correctly substituted their coefficients into the determinant and equated it to nought.

Limited responses
- Some candidates produced the correct quadratic equation but did not use the determinant.
- Some candidates produced the correct quadratic equation but used incorrect coefficients in the determinant.
- Some candidates produced the correct quadratic equation but substituted $x=0$.

(c) **Comprehensive responses**
- Candidates used the solutions to the quadratic equation in **(b)** to find the coordinates of *P, Q, R* and *S*.
- Candidates used one of several valid methods to find the required area.

Limited responses
- Some candidates correctly found the vertices but did not successfully apply a method to calculate the whole area.

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MATHEMATICS

Paper 9709/15
Pure Mathematics 1

Key messages

What candidates did well
- Candidates demonstrated skillful use of algebraic techniques, with examiners reporting many examples of accurate algebraic manipulation.
- Good analysis and problem-solving were seen throughout the paper, with candidates often selecting efficient methods.
- Examiners commented on the neat and logical presentation of solutions, with few instances of working that were difficult to follow.

What candidates needed to improve
- Candidates should pay greater attention to showing all necessary working clearly, especially when solving quadratic equations, simplifying surds, and using limits in definite integration.
- Candidates should show clearly and logically the stages of their working for questions where an answer is given.

Comments on specific questions

Question 1

Comprehensive responses
- The requirement to eliminate x or y by substitution of a linear expression for y^2 or x^2 in the first equation was well understood, and many complete solutions were reported.

Limited responses
- Candidates should recognise that the instruction to solve the simultaneous equations requires values of x and y, rather than just x or y.
- Candidates should show a clear method when solving quadratic equations.

Question 2

Comprehensive responses
- Most candidates recognised the need to differentiate V with respect to h.
- Many candidates used the chain rule with clear notation.
- The required substitution and calculation usually followed a correct application of the chain rule.

Limited responses
- The correct answer of $\frac{1}{5\pi}$ was regularly seen as $\frac{1}{5}\pi$.
- Incorrect versions of the chain rule were used.

Question 3

(a) **Comprehensive responses**
- The general term of the binomial expansion was used successfully to find the required terms.
- Most candidates recognised the need to equate the coefficients and make p the subject.

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Limited responses

- Finding all the terms in each binomial expansion and selecting those required was a source of error for candidates who did not use the general term.
- Incorrect squaring of $-2q$ was an error seen on some papers.

(b) **Comprehensive responses**

- The expression for p was used successfully to find the two values of q.
- The general term of the expansion was usually used correctly to find the required term.

Limited responses

- Some candidates gave the term in x^3 rather than its' coefficient.

Question 4

(a) **Comprehensive responses**

- The required differentiation was nearly always completed correctly.
- The derivative was also nearly always used correctly to find the x-coordinate of the turning point.

Limited responses

- Methods other than differentiation, such as completing the square, did not meet the requirements of the question.

(b) **Comprehensive responses**

- Many candidates correctly used the answer to **part (a)** divided by two.

Limited responses

- Although unnecessary, some candidates attempted to find the equation of the transformed curve and then find its' turning point.
- Multiplying by two rather than dividing was the most common error.

(c) **Comprehensive responses**

- Multiplying the right-hand side of the equation by 3 and replacing x with $2x$ was widely applied, resulting in many completely correct answers.
- The required algebraic process was usually set out well.

Limited responses

- Some candidates did not present the result as an equation, as required by the question.
- Errors were unnecessarily introduced when the equation was rearranged into completed square form.

Question 5

(a) **Comprehensive responses**

- Most candidates completed the square correctly.

Limited responses

- A few incorrect answers were the result of sign errors.

(b) **Comprehensive responses**

- In many cases, the completed square form was adapted successfully, either by substitution or by replacing x by x^4.to give the higher order equation.
- Correctly adapted forms were solved with clear working to obtain the two exact answers.

Limited responses

- Some candidates did not realise that there was a requirement to use the answer to **part (a),** as indicated by the first word of this part, 'Hence'.
- Some candidates did not appreciate that a rounded value is not an exact solution to an equation.

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Question 6

Comprehensive responses

- Elimination of y between the two equations was almost always carried out correctly.
- A correct quadratic equation in x and k nearly always followed.
- Most candidates realised that the discriminant could be used and were able to express it in terms of k.
- Solving the inequation from the discriminant was mostly carried out correctly.
- Some candidates used the gradients of the line and the curve to obtain correct answers.

Limited responses

- The case where the discriminant was zero was not considered by some candidates.
- A single value of k or an incorrect range were given.

Question 7

(a) **Comprehensive responses**

- Various correct common denominators were successfully formed.
- Correct use of the trigonometric identity was seen in nearly all attempts.
- Correct factorisation and simplification were also seen in most attempts.

Limited responses

- Some notation and use of brackets were inconsistent.
- The requirement to prove the identity was sometimes ignored, with the identity being treated as an equation.

(b) **Comprehensive responses**

- Most candidates transformed the left-hand side of the equation using the given result from **part (a).**
- The resulting simple trigonometric equation was frequently solved correctly to find the two solutions in the given range.

Limited responses

- Incorrect solutions without logical working could not gain credit.
- Occasionally, only one answer was given.
- Some candidates ignored the given range and gave answers in radians.

Question 8

(a) **Comprehensive responses**

- Simple trigonometry and either Pythagoras' theorem or the cosine rule were used effectively.
- Calculations in surd form enabled a length in the given form to be obtained.

Limited responses

- Some candidates were unable to convert their surd answers to the given form.
- Errors using surd form within Pythagoras' theorem and the cosine rule were seen.

(b)(i) **Comprehensive responses**

- The result from **(a)** was mostly used correctly to find an expression for $\sin RQS$.
- A few candidates were able to manipulate their correct value of $\sin RQS$ to the given answer.

Limited responses

- There was often no working shown linking the candidate's $\sin RQS$ to the given final answer.

(ii) **Comprehensive responses**

- Candidates who recognised that the answer to **part (b)(i)** was exact used this and angle RQP to obtain the required result.
- A minority used the sine rule and obtained an alternative correct exact answer.

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Limited responses

- A decimal value of angle RQS was given by some candidates.

Question 9

(a) (i) Comprehensive responses

- The meaning of the notation $f'(x)$ was clear to nearly all candidates.
- The differentiation of the function was usually set out clearly, leading to a correct expression for $f'(x)$.

Limited responses

- Some sign errors were seen in otherwise correct methods.
- A few candidates confused $f'(x)$ and $f^{-1}(x)$.

(ii) Comprehensive responses

- Candidates who obtained correct solutions clearly justified why the derivative is always positive.

Limited responses

- The derivative was often stated to be positive without clear justification.
- Some candidates thought that the derivative could be zero and that this formed part of the condition for an increasing function.

(b) (i) Comprehensive responses

- Most candidates showed the algebraic manipulation required to obtain the inverse.
- A correct expression with a subject was also nearly always seen.

Limited responses

- Some sign errors and failures to interchange y and x were noted.

(ii) Comprehensive responses

- The range of the inverse function was mostly quoted correctly.
- Candidates who correctly deduced the range of the function were nearly always able to quote this as the domain of the inverse function.

Limited responses

- It was not always made clear which inequality was the domain and which was the range.
- The wrong inequality was frequently seen with the correct numerical value.

Question 10

Comprehensive responses

- Correct and complete working to obtain the coordinates of the points of intersection of the line and the curve was the usual starting point.
- The required subtraction of two integrals was successfully carried out either before or after integration.
- Clear use of limits was a feature of the completely correct answers.
- Candidates who viewed the area under the line as a trapezium mostly used the *[coordinates]* to find its area correctly.

Limited responses

- The solution of the line and curve equations to find the points of intersection was not always shown clearly.
- Some integral results appeared without any evidence of integration.
- Some integral results appeared following correct or incorrect integration, with no working shown to support the substitution of limits.

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Question 11

(a) **Comprehensive responses**

- The need to eliminate y from the circle equation to find either A or B was well understood and often carried out successfully.
- This procedure was usually followed correctly to find the second coordinate.
- It was deemed reasonable for candidates to assume AB is horizontal and use their first y coordinate in the second linear equation to find the second coordinate generally obtained correct results.
- Some candidates found the equations of the tangents at A and B and solved these simultaneously with the equations of the corresponding radii, obtaining the correct coordinates of A and B.

Limited responses

- The solutions of quadratic equations were often not justified by a method.

(b) **Comprehensive responses**

- In most attempts, candidates realised that the radius was required and used the circle equation to find it correctly.
- The most common correct approach was to find the area of sector ACB and subtract the area of triangle ACB. The required formulae were usually applied correctly.
- Methods involving the segment area formula or considering the whole circle as a starting point often led to the correct area.

Limited responses

- Half the required angle ACB was mistakenly used as ACB in otherwise correct formulae for sector and triangle areas.
- Candidates who chose to use a calculus method were often unable to find the required integral.
- Some candidates did not give their answer to three significant figures, as requested in the question.

Question 12

(a) **Comprehensive responses**

- The nth term formula or logical deduction was used effectively to identify the position of the required term in the progression.
- The nth term formula or logical deduction was often used a second time to find the required term.

Limited responses

- There was some confusion over the value of the required term and its position in the progression.
- When an inequality was formed, the use of a negative common difference sometimes resulted in the inequality being reversed.

(b) (i) **Comprehensive responses**

- The common ratio was often found and simplified correctly.
- The range of values of the common ratio for which a sum to infinity exists was often applied correctly using a simplified form of the common ratio.

Limited responses

- A common misunderstanding was that $\cos\theta > \frac{1}{2} \Rightarrow \theta > \frac{1}{2}$.
- The value $\theta = 0$ was incorrectly included in some answers.

(ii) **Comprehensive responses**

- The correct formula for the sum to infinity of a geometric progression was often seen and used correctly to obtain an initial answer.
- A minority of candidates showed clearly how their initial answer could be rearranged to obtain an answer in the given form.

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Limited responses

- The stages in converting the initial expression for the sum to infinity to the required form of the answer were often not shown.

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MATHEMATICS

Paper 9709/21
Pure Mathematics 2

Key messages

What candidates did well
- Most candidates recognised the correct methods required and attempted to apply them to obtain solutions.

What candidates needed to improve
- Candidates should recognise the significance of the instruction 'Hence' when it is used in a later part of a question.
- Candidates should ensure that they give their final answers to the level of accuracy stated in the question where this differs from that given in the rubric.

Comments on specific questions

Question 1

Comprehensive responses
- Many candidates took logarithms of both sides of the given equation and applied the power law of logarithms. The resulting equation was usually rearranged into the form $y = mx + c$.

Limited responses
- Many candidates omitted brackets when applying the power law of logarithms and these were often not recovered in subsequent work.
- A common response to the question was $y = \left(\frac{4\ln 2}{\ln 3} - 1\right)x + \frac{\ln 2}{\ln 3}$. Candidates with this form of the answer had not used logarithmic laws again to obtain the constant m in the required form $\frac{\ln p}{\ln q}$ as required.

Question 2

(a) **Comprehensive responses**
- Most candidates used a correct approach by either forming two linear equations or squaring each side of the given equation to obtain a three-term quadratic equation.
- Many candidates chose to use the squaring method.
- Many correct solutions were seen.

Limited responses
- Sign errors in both methods, together with arithmetic slips, caused problems for some candidates

(b) **Comprehensive responses**
- Many candidates made the connection between **parts (a)** and **(b)** and realised that they could equate their answers to **part (a)** to $\cot\theta$.
- Candidates who realised that if $\cot\theta = 8$ then $\tan\theta = \frac{1}{8}$ and likewise for the second solution or their solutions to **part (a)**, usually progressed well.

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Limited responses

- Some candidates restarted the question, not recognising the significance of the instruction 'Hence'.
- Many candidates were unable to solve an equation in terms of $\cot\theta$.
- Some candidates did not give their answers to the required level of accuracy.

Question 3

(a) **Comprehensive responses**

- Some candidates applied the trapezium rule correctly and obtained the correct answer to the required level of accuracy.

Limited responses

- Some candidates attempted integration rather than applying the trapezium rule.
- Some candidates made errors when splitting the given range into three intervals.
- Some candidates made errors when applying the formula.
- Some candidates did not give their answer to the required level of accuracy.
- Some candidates used $y = 0$ when $x = 0$, rather than $y = 3$ when $x = 0$.

(b) **Comprehensive responses**

- Some candidates obtained the correct conclusion together with the correct result.
- A diagram with a correct explanation was acceptable, as were the comment 'concave up' and other valid explanations.

Limited responses

- Some candidates did not give a reason for their conclusion. Some candidates considered only one trapezium.

Question 4

(a) **Comprehensive responses**

- Most candidates were able to obtain the value $\sqrt{34}$.
- Many candidates used a correct method to find α but did not give their answer to the required level of accuracy.

Limited responses

- Some candidates made sign errors in the attempting to apply the formula.
- Some candidates used $\tan\alpha = \frac{5}{3}$ rather than $\tan\alpha = \frac{3}{5}$ to find α.
- Values of α. were not given to the required level of accuracy.

(b) **Comprehensive responses**

- Many candidates found the positive angle using a correct method of solution.
- Fewer candidates obtained the correct negative angle.

Limited responses

- Some candidates did not use their answer to **part (a)** because they did not recognise the significance of the instruction 'Hence'.
- Many candidates did not obtain the correct negative angle.

Question 5

(a) **Comprehensive responses**

- Many fully correct solutions were seen.
- Candidates using algebraic long division were usually more successful than candidates using synthetic division.

Limited responses

- Candidates using synthetic division often omitted dividing their result by 2 to obtain the correct quotient.

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- Some sign errors and arithmetic slips also led to errors in both the quotient and the remainder.

(b) **Comprehensive responses**

- Some candidates recognised that they needed to use their work from **part (a)** to obtain the value of α using the factor $(2x+3)$.
- They then rearranged the quotient obtained in **part (a)** to obtain the given result.

Limited responses

- Many candidates were able to find the value α of but were unable to complete the question.

(c) **Comprehensive responses**

- Many candidates realised that they were seeking a sign change and were successful when using a correct function.
- Candidates who evaluated β at 1.5 and 1.6 often failed to compare these values with 1.5 and 1.6 respectively.

Limited responses

- Candidates who evaluated β at 1.5 and 1.6 often omitted to compare with 1.5 and 1.6 respectively.

(d) **Comprehensive responses**

- Many candidates used the iterative formula correctly, providing sufficient iterations to obtain a correct answer to the required level of accuracy.

Limited responses

- Some candidates did not use enough iterations or used an inappropriate level of accuracy in either their iterations or their final answer.

Question 6

(a) **Comprehensive responses**

- Many candidates attempted to use the quotient rule to obtain $\frac{\mathrm{d}y}{\mathrm{d}t}$.
- Many candidates then found $\frac{\mathrm{d}x}{\mathrm{d}t}$ and used a correct method to find $\frac{\mathrm{d}y}{\mathrm{d}x}$.

Limited responses

- Some candidates did not use the quotient rule.
- Some candidates made simplification errors and sign errors.
- Some candidates could not differentiate the exponential terms correctly.

(b) **Comprehensive responses**

- Few candidates were able to set either $\frac{\mathrm{d}y}{\mathrm{d}x}$ or $\frac{\mathrm{d}y}{\mathrm{d}t}$ to zero subsequently find the value of the parameter and hence the coordinates of the maximum point.

Limited responses

- Many candidates did not have an expression for $\frac{\mathrm{d}y}{\mathrm{d}x}$ in the correct form,
- Some candidates were able to find the value of the parameter but did not go on to find the coordinates of the maximum point.

(c) **Comprehensive responses**

- Many candidates were able to find the value of the parameter using a correct method but did not always complete the solution and find the gradient.

Limited responses

- Some candidates used a correct method to find the value of the parameter but substituted into an incorrect gradient function.

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Question 7

Comprehensive responses

- Very few correct solutions were seen.
- Many candidates attempted differentiation to find the values of α and β.
- Fewer candidates were able to obtain the correct values.
- Very few candidates made correct use of the appropriate double angle formula to obtain an integrand in the correct form.
- Few candidates obtained a correct integral and substituted the correct limits to give an exact answer.

Limited responses

- Candidates often used the incorrect values for α and β as they had considered the solutions of the equation $\sin 2x = 0$ as well as the solutions of the equation $\cos 2x = -\frac{1}{2}$,
- Little progress could be made if the integrand was not written in the correct form.

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MATHEMATICS

Paper 9709/22
Pure Mathematics 2

Key messages

What candidates did well
- Most candidates used correct methods when attempting solutions.

What candidates needed to improve
- Candidates should recognise the significance of the instruction 'Hence' in later parts of questions.
- Candidates need to ensure that their answers are written in the required form and that they have answered the question.
- Candidates should ensure that they use the level of accuracy specified in the question where this differs from that given in the rubric.
- When an exact answer is required, candidates should give an exact answer rather than a calculator approximation.

Comments on specific questions

Question 1

Comprehensive responses
- Some candidates recognised that they needed to expand the integrand before integration.
- Candidates who did so were often able to find a correct integral and apply the limits correctly.

Limited responses
- Some candidates omitted to collect like terms and simplify their final answer.
- Some candidates attempted integration without expanding the original integrand.

Question 2

Comprehensive responses
- Many candidates made use of a correct trigonometric identity.
- Many candidates obtained a correct trigonometric equation in terms of one trigonometric function.
- Most candidates were then able to obtain at least two correct solutions.

Limited responses
- Some candidates made sign errors.
- Candidates who rewrote the original equation in terms of sine and cosine and then a single trigonometric function were less successful than those who used $\cot^2\theta + 1 = \operatorname{cosec}^2\theta$.

Question 3

Comprehensive responses
- Few candidates were able to obtain a completely correct solution.
- Few candidates were able to obtain the equation $\ln y = \ln k + (x+2)\ln a$.
- Some candidates were able to use the given coordinates correctly to find the value of $\ln a$, making use of the gradient.

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Limited responses
- Candidates who did not obtain a correct equation involving logarithms were generally limited to finding the correct gradient and hence the value of *a.*
- The given coordinates were used incorrectly.

Question 4

Comprehensive responses
- Most candidates differentiated correctly, making use of the quotient rule.
- The gradient at point P was then usually calculated correctly.
- Many candidates were able to find the coordinates of point P.
- Some candidates were able to obtain the equation of the normal in the correct form.

Limited responses
- Some candidates found the equation of the tangent instead.
- Some candidates did not write their final answer in the required form.

Question 5

(a) **Comprehensive responses**
- Many candidates were able to produce a correct solution either by considering two appropriate linear equations or by using the squaring method.
- Most candidates were then able to obtain the correct critical values and complete the final solution.

Limited responses
- Some candidates made sign errors in both methods.
- Having obtained correct critical values, some candidates did not obtain the correct inequality solutions.

(b) **Comprehensive responses**
- Many candidates made use of their answers to **part (a)** and equated them to $\ln\left(\frac{1}{2}N\right)$.
- Many candidates obtained the resulting values of 3.895 and 296.8.
- Few candidates gave their answers as integers, as required.

Limited responses
- Some candidates did not recognise the significance of the instruction ‘Hence’ and either restarted the question again or attempted an incorrect method.
- Many candidates did not recognise answers were required in integer form.

Question 6

(a) **Comprehensive responses**
- Most candidates found $\mathrm{f}(-2)$, equated it to zero and found the correct value of a.

Limited responses
- Some arithmetic slips occurred.
- Some candidates found $\mathrm{f}(2)$.

(b) **Comprehensive responses**
- Many candidates used their value of *a* and applied algebraic long division or synthetic division to obtain a cubic quotient.
- Many candidates equated this cubic quotient to zero and rearranged to obtain the given answer.

Limited responses
- Some candidates did not complete the algebraic long division or synthetic division correctly and were unable to obtain the given result.

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(c) **Comprehensive responses**

- Many candidates used the iterative formula correctly, stating intermediate steps and the final answer to the correct degree of accuracy.

Limited responses

- Some candidates did not complete enough iterations.
- Some candidates had intermediate calculations which were not to the required level of accuracy.
- Some candidates did not use the correct level of accuracy in their final answer.

Question 7

(a) **Comprehensive responses**

- Few candidates produced a completely correct solution.
- Candidates needed to find the *x*-coordinates of the points of intersection of the curve and the *x-axis*.
- Some candidates obtained the correct x-coordinates by solving a correct cubic equation in $\cos 2x$.
- Few candidates recognised that $\frac{1}{\cos^2 2x}$ was $\sec^2 2x$ which could easily be integrated.

Limited responses

- Many candidates were unable to integrate correctly and were unable to find the correct area.

Question 8

(a) **Comprehensive responses**

- Most candidates were able to find $\frac{\mathrm{d}y}{\mathrm{d}t}$ and $\frac{\mathrm{d}x}{\mathrm{d}t}$ correctly.
- Most candidates made a correct attempt to find $\frac{\mathrm{d}y}{\mathrm{d}x}$ and hence the value of the gradient when t = 0.

Limited responses

- Some candidates made sign and coefficient errors when differentiating.
- Some candidates equated the gradient function to zero.

(b) **Comprehensive responses**

- Few correct responses were seen.
- Many candidates equated either $\frac{\mathrm{d}y}{\mathrm{d}x}$ or $\frac{\mathrm{d}y}{\mathrm{d}t}$ to zero.
- Many candidates obtained $\sin t = \frac{5}{12}$.
- Few candidates showed all their exact working correctly to obtain the answer $\frac{97}{24}$.

Limited responses

- Some candidates used a calculator to find the exact *y*-coordinate of *M*.

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MATHEMATICS

Paper 9709/23
Pure Mathematics 2

Key messages

What candidates did well
- Most candidates used correct methods when attempting solutions.

What candidates needed to improve
- Candidates should recognise the significance of the instruction 'Hence' in later parts of questions.
- Candidates need to ensure that their answers are written in the required form and that they have answered the question.
- Candidates should ensure that they use the level of accuracy specified in the question where this differs from that given in the rubric.
- When an exact answer is required, candidates should give an exact answer rather than a calculator approximation.

Comments on specific questions

Question 1

Comprehensive responses
- Some candidates recognised that they needed to expand the integrand before integration.
- Candidates who did so were often able to find a correct integral and apply the limits correctly.

Limited responses
- Some candidates omitted to collect like terms and simplify their final answer.
- Some candidates attempted integration without expanding the original integrand.

Question 2

Comprehensive responses
- Many candidates made use of a correct trigonometric identity.
- Many candidates obtained a correct trigonometric equation in terms of one trigonometric function.
- Most candidates were then able to obtain at least two correct solutions.

Limited responses
- Some candidates made sign errors.
- Candidates who rewrote the original equation in terms of sine and cosine and then a single trigonometric function were less successful than those who used $\cot^2\theta + 1 = \operatorname{cosec}^2\theta$.

Question 3

Comprehensive responses
- Few candidates were able to obtain a completely correct solution.
- Few candidates were able to obtain the equation $\ln y = \ln k + (x+2)\ln a$.
- Some candidates were able to use the given coordinates correctly to find the value of $\ln a$, making use of the gradient.

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Limited responses
- Candidates who did not obtain a correct equation involving logarithms were generally limited to finding the correct gradient and hence the value of *a.*
- The given coordinates were used incorrectly.

Question 4

Comprehensive responses
- Most candidates differentiated correctly, making use of the quotient rule.
- The gradient at point P was then usually calculated correctly.
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- Some candidates were able to obtain the equation of the normal in the correct form.

Limited responses
- Some candidates found the equation of the tangent instead.
- Some candidates did not write their final answer in the required form.

Question 5

(a) **Comprehensive responses**
- Many candidates were able to produce a correct solution either by considering two appropriate linear equations or by using the squaring method.
- Most candidates were then able to obtain the correct critical values and complete the final solution.

Limited responses
- Some candidates made sign errors in both methods.
- Having obtained correct critical values, some candidates did not obtain the correct inequality solutions.

(b) **Comprehensive responses**
- Many candidates made use of their answers to **part (a)** and equated them to $\ln\left(\frac{1}{2}N\right)$.
- Many candidates obtained the resulting values of 3.895 and 296.8.
- Few candidates gave their answers as integers, as required.

Limited responses
- Some candidates did not recognise the significance of the instruction ‘Hence’ and either restarted the question again or attempted an incorrect method.
- Many candidates did not recognise answers were required in integer form.

Question 6

(a) **Comprehensive responses**
- Most candidates found $\mathrm{f}(-2)$, equated it to zero and found the correct value of a.

Limited responses
- Some arithmetic slips occurred.
- Some candidates found $\mathrm{f}(2)$.

(b) **Comprehensive responses**
- Many candidates used their value of *a* and applied algebraic long division or synthetic division to obtain a cubic quotient.
- Many candidates equated this cubic quotient to zero and rearranged to obtain the given answer.

Limited responses
- Some candidates did not complete the algebraic long division or synthetic division correctly and were unable to obtain the given result.

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(c) **Comprehensive responses**

- Many candidates used the iterative formula correctly, stating intermediate steps and the final answer to the correct degree of accuracy.

Limited responses

- Some candidates did not complete enough iterations.
- Some candidates had intermediate calculations which were not to the required level of accuracy.
- Some candidates did not use the correct level of accuracy in their final answer.

Question 7

(a) **Comprehensive responses**

- Few candidates produced a completely correct solution.
- Candidates needed to find the *x*-coordinates of the points of intersection of the curve and the *x-axis*.
- Some candidates obtained the correct x-coordinates by solving a correct cubic equation in $\cos 2x$.
- Few candidates recognised that $\frac{1}{\cos^2 2x}$ was $\sec^2 2x$ which could easily be integrated.

Limited responses

- Many candidates were unable to integrate correctly and were unable to find the correct area.

Question 8

(a) **Comprehensive responses**

- Most candidates were able to find $\frac{\mathrm{d}y}{\mathrm{d}t}$ and $\frac{\mathrm{d}x}{\mathrm{d}t}$ correctly.
- Most candidates made a correct attempt to find $\frac{\mathrm{d}y}{\mathrm{d}x}$ and hence the value of the gradient when t = 0.

Limited responses

- Some candidates made sign and coefficient errors when differentiating.
- Some candidates equated the gradient function to zero.

(b) **Comprehensive responses**

- Few correct responses were seen.
- Many candidates equated either $\frac{\mathrm{d}y}{\mathrm{d}x}$ or $\frac{\mathrm{d}y}{\mathrm{d}t}$ to zero.
- Many candidates obtained $\sin t = \frac{5}{12}$.
- Few candidates showed all their exact working correctly to obtain the answer $\frac{97}{24}$.

Limited responses

- Some candidates used a calculator to find the exact *y*-coordinate of *M*.

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MATHEMATICS

Paper 9709/25
Pure Mathematics 2

There were too few candidates for a meaningful report to be produced.

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MATHEMATICS

Paper 9709/31
Pure Mathematics 3

Key messages

What candidates did well

- The solutions were clear and easy to follow.
- Candidates were proficient in the basic processes of calculus, such as differentiating a product (**Question 6 (a)**) and integrating by parts (**Question 8)**).

What candidates needed to improve

- The presentation of mathematical arguments should make the method clear.
- Mathematical terminology should be used correctly. For example, using the correct structure $\int \mathrm{f}\left(x\right) \mathrm{d}x$, where the integral sign and '*dx*' should be seen as essential, not as an optional extra.

Comments on specific questions

Question 1

Comprehensive responses

- There were many concise responses, with clear working and a logical flow.

Limited responses

- Algebraic errors were common, particularly with $\left[3\left(x+4\right)\right]^2 = 3\left(x+4\right)^2$.
- Candidates working with linear equations and inequalities usually identified one relevant equation.
- Candidates did not consider the combination of signs necessary to obtain the second relevant equation.
- Candidates with the correct critical values did not always state an appropriate conclusion or gave an incorrect conclusion.
- The incorrect statement $-\frac{11}{5} < x < -13$ was common.

Question 2

Comprehensive responses

- Solutions were concise and accurate, working with the index form given in the question, or starting by taking logarithms of both sides of the equation.
- There were some rounding errors introduced by using rounded values from one calculation and then giving inappropriate accuracy in the next answer.

Limited responses

- Candidates treated the values of ln*y* as values of *y*, so they worked with incorrect equations from the start.
- Errors in the algebra and arithmetic resulted in incorrect answers from correct equations.

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Question 3

Comprehensive responses
- Candidates applied the quotient rule correctly.
- Incorrect final answers were usually the result of slips in the algebraic or arithmetic slips.

Limited responses
- Some candidates tried to use the product rule in place of the quotient rule – this usually resulted in more complicated working.
- There was some confusion between the tangent and the normal.
- Candidates did not always comply with the request for the coefficients in the final equation to be given as integers.

Question 4

Comprehensive responses
- Candidates who were familiar with the method gave concise, correct solutions.
- Confusion over the roots of the quartic equation resulted in some incorrect final answers.

Limited responses
- There were several blank responses.
- Some candidates used an incorrect method, starting by squaring $-71-\left(20\sqrt{3}\right)\mathrm{i}$.

Question 5

(a) **Comprehensive responses**
- Most candidates worked from left to right.
- Some solutions were longer than necessary, for example taking several lines to simplify $-\frac{\cos x}{\cos x}+\frac{\sin x}{\sin x}$.

Limited responses
- sec*x* and cosec*x* were often confused.
- Solutions that tackled both sides of the identity did not meet up in the middle.
- $\frac{\cos 2x}{\sin 2x}$ was not recognised as $\cot 2x$.

(b) **Comprehensive responses**
- Some candidates were able to work with $\cot 2x = \frac{3}{2}$ or $\tan 2x = \frac{2}{3}$, and others converted the equation into a quadratic in tan*x*.
- Most candidates obtained one correct solution; the second solution was often missing.
- The correct answers 0.294 and 1.86 were sometimes replaced by 0.0936π and 0.594π. An answer in radians does not need to be expressed as a multiple of π.

Limited responses
- The link with the identity in part **(a)** was not always recognised.
- The trigonometric equation was not always processed correctly, for example, by using $\tan 2x = 2\tan x$.

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Question 6

(a) **Comprehensive responses**

- Candidates applied the product rule correctly.
- The derivative of e^{x^2+4x} was usually correct.
- Some candidates used the double angle formula to rewrite $\cos^2 x$ before differentiating.
- Some candidates were not able to derive the given equation from the correct derivative, usually because of errors in taking out the common factors.
- A few candidates started by taking logarithms to obtain $\ln y = x^2 + 4x + 2\ln(\cos x)$ before differentiating.

Limited responses

- The product rule was not applied correctly.
- There were errors in differentiating $\cos^2 x$, for example $\frac{d}{dx}(\cos^2 x) = \pm\sin^2 x$.

(b) **Comprehensive responses**

- Solutions included sketches showing two clear components.
- Some candidates did not make it clear how their sketch indicated a root of the equation.

Limited responses

- The sketch of $y = \tan x$ was incorrect, or it was shown over an incorrect interval.

(c) **Comprehensive responses**

- The candidates gave correct values for a relevant expression at each end of the given interval.

Limited responses

- The candidates worked in degrees rather than radians.
- Candidates referred to the values of the function without starting the actual the values.

(d) **Comprehensive responses**

- The required iterations were given to at least the level of accuracy specified in the question.
- The candidates recognised when they had completed sufficient iterations to reach a conclusion.

Limited responses

- The candidates worked in degrees rather than radians.
- The answers were not given to the required level of accuracy.

Question 7

(a) **Comprehensive responses**

- The two inequalities were stated correctly.

Limited responses

- There were incorrect statements such as $z \geq -2$ in place of $\mathrm{Re}(z) \geq -2$
- There were several blank responses.

(b) **Comprehensive responses**

- The candidates had a correct method for finding the value of y at the relevant point.
- They proceeded to find the correct value for $|z|$.

Limited responses

- There were many blank responses.
- Candidates who attempted the question did not show a clear strategy for finding the correct point.

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Question 8

Comprehensive responses
- The process for integration by parts was understood.
- The solutions were presented clearly.
- The process for finding the value of a definite integral was understood.

Limited responses
- There were errors in the coefficients in the integrals.
- There was a sign error in the formula used for integration by parts.
- The second stage of the integration was not completed.

Question 9

(a) **Comprehensive responses**
- There were many fully correct responses, working from either point *A* or point *B.*

Limited responses
- The distinction between the vector $\overrightarrow{AB}$ and the equation of the line through *A* and *B* was not understood.
- Most candidates started by finding a correct expression for $\overrightarrow{AB}$.
- The correct format for the vector equation of a line was not used. Many answers started *l* = …or *t* = …

(b) **Comprehensive responses**
- The process for finding the intersection of two lines was understood.
- Some candidates made errors in the algebra when solving the simultaneous equations.
- The process for testing for parallel lines was understood.

Limited responses
- There were many blank responses.
- Candidates often stated that the direction vectors were not parallel without identifying the correct direction vectors for the lines.

Question 10

(a) **Comprehensive responses**
- Candidates who applied the factor theorem and remainder theorem correctly usually obtained a correct pair of simultaneous equations.
- Candidates who used algebraic long division were often successful, although their working was generally more extensive.

Limited responses
- Candidates attempted long division, with varying degrees of success.
- Candidates often confused the factor with the remainder obtained on division.
- The use of synthetic division with algebraic terms often resulted in slips and errors.

(b) (i) **Comprehensive responses**
- Candidates were able to use their values for *a* and *b* to obtain a quadratic factor.
- Candidates with incorrect values for *a* and *b* often identified and corrected their error.

Limited responses
- Candidates who did not obtain values for *a* and *b* were unable to make further progress.

(ii) **Comprehensive responses**
- Candidates used their critical values correctly to draw a conclusion.

Limited responses.
- There were many blank responses.

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Question 11

(a) **Comprehensive responses**

- Candidates used the quotient rule to differentiate the given function.
- Candidates simplified their answer correctly.

Limited responses

- Some candidates quoted the result from the formula book rather than differentiating the given function.
- Some candidates who started correctly then made a major error such as $\frac{-4\sin^2 4x - 4\cos^2 4x}{\sin^2 4x} = \frac{-1-4\cos^2 4x}{1}$.

(b) **Comprehensive responses**

- Candidates separated the variables correctly.
- Candidates identified the forms of the two integrals correctly.
- Some candidates made errors in the coefficients when integrating.
- Some candidates made calculation errors when applying the limits.

Limited responses

- Some candidates did not attempt to separate the variables.
- Some candidates attempted the integral of the exponential function but were unable to complete the solution.
- Candidates who did not recognise the link between the two parts of the question were unable to complete the integration.

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MATHEMATICS

Paper 9709/32
Pure Mathematics 3

Key messages

What candidates did well

- Candidates performed well on familiar tasks, particularly finding the square roots of a complex number (**Question 5**), solving the trigonometric equation (**Question 7(b)**), and using partial fractions (**Question 10(a)**).

What candidates needed to improve

- Candidates should take care when writing algebraic expressions. They need to use brackets correctly. For example, $(x+1)\ln 4 \neq x+1\ln 4$ (**Question 2**), and $(2-\cos 3x)\times 3\cos 3x \neq 2-\cos 3x\times 3\cos 3x$ (**Question 7**).
- Candidates need to be familiar with the standard terminology. For example, $\tan^{-1}3x \neq \dfrac{1}{\tan 3x}$ (**Question 6**), and $\operatorname{cosec}\frac{1}{2}x = \dfrac{1}{\sin\frac{1}{2}x}$ (**Question 8**).

Comments on specific questions

Section A

Question 1

Comprehensive responses

- Most candidates attempted algebraic long division.
- Many candidates produced fully correct solutions.

Limited responses

- Unclear presentation of the division led to misalignment of the columns and subsequent errors.
- Many candidates made sign errors when completing the process.
- Two common errors at the final step were $2-(-3)=6$ and $2-(-3)=\pm 1$.

Question 2

Comprehensive responses

- Candidates were successful in taking logarithms and rearranging the given equation to obtain a simpler index equation
- Some candidates did not complete the solution to obtain an answer in the required form, for example, leaving the final answer as $\dfrac{\ln\frac{1}{24}}{\ln\frac{1}{16}}$ or $\dfrac{\ln 24}{2\ln 4}$.

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Limited responses

- Candidates made little progress when trying to rearrange the equation in index form.
- Candidates did not deal correctly with the 3, for example $3\left(2^{5-2x}\right)$ became 6^{5-2x}.
- Many candidates made algebraic and arithmetic slips when trying to obtain a value for x from $(5-2x)\ln 2 = (x+1)\ln 4 - \ln 3$, or equivalent.

Question 3

(a) **Comprehensive responses**

- Most candidates were able to read the question and write down the answer.
- Some candidates correctly quoted the rule for multiplying the moduli and adding the arguments.

Limited responses

- Many candidates left this question blank.
- Some candidates obtain an expression with 6 as a factor.
- Many candidates obtained an incorrect answer when combining the angles.

(b) **Comprehensive responses**

- Candidates used the correct terminology for the geometric transformations, referring to enlargement and rotation.

Limited responses

- Candidates described one aspect of the transformation correctly.
- Candidates did not always use the standard terminology for transformations.
- There were errors in directions and magnitudes stated.

Question 4

Comprehensive responses

- Candidates who were familiar with the method gave concise and correct solutions.
- Some candidates were unsure how to interpret the roots of the quartic equation, resulting in incorrect final answer.
- Some candidates gave only one root.

Limited responses

- Some candidates used an incorrect method, starting by squaring $3-\left(6\sqrt{2}\right)\mathrm{i}$.

Question 5

(a) **Comprehensive responses**

- Candidates correctly differentiated x and y with respect to θ.
- Candidates combined the derivatives correctly.
- Most candidates used the correct form $1+\tan^2 x = \sec^2 x$.
- Candidates made sign errors or errors when cancelling terms at the final step.

Limited responses

- The coefficients of the terms were often incorrect and the 2's lost in the process, for example $\frac{\mathrm{d}y}{\mathrm{d}\theta} = 6 - 2\frac{\sin 2\theta}{\cos 2\theta}$, and $\frac{\mathrm{d}x}{\mathrm{d}\theta} = 2 - \sec^2\theta$.
- The incorrect process was used to obtain $\frac{\mathrm{d}\theta}{\mathrm{d}x}$, commonly $\frac{\mathrm{d}\theta}{\mathrm{d}x} = \frac{1}{2} - \frac{\cos^2 2\theta}{2}$.
- Some candidates were unable to express their answer in terms of $\tan 2\theta$. This was sometimes because their expression could not be written in this form and sometimes because they did not recognise the relevant forms.

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(b) **Comprehensive responses**

- A correct answer to part **(a)** usually let to a correct quadratic equation in $\tan 2\theta$.
- Candidates were able to select the correct root, with correct expressions for x and y following.

Limited responses

- An incorrect answer to part **(a)** often still produced a quadratic equation in $\tan 2\theta$.
- If this equation did not have real roots, no further progress could be made.
- Incorrect equations that could be solved did not usually produce exact expressions for the coordinates.

Question 6

(a) **Comprehensive responses**

- Some candidates worked from first principles to find the derivative of $\tan^{-1} 3x$.
- Most candidates adapted the standard form given in the formula booklet.
- Some candidates used $\tan^{-1} 1 = 45°$, which is not appropriate for a calculus question.

Limited responses

- Many candidates tried to use the standard form for the derivative of $\tan - 3x$.
- The 3 was not always processed correctly; common errors included $\frac{3}{1+3x^2}$ and $\frac{1}{1+9x^2}$.
- Many candidates made errors when applying the product rule.

(b) **Comprehensive responses**

- Candidates completed the first stage of integration by parts correctly.
- Candidates attempted a correct method to tackle $\int \frac{kx^2}{1+9x^2}\,\mathrm{d}x$.
- Candidates used the limits correctly to evaluate the integral.
- Some candidates made sign errors and errors in the coefficients.

Limited responses

- Candidates who were unable to differentiate $\tan^{-1} 3x$ in **part (a)** usually encountered the same difficulties here.
- Many candidates made no progress with the second stage of integration by parts.
- The error $\int \frac{x^2}{1+9x^2}\,\mathrm{d}x = k\ln\left(1+9x^2\right)$ was common.

Question 7

(a) **Comprehensive responses**

- Candidates applied the quotient rule correctly.
- Candidates worked through the method correctly to obtain the given quadratic.

Limited responses

- Many candidates dd not apply the quotient rule correctly; for example, the denominator was sometimes omitted or the terms in the numerator were subtracted in the wrong order.
- Missing brackets in the numerator led to errors in the terms.
- Candidates made sign errors when differentiating the trigonometric terms, including errors such as $\frac{\mathrm{d}}{\mathrm{d}x}\sin 3x = \cos 3x$.
- Candidates made sign and arithmetic errors when rearranging the terms.

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(b) **Comprehensive responses**

- Candidates obtained a correct value for $\sin 3a$.
- This was used correctly to find at least one correct value for a.
- A full set of four values for a was uncommon, often because of rounding errors in the working.

Limited responses

- Many candidates left this question blank.
- Candidates who obtained a value for $\sin 3a$ often treated this as a value for $3a$.
- Many candidates did not attempt to find all possible value for a.

Question 8

(a) **Comprehensive responses**

- A small number of candidates produced correct sketches.
- On otherwise correct sketches, candidates often did not indicate how the sketch showed that the equation had only one root.

Limited responses

- Many candidates gave no response.
- The minimum value of $\text{cosec}\,\frac{1}{2}x$ was not consistent with any vertical scale shown on the sketch.
- When there was a vertical asymptote, it was some distance from the y axis.
- The graph of $y = \frac{1}{2}(x+3)$ did not cut the y axis at $\left(0, \frac{3}{2}\right)$.

(b) **Comprehensive responses**

- Candidates found correct values for relevant expressions at each end of the interval and drew the correct conclusion.

Limited responses

- Having found values for the relevant expressions, candidates did not explain how these confirmed the presence of a root.
- Candidates used degrees instead of radians.

(c) **Comprehensive responses**

- Most candidates started with the iterative formula and derived the equation from part **(a)**.
- Candidates who worked in the other direction often stopped before reaching the iterative formula.

Limited responses

- Some candidates used $\sin^{-1}\alpha = \dfrac{1}{\sin\alpha}$.
- Some candidates were confused between $\sec\alpha$ and $\text{cosec}\,\alpha$.
- Several candidates gave a response to part **(c)** that would have been more appropriate for part **(d)**.

(d) **Comprehensive responses**

- The required iterations were given to the level of accuracy specified in the question.
- Candidates recognised when they had completed sufficient iterations to reach a conclusion.
- After obtaining a correct set of iterative values, candidates often reached an incorrect conclusion $x = 1.036$ was common.

Limited responses

- Candidates worked in degrees rather than radians.
- Answers were not given to the required level of accuracy.
- There were several blank responses.

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Question 9

(a) **Comprehensive responses**

- Many candidates gave fully correct responses, working from either point *A* or point *B.*

Limited responses

- Candidates did not distinguish between the vector $\overrightarrow{AB}$ and the equation of the line through *A* and *B* was not understood.
- Most candidates started by finding a correct expression for $\overrightarrow{AB}$.
- The correct format for the vector equation of a line was not used. Many answers started *l* = …or *m* = …

(b) **Comprehensive responses**

- The process for finding the intersection of two lines was understood.
- Some candidates made errors in the algebra when solving the simultaneous equations.
- The process for testing for parallel lines was understood.

Limited responses

- There were several blank responses.
- Candidates who used the *i* and *j* components to obtain $\lambda = 3 + \mu$ and $\lambda = 5 + \mu$ did not draw a correct conclusion.
- Candidates often stated that the direction vectors of the lines were not parallel without identifying which vectors represented the directions of the lines.

(c) **Comprehensive responses**

- Candidates started with an appropriate pair of vectors, such as $\overrightarrow{AP}$ and $\overrightarrow{AB}$, and applied the scalar product formula correctly.
- The candidates formed and solved a quadratic equation in μ.
- Some candidates gave 2 answers and did not eliminate the one that gave $\cos 60° = -\frac{1}{2}$.
- Some candidates found $\overrightarrow{AP}$ rather than $\overrightarrow{OP}$.

Limited responses

- Candidates started with an incorrect pair of vectors to find the scalar product.
- Candidates did not use their scalar product to form an equation in a single parameter.
- There were several blank responses to this part of the question.

Question 10

(a) **Comprehensive responses**

- Candidates split the expression correctly into partial fractions.

Limited responses

- Some candidates started by treating this expression as an improper fraction.
- Some candidates made an error in solving $2B = 3 + 3,$ often obtaining $B = 6$.

(b) **Comprehensive responses**

- The variables were separated correctly.
- Candidates obtained the correct forms for both integrals.
- Some candidates made errors when simplifying after substituting the limits, in particular $1 \times \ln(2 \times 1)$ had the value zero.

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Limited responses

- After the separating the variables, dx and dy were not always in the numerator, or one function was inverted.
- The candidates used an incorrect method to find $\int \ln 2y \, \mathrm{d}y$, often concluding that it was $\frac{1}{2y}(+C)$.

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MATHEMATICS

Paper 9709/33
Pure Mathematics 3

Key messages

What candidates did well
- Many candidates attempted all questions, demonstrating knowledge of the syllabus content and the ability to apply this knowledge correctly.
- Most candidates applied appropriate methods correctly to obtain solutions.

What candidates needed to improve
- Candidates should ensure that each step in a solution is shown clearly, especially in questions where the required form of the answer is given.
- Candidates should ensure that their final answers are in the form required by the question.
- Candidates should ensure that their final answer is clearly indicated.

Comments on specific questions

Question 1

Comprehensive responses
- Most candidates used the laws of logarithms correctly to obtain a quadratic equation in terms of x.

Limited responses
- Some candidates did not check that their answers to the quadratic equation satisfied the original equation given. They did not reject the solution $\frac{23-5\sqrt{17}}{2}$.

Question 2

Comprehensive responses
- Most candidates used a correct approach to solve the inequality.
- There appeared to be no preferred method of solution.
- Candidates either formed two non-modular inequalities or equations or formed a quadratic equation by squaring the given inequality.
- Most candidates were able to solve an equation of the form $3^{2x-1} = a,\ a > 0,$ or equivalent.

Limited responses
- Errors with inequality signs were sometimes seen.
- The question required answers to be given correct to 3 significant figures.
- Some candidates did not give their final answers to 3 significant figures and, in some cases, rounded incorrectly.

Question 3

Comprehensive responses
- Most candidates sketched an appropriate circle with the relevant points clearly shown.
- The coordinates of the relevant points could be determined from either numbered axes or axes marked with unit intervals.

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- The coordinates of the centre of the circle were correct, and it could be seen that the circle had a radius of 3 units.
- The point with coordinates (2, – 2) or the point with coordinates (1, – 1) was shown together with the perpendicular bisector of the line joining the appropriate points.

Limited responses
- Some candidates did not clearly indicate the scales on the axes, making it difficult to determine the centre and radius of the circle from the sketch.
- Correct statements concerning the centre and radius of the circle were also seen.
- Some candidates did not shade the correct region.

Question 4

Comprehensive responses
- Most candidates used the correct trigonometric formulae and substituted the values of sine and cosine of 45°.
- Most candidates obtained the correct trigonometric equation of $\sqrt{2}\sin 2\theta = -1$ or an equivalent form and then attempted to find at least one solution.

Limited responses
- Some candidates did not recognise the need to use trigonometric formulae.
- Sign errors occurred when some candidates applied the trigonometric formulae.
- Some candidates did not give all the solutions to the equation $\sqrt{2}\sin 2\theta = -1$ in the given interval.
- Candidates with sign errors in their work usually followed a correct method to solve their equation in $\sin 2\theta$.

Question 5

(a) **Comprehensive responses**
- Most candidates were able to correctly differentiate $\tan 2t$, with respect to t.
- When differentiating $\frac{1}{\sin 2t}$ with respect to t, candidates either attempted to make use of the formula given in the formula book, or the chain rule of the quotient rule, with varying levels of success.
- Candidates recognised that $\frac{\mathrm{d}y}{\mathrm{d}x} = \frac{\mathrm{d}y}{\mathrm{d}t} \times \frac{\mathrm{d}t}{\mathrm{d}x}$, substituting in their derivatives, with an attempt to simplify to the form given in the question.

Limited responses
- Most errors involved the coefficients of the derivatives or miswriting $2t$ as t in the derivatives,
- Candidates usually used their derivatives correctly but were then unable to rearrange or simplify their expression for $\frac{\mathrm{d}y}{\mathrm{d}x}$ to the required form.

(b) **Comprehensive responses**
- The correct Cartesian coordinates of the required point were obtained by most candidates.
- Most candidates correctly determined the gradient of the tangent, provided they had obtained the required form in **part (a)**.
- An exact form of the equation of the tangent was attempted, with many correct solutions seen.

Limited responses
- Candidates obtained the correct coordinates of the point but were unable to progress further because their derivative in **part (a)** was not in the required form.

Question 6

Comprehensive responses
- Many completely correct solutions were seen.

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- The majority of candidates applied a correct process, using the given substitution, reaching the result of $\int 2\cos 3u \ du$ and then $\frac{2}{3}\sin 3u$.
- Most candidates substituted the limits in terms of u, with few candidates choosing instead to revert to an integral in terms of x before substituting the original limits.
- Some sign errors occurred when giving the final answer due to both terms being negative.
- Most candidates gave exact answers as required.

Limited responses

- Some candidates did not differentiate the given substitution and were unable to obtain the correct integrand.
- Some sign and coefficient errors occurred when integrating and when substituting the limits.

Question 7

Comprehensive responses

- The term $x + iy$ was squared and then the real and imaginary parts of both this and $3 - \left(20\sqrt{7}\right)i$ were equated.
- Most candidates obtained the equations $x^2 - y^2 = 3$ and $2xy = -20\sqrt{7}$.
- Many candidates eliminated one of the variables and obtained a quartic equation with two real roots and two imaginary roots.
- Using the real roots, candidates determined the corresponding real values of the other variable and hence the correct square roots.
- Many correct solutions were seen.

Limited responses

- Some candidates chose to square both $x + iy$ and $3 - \left(20\sqrt{7}\right)i$. Little correct progress was then made.
- Omitting the negative sign in the equation $2xy = -20\sqrt{7}$. resulted in the same quartic equation, but different final solutions.
- Some candidates, having found the correct values needed for the square roots, omitted to write down the actual square roots.

Question 8

(a) **Comprehensive responses**

- The sketch required a considerable amount of detail.
- Candidates were expected to show the correct graph of $y = x^3$ in both the first and third quadrants.
- They also needed to show the correct graph of the straight line $y = 4 - 2x$ in the first, second and fourth quadrants.
- The point of intersection needed to be clearly identified, for example by circling it or by using a cross or dotted line to indicate the required solution.
- A statement identifying the required solution was also seen.
- Other pairs of graphs were also seen, although these were less common.

Limited responses

- Many candidates omitted some of the relevant details from their graphs.

(b) **Comprehensive responses**

- Most candidates wrote the given iterative form as $x = \frac{3x^3 + 4}{4x^2 + 2}$ and then rearranged to correctly to obtain the equation $x^3 = 4 - 2x$.
- Working from $x^3 = 4 - 2x$ to obtain $x_n = \frac{3x_n^{\ 3} + 4}{4x_n^{\ 2} + 2}$ was also acceptable.

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Limited responses

- Candidates working from $x^3 = 4 - 2x.$ often omitted writing their result as an interactive formula.

(c) **Comprehensive responses**

- Most candidates chose to substitute the values 1 and 2 into an equation such as $f(x) = 4 - 2x - x^3$ or equivalent form. The correct values were shown.
- Comparisons between values of expressions derived from $y = x^3$ and $y = 4 - 2x$ using substituted values of 1 and 2, were also seen.
- Some candidates also used the given iterative formula to make comparisons.
- Most candidates gave a correct conclusion, usually stating that there was a change of sign.

Limited responses

- Some calculation errors were seen.
- Some candidates did not give a conclusion, while others did not make their comparisons clear.

(d) **Comprehensive responses**

- Most candidates were able to apply the iterative formula correctly and obtain the correct solution to the level of accuracy required.

Limited responses

- Insufficient iterations or calculations not carried out to the required level of accuracy were common errors.

Question 9

(a) **Comprehensive responses**

- Many candidates used a correct method of dealing with partial fractions and obtained the correct result.
- Some candidates used a substitution method to find the unknowns, whilst others used a comparison of like terms.
- The substitution method appeared to be quicker and less likely to produce errors than the comparison method.

Limited responses

- Some candidates made errors in the required form of the partial fractions, which meant that a correct solution could not be obtained.
- An error in the comparison method often resulted in all the unknowns being incorrect, whereas an error in the substitution method often resulted in one of the unknowns being correct.

(b) **Comprehensive responses**

- Many candidates used the correct binomial expansions together with the correct values obtained in **part (a)**.
- Some errors occurred, usually due to sign errors or arithmetic slips when simplifying the terms.

Limited responses

- Some candidates used incorrect binomial expressions and consequently obtained incorrect expansions.

(c) **Comprehensive responses**

- Many candidates wrote down the set of values for each separate binomial expansion first but did not state the final answer.

Limited responses

- Some candidates made incorrect statements involving the modulus of x and a negative value.
- Some candidates gave the set of values for the other binomial expansion.

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Question 10

(a) **Comprehensive responses**

- Most candidates were able to separate the variables correctly.
- Many candidates then went on to use integration by parts to integrate xe^{-2x} with respect to x.
- Many candidates also integrated $\frac{1}{y+3}$ with respect to y correctly.
- The positioning of the number 4 caused problems for some candidates.
- Provided their answers were in the required form, most candidates were able to obtain a value for the arbitrary constant and give their final answer in the required form.

Limited responses

- Candidates often omitted the 4 or dealt with it incorrectly, especially when it formed part of the integration by parts.
- Common errors included sign errors and not giving the answer in the required form.

Question 11

(a) **Comprehensive responses**

- Most candidates were able to obtain a correct vector expression for the line.
- Many did not write their final answer using the correct vector expressions as a vector equation using r = … or $\begin{pmatrix} x \\ y \\ z \end{pmatrix} = ...$

Limited responses

- Some candidates added the position vectors rather than subtracting them to obtain a direction vector.

(b) **Comprehensive responses**

- Many completely correct solutions were seen, with candidates making correct use of the scalar product and the magnitudes of the relevant vectors.
- Answers in either degrees or radians were also seen.

Limited responses

- Some candidates did not use the direction vectors of the lines when applying the scalar product and calculating the magnitudes.

(c) **Comprehensive responses**

- Many candidates found the position vector of a general point on the line AQ and then formed the scalar product of this vector with the direction vector for the line, expressed in terms of s. They then equated this to zero and obtained a value for the parameter.
- Many correct final answers were seen.
- Alternative methods were also seen, although these were less common.

Limited responses

- Some candidates were unable to identify a suitable approach to the solution.
- Some candidates introduced a second general point on the other line, which did not lead to a successful solution.
- Some candidates, having obtained the correct value of the parameter, found the length from the origin rather than from point A.
- Sign errors and arithmetic slips also contributed to limited responses.

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MATHEMATICS

Paper 9709/35
Pure Mathematics 3

Key messages

What candidates did well
- Implicit differentiation.
- Inequalities.
- Solving differential equation.
- Converting one integral into another using a substitution.

What candidates needed to improve on
- Sketching graphs.
- Introducing diagrams into geometrical questions.
- Solution to 'show that' questions.
- Integration using reverse chain rule.

Comments on specific questions

Question 1

(a) Comprehensive responses

- Most candidates dealt successfully with $\left(1+\frac{x}{2}\right)^{-3}$ to obtain the required two terms in the binomial expansion, together with the multiplier of $\frac{1}{8}$.
- Almost all candidates successfully multiplied their binomial expansion by $(2 + 3x)$.

Limited responses
- A few candidates did not deal correctly with the power of 2, and some did not bring the denominator into the numerator.

(b) Comprehensive responses
- Many correct solutions were observed.

Limited responses
- Some candidates were unable to identify the correct range of values of x, with common incorrect answers such as $|x| < \frac{1}{2}$ and $x > -2$ seen.

Question 2

Comprehensive responses
- Most candidates appeared to know how to undertake implicit differentiation, as well as find the values of x from the value of y and then to choose that value of x which matched the given condition.

Limited responses
- None.

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Question 3

(a) **Comprehensive responses**

- Virtually every candidate knew to take logs as their first step, and almost all successfully obtained a correct equation. A few had k instead of log k. Many then continued by comparing this with $y = mx + c$ to produce a fully correct solution.

Limited responses

- A few candidates tried to justify the straight-line status by simply giving the gradient and the intercept.

(b) **Comprehensive responses**

- Most candidates who had successfully produced a correct equation in **(a)** were immediately able to substitute for x and for y, and to then obtain the values of a and k to the required accuracy.

Limited responses

- A few candidates treated a as their gradient by using $a = \frac{y_2 - y_1}{x_2 - x_1}$.

Question 4

(a) **Comprehensive responses**

- Most candidates chose to square both sides and then successfully solve the resulting quadratic equation. Those that used other approaches were usually successful.

Limited responses

- Only a few candidates gave the wrong roots or omitted one.

(b) **Comprehensive responses**

- Most candidates were able to use the upper limit from **(a)**, together with expressing the equation in logarithmic form, to determine the value of n.

Limited responses

- A few candidates relied on trial and error instead of an algebraic method to find the correct value of n.

Question 5

(a) **Comprehensive responses**

- Most candidates correctly applied the quotient rule to differentiate the given function. They were then
- able to use the double-angle formula, together with the identity $\sin^2 x = 1 - \cos^2 x$ to simplify their expression into a single fraction in terms of $\cos x$. A few candidates chose to use the product rule instead and were generally successful.

Limited responses

- Common errors were using the negative of the quotient rule, differentiating $\cos 2x$ incorrectly and splitting the fraction into separate terms.

(b) **Comprehensive responses**

- Many candidates with an incorrect value of $\frac{\mathrm{d}y}{\mathrm{d}x}$ were able to earn the appropriate follow-through marks by obtaining the gradient of the normal and then correctly applying the equation of the straight line using this gradient.

Limited responses

- Some candidates were able to determine the gradient of the normal correctly and reached that stage of the solution without proceeding to write the equation of the normal. Whilst other candidates continued to use the gradient of the tangent instead of that of the normal.

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Question 6

Comprehensive responses
- Many fully correct solutions.

Limited responses
- Some attempts were nothing more than a statement of the correct differential equation. Others found the gradient between the two given points to form two simultaneous equations involving e and then an attempt to solve for the constant *c*. Such an approach did not address the formation of the differential equation demanded by the question.

Question 7

(a) **Comprehensive responses**
- Candidates employed a variety of methods, some very cumbersome, nevertheless, most resulted in the given answer being achieved.
- Probably the most straight forward method chosen was to multiply both sides by $(a - 3i)$ and equate their real and imaginary parts to obtain two equations. Then to realise that the ratio of the real and imaginary parts was 1: 5 and that the quadratic equation to be proven was obvious.
- Other methods saw candidates multiply their LHS with the conjugate $(a + 3i)$ top and bottom. With this method they often had an errors in their denominator by way of $a + 9$ or $a^2 + 3$.
- The very cumbersome approach was to divide the LHS by $(1 - 5i)$ and then multiply top and bottom by the complicated conjugate of their denominator. Those who used this method did not always provide a sufficient argument by way of clearly stating that λ was real hence the imaginary part of the resulting expression was zero.

Limited responses
- None.

(b) **Comprehensive responses**
- Candidates who secured a correct expression for λ in **(a)**, usually obtained its two correct numerical values in this section.

Limited responses
- None.

Question 8

(a) **Comprehensive responses**
- None.

Limited responses
- Candidates found it difficult to sketch either curve. Sketches should always include the values where the curves cut the *y*-axis, and/or at the end points of the domain, together with a scale on the *x*-axis. The decimal value of these *y*-values should be calculated to gauge where the actual end points are. For example, sec $(\pi/3) = 2$ was often seen above 3 and sometimes going towards infinity.
- Of those who sketched perfect curves, several forgot to make their justification clear, either by the indication on the diagram of the crossing point or by a statement that there is exactly one point of intersection so one root for the given equation.

(b) **Comprehensive responses**
- Most candidates produced excellent solutions, nearly always giving the correct calculated values (to at least 3 s.f. as required by the rubric) and providing the necessary sign change justification.

Limited responses
- None.

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(c) **Comprehensive responses**

- Candidates opted for two different starting points to prove the iterative formula. One group used the most straight forward approach, that is, they started from the given iterative equation and removed the subscripts n and $n + 1$. They then proceeded to the original equation, thereby establishing the required result. The other group started with the original equation $\sec(x/3) = 3e^{-x}$ and proceeded to show the iterative formula. Whilst this method also valid, many candidates stopped at the stage $x = \ln(3\cos(x/3))$ and made no further progress, often omitting the subscripts.

Limited responses

- None.

(d) **Comprehensive responses**

- Almost all candidates produce a correct solution, except for those who left their calculator in degrees mode.

Limited responses

- None.

Question 9

(a) **Comprehensive responses**

- Most candidates obtained the correct values for R and α.

Limited responses

- Some incorrectly used the expansion of $R\cos(\theta - \alpha)$ seen by the introduction of a negative sign into $\alpha = \tan^{-1}$.

(b) **Comprehensive responses**

- Most candidates understood the meaning of 'hence' and proceeded with the form found in **(a)** by replacing $5\cos\theta - 3\sin\theta$ in the denominator with their $R\cos(\theta + \alpha)$.

Limited responses

- Some less able candidates made no progress following the substitution, whilst others were quick to identify that the substitution leads to the integral of $2\sec^2(\theta + \alpha)$ and were successful in obtaining $2\tan(\theta + \alpha)$.
- From the point onwards, most candidates used their calculator to evaluate their $\tan(\theta + \alpha)$ when $\theta = \alpha$ and when $\theta = 0$ instead of the double angle formula for $\tan 2\alpha$ with $\tan\alpha = 3/5$. As the answer was given, candidates needed to show explicitly how they arrived at it using coherent working.

Question 10

(a) **Comprehensive responses**

- None.

Limited responses

- Whilst a considerable number of candidates had little trouble transforming the integral via a substitution many others had some misconceptions. These included differentiating $x = 2\sin u$ to $\frac{du}{dx} = 2\cos u$ or $\frac{dx}{du} = \cos u$, unnecessarily rewriting the substitution to $u = \sin^{-1}(x/2)$, omitting dx from the original integral or du from the final integral, simply replacing dx by du, not changing the limits correctly, or not at all, using degrees rather than radians, etc.
- Many candidates did not demonstrate the required examination technique here, as they had been instructed 'to show' that the statement was true rather than simply write down the given true statements. All stages of the manipulation needed to be shown rather than completed mentally.

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(b) **Comprehensive responses**

- None.

Limited responses

- Few candidates had a strategy for integrating $\sin^n x$ or $\cos^n x$ and consequently found this question difficult. Candidates should be familiar with integrating a wide range of functions using different integration techniques so that integrals of this type can be tackled efficiently.
- Few candidates recognised the use of integration by the reverse of the chain rule and instead applied a substitution approach to make progress.
- A sizeable number of candidates tried using integration by parts. Whilst this approach can be made to work, it is considerably longer and more complicated than necessary, making it more susceptible to algebraic and sign errors.
- Many candidates decided simply to omit this section.

Question 11

(a) **Comprehensive responses**

- None.

Limited responses

- Although many candidates answered this question well, a significant number made basic errors. Since this was a 'show that; question candidates needed to do more than state that vectors *AB and DC* are parallel; they needed to find the numerical value linking them.
- Many candidates did not appreciate that the vertices of quadrilateral *ABCD are A*, *B*, *C* and *D,* in anticlockwise order around the perimeter. As a result, many candidates thought *AC* and *BD* were the sides of the quadrilateral and did the question accordingly.
- Few candidates drew a diagram, despite this being an important aid for a question of this type. Other errors made by candidates were not labelling the vectors they calculated, misusing or omitting vector notation or believing that a trapezium is necessarily an isosceles trapezium. Whilst in this question, many candidates felt they had proved that the result by showing that ***AD*** and ***BC*** are equal in length; in fact, this is true for both a trapezium and a parallelogram and therefore does not distinguish between them.
- Finally, it was common for candidates to leave part of the proof incomplete by stating that the sides *AD* and *BC* are not parallel without concluding that the quadrilateral therefore cannot be a parallelogram.

(b) **Comprehensive responses**

- Many candidates succeeded in producing a correct solution despite it being a relatively difficult question.

Limited responses

- Again, few candidates drew a diagram, which would have provided useful support for answering the question.
- A key issue highlighted by this question was that many candidates did not distinguish between the displacement vector of point *D* from point *C* and the position vector of point *D* on the line through *C* and *D.*

(c) **Comprehensive responses**

- Many candidates produced a quick solution.

Limited responses

- Whilst a considerable number did not recognise the connection with **(b)** and tried other approaches which rarely succeeded.
- A common approach was to find angles, which was sound approach, but without a diagram usually met with little success.
- Some split the trapezium into two triangles, again with mixed success. A few used an incorrect formula for the area of a trapezium involving three lengths, which indicated that their approach was not valid.

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MATHEMATICS

Paper 9709/41
Mechanics

Key messages

What candidates did well
- Many candidates demonstrated excellent understanding and application of the syllabus content.
- Many candidates worked to a sufficient degree of accuracy when giving non-exact answers to three significant figures.
- Many candidates drew fully labelled force diagrams when these were helpful in answering questions.

What candidates needed to improve
- Candidates should follow the rubric of the paper by approximating non-exact answers to three significant figures only when required.
- When more than one attempt is made to a question, candidates should cross out the work that is not to be assessed.
- Candidates should show full working when providing an answer.

Comments on specific questions

Question 1

Comprehensive responses
- Many candidates resolved the forces into two perpendicular components.
- Many candidates used the components to find the magnitude of the resultant force.
- Many candidates gave both the magnitude and direction of the resultant force.

Limited responses
- Some candidates resolved the forces using inconsistent signs or incorrect trigonometric components.
- Some candidates gave an angle without stating the direction of the resultant force.

Question 2

(a)

Comprehensive responses
- Many candidates used the correct relationship between power, driving force and speed.
- Most candidates formed a Newton's second law equation with the correct number of terms.

Limited responses
- Some candidates omitted the constant resistive force.

(b)

Comprehensive responses
- Most candidates formed a Newton's second law equation with the correct number of terms.
- Some candidates used the constant speed condition correctly.
- Some candidates included the resistance and the component of the weight parallel to the slope.

Limited responses
- Some candidates omitted the weight component when applying Newton's second law.

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Question 3

(a) **Comprehensive responses**

- Most candidates differentiated the given function correctly.
- Most candidates set the velocity equal to zero.
- Most candidates solved the resulting quadratic equation to find the two values of *t*.

Limited responses

- A few candidates integrated the function instead of differentiating it.
- A few candidates did not differentiate the displacement function before using the condition for instantaneous rest.

(b) **Comprehensive responses**

- Some candidates identified the change of direction within the given time interval.
- Some candidates evaluated the displacement at the relevant times.
- Some candidates used these values to find the total distance travelled.

Limited responses

- Some candidates found the displacement over the interval rather than the total distance travelled, without accounting for the change of direction.

(c) **Comprehensive responses**

- Many candidates differentiated the velocity correctly to find the acceleration.
- Many candidates substituted t = 3 correctly.
- Many candidates gave the magnitude of the acceleration as a positive quantity.

Limited responses

- Some candidates gave the signed acceleration rather than its magnitude.

Question 4

(a) **Comprehensive responses**

- Some candidates applied Newton's second law to particle A and to particles B and C.
- Some candidates used the given tension correctly.
- Some candidates solved their equations to find the mass of particle C.

Limited responses

- Some candidates used inconsistent directions for the acceleration when forming the two Newton's second law equations.
- Some candidates did not include all three particles correctly when forming the equations of motion.

(b) **Comprehensive responses**

- Some candidates considered the motion in two separate stages.
- Some candidates found the speed when C separated from B.
- Some candidates used this speed as the initial speed for the second stage.
- Some candidates found the time for each stage and added the two times.

Limited responses

- Some candidates continued to use the acceleration from **part (a)** after C separated from B.
- Some candidates used zero as the initial speed for the second stage rather than the speed when C separated from B.

Question 5

(a) **Comprehensive responses**

- Some candidates resolved the forces parallel and perpendicular to the plane with the correct number of terms.
- Some candidates found the normal reaction.
- Some candidates used the limiting friction relationship correctly.
- Some candidates identified the correct direction of friction.

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Limited responses

- Some candidates omitted a force in one of the resolved equations.
- Some candidates used the wrong direction for the limiting friction.

(b) **Comprehensive responses**

- Some candidates found the new normal reaction after the horizontal force was removed.
- Some candidates used the coefficient of friction to find the frictional force.
- Some candidates used Newton's second law and a constant acceleration formula to find the speed.
- Some candidates used an energy method.

Limited responses

- Some candidates continued to include the horizontal force after it had been removed.
- Some candidates used the normal reaction from **part (a)** rather than recalculating the normal reaction after the horizontal force had been removed.

Question 6

(a) **Comprehensive responses**

- Some candidates formed a correct equation using conservation of linear momentum.
- Some candidates used a consistent positive direction for the velocities.
- Some candidates solved the resulting equation and selected the physically possible value of the mass.

Limited responses

- Some candidates used inconsistent signs for the velocities when applying conservation of linear momentum.

(b) **Comprehensive responses**

- Some candidates formed a conservation of linear momentum equation for the collision between B and C.
- Some candidates used the loss of kinetic energy to form a second equation.
- Some candidates solved the equations to find possible speeds after the collision.
- A few candidates selected the physically possible solution and determined whether A and B collide again.

Limited responses

- Some candidates did not reject the algebraic solution that was inconsistent with the motion after the collision.
- Some candidates did not compare the subsequent speeds of A and B when deciding whether a further collision would occur.

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MATHEMATICS

Paper 9709/42
Mechanics

Key messages

What candidates did well

- Many candidates answered the requests well, demonstrating a good understanding and application of the syllabus content.
- Candidates demonstrated competence in questions requiring one or two-stage solutions.
- Many candidates worked to a sufficient degree of accuracy to give non-exact answers to three significant figures.

What candidates needed to improve

- When more than one solution is given to a question, candidates should make it clear which response is to be assessed by crossing out any responses that are not intended for assessment.
- Questions where the scenario changed in a subsequent part were not answered well.
- Candidates should be aware that a normal reaction force is not always equal to weight.
- In **Question 4 and Question 6**, the angle θ was given exactly. Candidates would benefit from using exact values of $\sin\theta$ and $\cos\theta$ where required when answering the questions.

Comments on specific questions

Question 1

(a) **Comprehensive responses**

- Many candidates answered this part well.
- Many candidates correctly calculated the power using 620×25.

Limited responses

- A few candidates included the weight of the car when calculating the force produced by the engine.

(b) **Comprehensive responses**

- Many candidates added the 12000 W increase to their answer to part **(a)** and then applied Newton's second law as $\frac{27500}{25} - 620 = 960a$.
- A few candidates realised that the increase in driving force resulting from the increase in power produced the acceleration, hence getting $\frac{12000}{25} = 960a$.

Limited responses

- A few candidates attempted to calculate a new speed at the instant the power was increased.

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Question 2

(a) **Comprehensive responses**

- Most candidates correctly used the principle of conservation of momentum to calculate a speed of 1.25 ms^{-1} after the collision between particle *A* and particle *B*.
- Many candidates correctly calculated the speed of *C* after colliding with the wall by determining 75% of its speed after the collision between particle *A* and particle *B*.

Limited responses

- A few candidates attempted to calculate the speed of particle *C* after colliding with the wall by determining only 25% of the speed after the collision between particles *A* and *B*.
- Some candidates, having correctly found 1.25 ms^{-1}, subtracted 0.25 to get 1 ms^{-1}.

(b) **Comprehensive responses**

- Most candidates correctly used the two speeds found in part **(a)** to calculate two times, which they then added together.

Limited responses

- Some candidates correctly used the two speeds found in part **(a)** to calculate two times without subsequently adding them together.
- A few candidates used the two speeds found in part **(a)** in a constant-acceleration formula, commonly seen as $9 = \frac{1}{2}(1.25 + 0.9375)t$.
- A few candidates attempted to find an acceleration for some part of the motion.

Question 3

(a) **Comprehensive responses**

- Many candidates correctly calculated the acceleration of the particles (3.75 ms^{-2}) using constant-acceleration formulae from the given values of $u = 0$, $s = 0.3$ and $t = 0.4$.
- Many candidates correctly applied Newton's second law to particle *B*.

Limited responses

- Some candidates formed the Newton's second law equation $T = 0.5a$ for particle A and used this, together with the correct equation for particle *B* to calculate the acceleration of the particles.
- Some candidates found a speed form $\frac{0.3}{0.4}$ and then used constant-acceleration formula to calculate the acceleration of the particles.

(b) **Comprehensive responses**

- Many candidates formed a correct Newton's second law equation using their value for the tension and a normal reaction of $0.5g$ N.

Limited responses

- Some candidates formed a Newton's second law equation using an acceleration of 0 ms^{-2}.
- A few candidates used a normal reaction of $0.5g \sin 55$ or $0.5g \cos 55$.

(c) **Comprehensive responses**

- A few candidates recognised that all the kinetic energy of particle *A* at the instant the string breaks is lost as the particle comes to rest, and that friction is the force responsible for this work. They then equated the work done by friction to the kinetic energy of particle *A* at the instant the string breaks.
- Most candidates found the frictional force and the resulting deceleration, before calculating the distance moved by particle *A*. They then used the relationship that work done equals force multiplied by distance.

Limited responses

- Some candidates used the acceleration before the string broke to calculate the distance moved by particle *A* after the string broke.

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- Some distances used 0.3 m as the distance moved by particle *A* after the string broke.

Question 4

(a) **Comprehensive responses**

- Most candidates correctly found the normal reaction to be 6m and then used this to calculate a frictional force of 2m.
- Some candidates formed a correct work-energy equation with the required, terms leading to the given answer of 0.8 m.

Limited responses

- Some candidates formed a dimensionally incorrect work-energy equation, usually by omitting a distance term associated with the frictional force.
- Some candidates had a correct kinetic energy of $\frac{1}{2}\text{m}(4)^2$ and equated this to *mgh* only, which does lead to *h* = 0.8 from incorrect work.
- A few candidates used a value for the unknown mass of the particle, while others attempted to find a value for the mass.
- Some candidates used an approximate value of θ, leading to a distance that rounded to 0.8 m.

(b) **Comprehensive responses**

- Most candidates used $0.8 = \frac{1}{2}(4+0)t$ to calculate the time of 0.4 seconds for the particle to travel from *A* to *B*.
- Some candidates correctly found an acceleration of 6 ms^{-2} for the particle on its journey from *B* to *A* and then used constant-acceleration formulae to find the time taken.

Limited responses

- Some candidates used an acceleration of 10 ms^{-2} for the particle on its journey from *B* to *A*.
- Some candidates assumed that the time for the particle to travel from *B* to *A* was equal to the time to travel from *A* to *B*.

Question 5

Comprehensive responses

- Some candidates had an expression of $\frac{1}{2}gt^2$ for particle *P* and $18(t-1)+\frac{1}{2}g(t-1)^2$ f for particle *Q*, or $\frac{1}{2}g(t+1)^2$ for particle *P* or $18t+\frac{1}{2}gt^2$ for particle *Q*.
- Some candidates equated their expressions, expanded the brackets correctly, and solved to find the correct time.
- Candidates who found the correct time were then able to calculate *h* correctly.

Limited responses

- Some candidates calculated only the time for particle *P* (1.625 s) or for particle *Q* (0.625 s) to reach the ground.
- Some candidates used a distance expression involving *t* s for *P* and an expression involving *t* + *1* s for *Q*.
- Some candidates formed one correct expression for either $\frac{1}{2}gt^2$ for particle *P* or $18\text{t}+\frac{1}{2}gt^2$ for particle *Q*.
- Some candidates treated the initial velocity of particle *Q* and the acceleration due to gravity as acting in opposite directions.
- Some candidates equated their expressions but expanded the brackets incorrectly.

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Question 6

(a) **Comprehensive responses**

- Most candidates correctly resolved forces vertically to obtain an equation involving the normal reaction to $R + 26 \times \frac{5}{13} = W$.
- Some candidates correctly resolved forces horizontally to obtain an equation, involving the frictional force that was equivalent to $26 \times \frac{12}{13} - \text{Friction} = \frac{W}{g} \times 1.5$.
- Some candidates used Friction = $0.25R$ to obtain an equation in W only and then solved it to find W.
- Some candidates used a mass m kg throughout their solution and then found W using $W = mg$.

Limited responses

- When resolving forces horizontally, some candidates obtained $26 \times \frac{12}{13} - \text{Friction} = 0$.
- When resolving forces vertically, some candidates obtained $R = W$.

(b) **Comprehensive responses**

- A few candidates used $R = W$ to calculate the frictional force and then formed a correct equation involving the deceleration, a, to get $-0.25W = \frac{W}{g}a$.
- Candidates who found the correct deceleration were usually able to calculate the distance AB from using constant-acceleration formulae.

Limited responses

- Some candidates used the normal reaction found in part **(a)** to calculate the frictional force.

Question 7

(a) **Comprehensive responses**

- Most candidates differentiated correctly, including the use of the chain rule where appropriate.
- Most candidates substituted $t = 1.25$ into their derivative and equated it to 0.5 or –0.5 to obtain an equation in k_1.

Limited responses

- Some candidates differentiated the first two terms of v without applying the chain rule.
- A few candidates differentiated k_2 as k_2.
- Some candidates made algebraic errors when simplifying their derivative of v.

(b) **Comprehensive responses**

- Most candidates substituted $t = 3.5$ into their derivative of v, using their value of k_1, and equated to 0 to get an equation in k_2.
- Most candidates integrated correctly, including the use of the chain rule in reverse where appropriate.
- Most candidates used the correct limits and showed the t values substituted into each individual term.

Limited responses

- Some candidates integrated by increasing the index by 1 and dividing by the new index, without applying the chain rule in reverse where required.
- Some candidates showed only the result of substituting limits into their integration, without showing the intermediate calculation.
- Some candidates assumed that substituting $t = 0$ into their integrated expression gave a value of 0.

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MATHEMATICS

Paper 9709/43
Mechanics

Key messages

What candidates did well
- Many candidates demonstrated excellent understanding and application of the syllabus content.
- Many candidates worked to a sufficient degree of accuracy when giving non-exact answers to three significant figures.
- Many candidates drew a fully labelled force diagram when this was helpful in answering a question.

What candidates needed to improve
- Candidates should follow the rubric of the paper by approximating non-exact answers to three significant figures only when required.
- When more than one attempt is made to a question, candidates should cross out the work that is not to be assessed.
- Full working should be shown in questions where an answer is given.

Comments on specific questions

Question 1

(a) **Comprehensive responses**
- Most candidates formed an equation by equating the heights of the particle at the two given times.
- Most candidates solved the resulting equation correctly to find the initial speed.

Limited responses
- Some candidates substituted correctly into the equation of motion for only one of the given times.
- Some candidates made errors when simplifying the equation before solving for the initial speed.

(b) **Comprehensive responses**
- Most candidates used their value of the initial speed from **part (a)** together with $v = 0$ in a suitable equation of motion.
- Most candidates correctly found the greatest height above the ground.

Limited responses
- Some candidates used the initial speed instead of zero as the final velocity in the equation of motion.
- Some candidates found the maximum height above the point of projection rather than above the ground.

Question 2

(a) **Comprehensive responses**
- Most candidates correctly differentiated the given expression for v and found the time at which the acceleration of P was zero.

Limited responses
- Some candidates attempted to use the equations of constant acceleration.

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- Some candidates did not solve the linear expression for a = 0 correctly.

(b) **Comprehensive responses**

- Most candidates integrated the given expression for *v* and used the limits of 0 and 3 to find the correct distance travelled by *P* in the given interval.

Limited responses

- Some candidates did not take the magnitude of their negative answer.
- A few candidates considered the limits from 0 to 1.5 and then from 1.5 to 3, rather than considering the interval from 0 to 3.

Question 3

Comprehensive responses

- Many candidates correctly applied Newton's second law parallel to the plane with the correct number of dimensionally consistent terms to find the required value of *m*.

Limited responses

- Some candidates did not include *g* in at least one of the two required terms (weight component, frictional term).
- A few candidates incorrectly included a component with the 20 N force.
- Some candidates made sign errors or used incorrect sine or cosine ratios when considering the components of the forces acting parallel to the plane.
- Some candidates could not solve the linear equation in *m* and made algebraic or numerical errors when attempting to make *m* the subject.

Question 4

Comprehensive responses

- Most candidates were able to set up at least one correct equation relating *a* and *t* namely $170 = 32t + \frac{1}{2}at^2$.
- Those candidates who could set up two correct equations in *a* and *t* usually went on to solve them simultaneously and arrive at the correct values of both *a* and *t.*

Limited responses

- Many candidates could not set up a second correct equation in *a* and *t* (usually for the journey from *A* to *B*).
- Some candidates were inconsistent with the use of *t* for the journey from *A* to *B* e.g. it was common to see $280 = 32 \times 2t - \frac{1}{2}at^2$ instead of the correct $280 = 32 \times 2t - \frac{1}{2}a \times (2t)^2$.

Question 5

(a) **Comprehensive responses**

- Most candidates correctly found the tension in the towbar by using $P = DF \times v$ together with two applications of Newton's second law.

Limited responses

- Some candidates did not include the correct resistive force when applying Newton's second law.
- A few candidates included the tension in the towbar when applying Newton's second law to the combined system of the trailer and lorry.

(b) **Comprehensive responses**

- Most candidates correctly calculated the change in KE of the system.
- Many candidates correctly calculated the change in PE and the work done against resistance and then applied the work-energy principle to form an equation with the correct number of dimensionally consistent terms.

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Limited responses

- Some candidates attempted to use Newton's second law together with equations of constant acceleration.
- Some candidates included the change in PE term twice in their work-energy equation.
- A few candidates only considered the motion of either the lorry or the trailer and not the entire system.

Question 6

(a) **Comprehensive responses**

- Most candidates resolved the forces vertically and horizontally and used Pythagoras to find the correct magnitude of the resultant force.

Limited responses

- Many candidates did not give a correct description of the direction of the resultant force.
- A few candidates made sign errors or used incorrect sine or cosine ratios when finding at least one of the components.

(b) **Comprehensive responses**

- Many candidates resolved vertically to form an equation for F and then used the value of F they found to correctly calculate the magnitude of the resultant force.

Limited responses

- Many candidates did not give a correct description of the direction of the resultant force.
- A few candidates resolved horizontally to form an equation for F.
- A few candidates made sign errors or used incorrect sine or cosine ratios when finding at least one of the components.

Question 7

(a) **Comprehensive responses**

- Many candidates applied Newton's second law and $F = \mu R$ parallel to the plane and correctly derived the given acceleration for P.
- Many candidates correctly calculated the distance that P travelled down the slope before it collided with Q.

Limited responses

- Some candidates did not show sufficient working when deriving the given answer for the acceleration of P down the plane.
- Some candidates made sign errors, particularly in the weight component term, when applying Newton's second law to the motion of Q up the plane.

(b) **Comprehensive responses**

- Many candidates correctly calculated the velocity of P before impact with Q.

Limited responses

- Many candidates used the initial velocities of P and Q, rather than their velocities immediately before the collision, when applying the principle of conservation of linear momentum.
- Many candidates used the given acceleration for P as the acceleration of Q after the collision.

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MATHEMATICS

Paper 9709/45
Mechanics

Key messages

What candidates did well

- Most candidates demonstrated sound knowledge of the various concepts involved such as:
  - Using Newton's law in a situation involving connected particles.
  - Resolving given forces to find an angle and another force.
  - Using calculus to solve problems involving distance, velocity and acceleration.
  - Using conservation of momentum and Newton's law or energy to find speeds and distances.
- Most candidates were able to produce fully correct responses to structured questions.
- Most candidates worked to a sufficient degree of accuracy to be able to give non-exact answers to three significant figures, or one decimal place in the case of angles.

What candidates needed to improve

- Some candidates needed to show more working to justify their answers. This was particularly the case when the question asked for something to be shown, as in **Question 6(a)**.
- In **Question 6** the angle was given exactly. There was no need to evaluate it, and retaining the exact value is preferable, as it can lead to a loss of accuracy.

There was an error in question **4(b)** where the values given for the power, distance and velocity were not valid for the model given. This has been corrected in the published version of the paper.

Comments on specific questions

Section A

Question 1

(a) **Comprehensive responses**

- Most candidates correctly found the total area for which the velocity was positive and for which the velocity was negative.
- Many candidates realised that to find the total distance, the difference of these two areas was required.

Limited responses

- The most common incorrect response was 260 m which comes from finding the sum rather than the difference of the two areas. A few candidates tried to use a trapezium to find the positive area in one go, perhaps thinking that the initial velocity was zero.

(b) **Comprehensive responses**

- Most candidates wrote down the correct answer of 260 m, using their answer to **Question 1(a)**.

Limited responses

- A few candidates did not find the distance correctly, usually because they had made an error in finding more of the areas in **Question 1(a)**.

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Question 2

(a) **Comprehensive responses**

- Most candidates correctly used the information given on the diagram then applied the appropriate Newton's second law equations to find the tension in the string and the acceleration of particle *B*.
- Although some candidates used Newton's second law for the system first to find the acceleration of particle *B*, most formed two equations, usually $0.4g - T = 0.4a$ and $T = 0.6a$, and solved these simultaneously.

Limited responses

- The most common error was incorrectly applying Newton's second law, especially for particle *A*, with the incorrect equation $T - 0.6g = 0.6a$, being commonly seen.
- Some candidates made arithmetic errors despite having the correct equations.

(b) **Comprehensive responses**

- Many candidates gave a fully correct solution. While the easiest approach was to use the constant acceleration equation $s = ut + \frac{1}{2}at^2$, some candidates chose instead to find the velocity first and then use this to determine the time.
- Those candidates who had an incorrect answer to the acceleration of particle *B* in **Question 2(a)** often correctly used their value of the acceleration to attempt to find the time.

Limited responses

- A few candidates, having found an acceleration in **Question 2(a)**, then used a different acceleration in this part (often $10\ \text{ms}^{-1}$).
- Candidates who had not found an answer to **Question 2(a)** often omitted this part.

Question 3

Comprehensive responses

- This question was answered fully correctly by most candidates.
- Almost all candidates set up equations for the 'horizontal' and 'vertical' directions and then solved these simultaneously. Some candidates found the value of *F* and the value of θ separately whereas others, having found one of the two used that value to find the other.

Limited responses

- Some candidates made an error in resolving in one or other of the two equations or sometimes omitted the force of magnitude 15 N altogether.
- A few candidates made arithmetic errors at some point in their working. Candidates should show all stages of their working, as this can allow progress to be recognised. For example, if a candidate obtained an incorrect value for $F\sin\theta$ from a correct equation, they could nevertheless be rewarded for correct method if they showed full working rather than just the value of $\tan\theta$.
- A small number of candidates did not work to sufficient accuracy and so their final answer for *F* was not correct to 3 significant figures or for θ, was not correct to 1 decimal place.

Question 4

(a) **Comprehensive responses**

- Most candidates answered this question correctly.
- The most frequently seen method was to first find the speed of the car and then use the fact that the speed was constant to find the value of the magnitude of the resistance force *R*.
- An alternative method which was seen occasionally was to first find the work done by the driving force and then use a work-energy equation to find *R*.

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Limited responses

- A few candidates found the driving force correctly and then did not state that this was equal to R.
- Some candidates found the velocity correctly and then got no further.
- A few candidates found both the velocity and the value of the driving force correctly and then did some further working rather than realising that the value of R was equal to the driving force.

(b) Due to an issue with question **4(b)**, full marks have been awarded to all candidates for this question to make sure that no candidates were disadvantaged.

Question 5

(a) **Comprehensive responses**

- This question part was very well answered, with most candidates giving a fully correct response.
- Some candidates used integration to find an expression for the distance in terms of time including a constant of integration, which they then went on the evaluate. They then stated that the distance OA was equal to this constant.
- Other candidates evaluated the integral of the velocity equation between $t = 0$ and $t = 25$ and then subtracted this from 700 to find the value of OA.

Limited responses

- A few candidates tried to use equations of constant acceleration to find OA. Questions which involve velocity given as a function of time should always be answered using calculus (unless the equation for velocity is $v = at + b$ where a and b are constants).
- Although some candidates found the constant of integration as 75, it was necessary to state that OA was 75 m rather than simply that the constant $c = 75$.
- A few candidates found the value of 625 from the integral of the velocity equation between $t = 0$ and $t = 25$ and then added this to 700 rather than subtracting it from 700.

(b) **Comprehensive responses**

- Most candidates answered this part fully correctly, finding the time at which the acceleration of the particle was zero and the time at which its velocity was zero and then substituting these into the equation for distance found in **Question 5(a)**.

Limited responses

- Some candidates made errors in finding the time at which the acceleration of the particle was zero and the time at which its velocity was zero. A number of these had the correct equation for acceleration, $a = 6 - \frac{3}{2}t^{\frac{1}{2}}$, and then square rooted rather than squaring when attempting to find the value of t.
- As in **Question 5(a)** a few candidates tried to use equations of constant acceleration.
- Some candidates found the correct distance and then also found another distance (often the distance for $t = 0$ to $t = 16$) and added this to the distance they had already found.

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Question 6

(a) **Comprehensive responses**

- Some candidates produced a fully correct answer to this part. There were several methods of showing that neither particle moved, as follows:
  - Find the maximum possible friction force for each particle, find the weight component down the plane for each particle, and show that for each particle the former is greater than the latter so neither particle moves.
  - Show that the difference between the maximum possible friction force and the weight component down the plane is negative for each particle so neither particle moves.
  - Assume that the particles are moving and then show that the acceleration would be negative, so in fact neither particle moves.
- A few candidates used one of the above methods and instead used a particle of mass m kg, rather than two separate particles, thereby saving themselves some time.

Limited responses

- A considerable number of candidates used one of the methods described above and then omitted to state that 'therefore neither particle moves.
- Some candidates used the wrong components for the friction force and the weight component.
- In this question**,** the angle was given exactly. There is no need to evaluate the angle in situations like this, and it is preferable not to do so, as it can lead to a loss of accuracy. A significant number of candidates showed all their working in terms of sin α and cos α rather than using sin α = 0.28 and working out that cos α = 0.96. If the final answer given by a candidate was incorrect then it was not clear whether they had used the correct values of sin α and cos α in their calculations.
- Some candidates made numerical errors in their calculations.

(b) **Comprehensive responses**

- There were many fully correct responses to this part. There were two methods to find the required velocity:
  - By using Newton's second law to first find the deceleration of particle P and then using this deceleration to find the velocity after the particle had moved 2.75 m. Some candidates had already found the acceleration in **Question 6(a)** and used this.
  - By using an energy equation involving the change in kinetic energy, the change in potential energy and the work done by friction.

Limited responses

- Some candidates who used the Newton's law approach used a positive acceleration rather than a deceleration.
- Some candidates who used the energy approach omitted the work done by friction and others had a sign error in their working.

(c) **Comprehensive responses**

- There were rather fewer fully correct responses to this part than to **Question 6(b)**. There were again two methods to find the required distance, having first used conservation of momentum to find the velocity of Q after the collision:
  - By using Newton's second law to first find the decelerations of particles P and Q and then using these decelerations to find the distance moved by each the particle until it came to rest.
  - By energy equations for each particle involving the change in kinetic energy, the change in potential energy and the work done by friction.

Limited responses

- Some candidates used an initial velocity of P of 6 ms^{-1}, which was the velocity with which P was projected, rather than the velocity just before the collision.
- For those using the Newton's second law method, some candidates thought that both decelerations were equal, forgetting that P was moving up the plane and so both the friction and the weight component were acting against the motion.
- For those using the energy method, some candidates made a very similar error to that described above, using a wrong sign for the potential energy component.
- There were often other sign errors for those using the energy method.

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Question 7

Comprehensive responses

- Some candidates gave a fully correct response to this question. There were many approaches which led to the correct answer, of which the three most common were:
  - Start off with some or all $v_B = u + 10a$, $v_C = u + 20a$ $v_D = u + 30a$ and then form two equations in u and a using any of $s = ut + \frac{1}{2}at^2$ or $s = \frac{1}{2}2(u+v)t$ (where u is the velocity at point A).
  - Use $v^2 = u^2 + 2as$ with $v_B = u + 10a$ and $s = 50$ and then again with $v_C = u + 20a$, $v_D = u + 30a$ and $s = 100$ to again form two equations in u and a.
  - Realise that the average velocity from A to B is $\frac{50}{10} = 5$, and from C to D is $\frac{100}{10} = 10$, and that these are also the velocities at the mid-points of AB and CD respectively. The time taken for this distance is $25 - 5 = 20$ so the acceleration is $\frac{10-5}{20}$.

Limited responses

- Many candidates gave partially correct responses, with the most successful of these evaluating the acceleration correctly and then omitting to find the increase in speed.
- Some candidates found two correct equations and then made errors in solving them.
- Many candidates found one correct equation, usually $50 = 10u + 50a$, and then made an error in finding a second equation using the distance CD, often getting confused about the points for which their velocities were: for example, using V_B and V_C rather than v_C and V_D.

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MATHEMATICS

Paper 9709/51
Probability & Statistics 1

Key messages

What candidates did well
- Many used lists or diagrams to support and inform their answers.
- Accuracy in working was correct to 4 s.f. or more to justify a 3 s.f. final answer.
- Appropriate probability distributions were often selected.

What candidates needed to improve
- Some needed to identify possible scenarios and outcomes more clearly.
- Statistical diagrams (in this case a stem-and-leaf diagram) needed to be more carefully drawn using the correct format, with attention to alignment and order.
- The appropriate form of wording to compare data sets needs to be thorough and clear.
- Some needed a greater understanding of the steps required to prove statistical independence.

Comments on specific questions

Section A

Question 1

(a) **Comprehensive responses**
- Candidates who identified the correct values for X typically gained most of the marks.
- Good answers involved checking that the probabilities summed to 1, which allowed access to the follow-through marks in **part 1(b)**.

Limited responses
- Some candidates provided probability space diagrams rather than the requested probability distribution table, while others couldn't make a start.
- Tables with incorrect values for X were sometimes seen.

(b) **Comprehensive responses**
- Those who showed all their working when finding E(X) and Var(X) scored well, even if there were some errors in **part 1(a)**.
- Good responses ensured that $(-1)^2$ was used rather than the incorrect -1^2 when calculating Var(X).

Limited responses
- Candidates who provided an incorrect number of values for X in **part 1(a)** were unable to gain more than 1 mark here.
- Errors in the variance formula were seen, such as omitting the subtraction of the mean squared or simply subtracting the mean.

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Question 2

(a) **Comprehensive responses**

- Candidates correctly interpreted the information from the table and calculated the probability by dividing the sum of the Art and Business students divided by the total number of students.

Limited responses

- Many gave the sum of Art and Business students without calculating a probability.

(b) **Comprehensive responses**

- Some responses showed the correct calculation, but rigorous solutions using correct set notation were rarely seen.

Limited responses

- Some used only words, with no attempt to find probabilities and apply them in an appropriate formula.
- Many candidates did not have a strategy for determining independence.
- Some did not appreciate the need to express the probabilities in a comparable form.

(c) **Comprehensive responses**

- Candidates demonstrated an understanding of the conditional probability notation and correctly selected 14 and 30 from the table.

Limited responses

- Many were unable to identify the correct values to select from the table, whilst others found the probability of selecting a male Arts student from the total.

(d) **Comprehensive responses**

- Candidates selected the required values (female students who did not study Business) from the table and calculated the appropriate probability.

Limited responses

- Some appeared not to understand the notation or attempted various calculations in which errors were made.

Question 3

(a) **Comprehensive responses**

- Many provided a stem-and-leaf diagram with the correct stem; a strategy such as crossing out the values as they were used ensured that no values were omitted.
- Candidates followed the instruction given in the question regarding the placement of the teams.
- Care was taken to order and align the entries.
- The correct key was provided, including both the team names and the appropriate units (cm).

Limited responses

- These often had the correct stem and data items, but incorrect alignment, the omission of a heading, inclusion of commas, and placing the teams incorrectly were seen often.
- In many responses, the key was missing or did not contain the required information.

(b) **Comprehensive responses**

- Candidates provided and correctly identified the median for the appropriate team.
- The quartiles were stated and subtracted, which allowed access to the method mark even if the quartiles themselves were within the appropriate range but not entirely accurate.

Limited responses

- Some provided data from the incorrect team.
- Some attempts to find the IQR involved subtracting the positions of the quartiles rather than the quartiles themselves.

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(c) **Comprehensive responses**

- Very few candidates appreciated the need to compare the snowfall data rather than simply compare the statistical measures.
- Comparison of the average amounts of snow and the consistency of snowfall were rarely seen.

Limited responses

- Many simply compared the medians or quartiles of the data rather than offering comparisons in context.

Question 4

(a) **Comprehensive responses**

- Successful solutions recognised this as a geometric distribution question and applied the formula correctly.
- Many solutions were seen in which the probabilities of getting a red marble on the 1st, 2nd, … 5th choice were summed; candidates should work to more than 3 s.f. to obtain an accurate answer.
- On occasions, full marks could not be awarded due to rounding to 2 s.f. only.

Limited responses

- Some candidates used an incorrect probability for choosing a red marble.
- Some attempted to apply a binomial distribution when modelling the selection of a red marble.

(b) **Comprehensive responses**

- Most candidates placed a green marble in the last position, then dealt with the previous green marble and seven yellow marbles, multiplying by 8 to allow for the different positions the first green marble could occupy.
- Some candidates gave their final answer correct to only 2 s.f.

Limited responses

- Candidates attempted to deal with all nine choices at once, whilst others applied the binomial distribution.

(c) **Comprehensive responses**

- Candidates demonstrated an understanding that this was an application of the binomial distribution and recognised that the probabilities of obtaining 0, 1, and 2 black marbles were required.
- Terms with the appropriate binomial coefficients were listed and calculated to at least 4 s.f.
- In some instances, premature approximation in the terms led to a solution outside the allowable range.

Limited responses

- Solutions contained just 1 or 2 terms; often the probability of getting 0 black marbles was ignored.
- Some candidates used an alternative method involving subtracting terms from 1; this was rarely successful because incorrect terms were included and/or inaccuracies in calculation led to an incorrect answer.

Question 5

(a) **Comprehensive responses**

- Those using a probability approach either summed the probabilities of getting 1, 2 or 3 Es, or subtracted the probability of obtaining no Es from 1 (the latter method was more succinct and reduced the room for errors).
- Some candidates listed the appropriate scenarios with their combinations and then divided by the number of possible selections.
- Subtracting the probability of obtaining selections with no Es from 1 was the most concise method.

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Limited responses

- Some did not realise that once a letter had been chosen it could not be selected again.
- Some gave only the combinations for the possible selections without dividing by the total number of selections.

(b) Comprehensive responses

- The number of arrangements of the letters, 7!, between the Rs was divided by 3! to take account of the repeated Es.
- Placing the 3 Es together gave five items to arrange, 5!, which was then subtracted.

Limited responses

- Attempts to subtract the arrangement with the Rs at the ends and the 3 Es together were often missing. Some candidates tried to deal with all 9 letters without placing the Rs at the ends.
- Some got as far as arranging T,I,V,S but did not have a strategy for placing the remaining letters.

(c) Comprehensive responses

- Solutions were often accompanied by a list showing the five possible positions of the Rs.
- This was then multiplied by the number of ways of arranging 7 letters where the 3 Es were repeated ($\frac{7!}{3!}$).

Limited responses

- Those who tried to use all 9 letters at once were not successful.
- Some did not allow for the repetition of the Es.
- Permutation/combination approaches were rarely correct.

Question 6

(a) Comprehensive responses

- Candidates gave both standardising formulae with their associated probabilities.
- The appropriate area was found, often using a supporting diagram.
- The probability was multiplied by 250 to find the expected number of elephants and the answer given as a single integer with no indication of rounding.

Limited responses

- Some candidates did not recognise that they needed to substitute 2.4 or 3.1 into the formula and instead tried to use 250.
- Candidates found the probability but made no attempt to calculate the expected number of elephants.
- The answer was not given as a single integer, or included a reference to rounding, for example '3 s.f.' or 'approximately'.

(b) Comprehensive responses

- The appropriate z-value, 0.306, was selected from the table (the value 0.305 was much more commonly seen).
- As 3.15 was smaller than the mean, -0.306 was used in the standardisation formula; a supporting diagram often demonstrated awareness of this.

Limited responses

- The probabilities 0.62 or 0.38 were used in the standardisation formula rather than a z-value.
- 0.305 or 0.306 were used rather than –0.305 or –0.306.

(c) Comprehensive responses

- The mean and variance were correctly calculated and identified.
- These were substituted into the standardisation formula with a continuity correction of 50.5.
- The correct area was identified, often accompanied by a supporting diagram (in a small number of cases, 0.875 was subtracted from 1).

Limited responses

- Some candidates did not find the mean and variance; instead, they used the values found in **part 6(b)**.

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- The continuity correction was not applied or was incorrect.
- Many candidates could not make a start on this part.

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MATHEMATICS

Paper 9709/52
Probability & Statistics 1

Key messages

What candidates did well
- Many candidates demonstrated a good understanding of the content and presented their solutions clearly, supported by relevant working.
- Candidates applied standard processes effectively in routine contexts.

What candidates needed to improve
- Candidates should work to a sufficient degree of accuracy when providing non-exact answers to 3 significant figures.
- Candidates should be aware of the difference between answers correct to 3 significant figures and answers correct to 3 decimal places.
- Candidates should manage their time effectively so that all questions can be attempted.
- Candidates should pay greater attention to the interpretation of success criteria, which is essential in this component.
- Fully correct numerical expressions were sometimes evaluated incorrectly or left unevaluated.

Comments on specific questions

Question 1

(a) **Comprehensive responses**
- The most common approach was to identify the scenarios that met the success criteria and use combinations to determine the total number of possible selections. Many candidates also stated the total number of possible scenarios clearly.
- Many candidates included a simple visual representation of the given conditions.
- Most candidates communicated clearly which scenarios were being calculated.
- Candidates using a probability approach recognised that there was no replacement and that some scenarios could occur in more than one way.

Limited responses
- The most common approach was to use combinations to calculate the number of possible scenarios, but candidates often omitted the scenario involving 5 men and 0 women.
- Many candidates did not form a probability expression or justify how the denominator was obtained.
- Candidates using a probability approach assumed that replacement occurred and that all scenarios could be obtained in only one way.

(b) **Comprehensive responses**
- Most candidates clearly identified the possible scenarios and listed them in a logical order.
- Most candidates evaluated the combinations accurately.

Limited responses
- A common misconception was to add the terms for the identified scenarios rather than multiply them.
- Some candidates assumed that each group would be selected from all 13 members and therefore calculated ${}^{13}C_6 \times {}^{13}C_4 \times {}^{13}C_3$.
- Some candidates used permutations.

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Question 2

(a) **Comprehensive responses**

- Most candidates created a clear probability distribution table with ruled lines. The most effective responses labelled the rows x and $\mathrm{P}(x)$.
- Many candidates included clear calculations to support the values in the table.
- Most candidates retained their answers as accurate fractions rather than converting them to decimals.
- Many candidates checked that the probabilities summed to 1.

Limited responses

- Some candidates did not present a clear probability distribution table and did not use lines to provide structure.
- Several candidates omitted $x = 0$ as an outcome.
- Some candidates did not consider the possible scenarios that could produce the outcomes $x = 1$ and $x = 2$.
- Some candidates did not check that the probabilities summed to 1.

(b) **Comprehensive responses**

- Most candidates interpreted the success criteria correctly and used the probabilities from **2(a)** appropriately.
- Most candidates stated the required calculation clearly.

Limited responses

- Many candidates interpreted 'obtaining at least 2 heads for the first time on the seventh throw' as either 'obtaining 3 heads for the first time on the seventh throw' or 'obtaining 2 heads for the first time on the seventh throw'.
- A common misconception was to assume that calculating the probabilities for the possible success criteria separately and adding was equivalent, for instance,
$\left(\frac{21}{27}\right)^6 \times \frac{6}{27} + \left(\frac{26}{27}\right)^6 \times \frac{1}{27} \equiv \left(\frac{20}{27}\right)^6 \times \frac{7}{27}$.
- A few candidates did not use probabilities from **2(a)**, with $\left(\frac{2}{3}\right)^6 \times \frac{1}{3}$ being the most common.

(c) **Comprehensive responses**

- Most candidates used the same probabilities as in **2(b)**.
- Many candidates used a simple visual representation to interpret the success criteria.
- Most candidates recognised that there were two distinct outcomes to consider and that, for each outcome, the required probability could be modelled using a binomial distribution.

Limited responses

- Many candidates did not recognise that the second success occurring on the sixth or seventh throw required a first success on an earlier throw.
- Some candidate recognised that there was a binomial element to the question but used
$\binom{6}{2} \times \left(\frac{20}{27}\right)^4 \times \left(\frac{7}{27}\right)^2$ or $\binom{7}{2} \times \left(\frac{20}{27}\right)^5 \times \left(\frac{7}{27}\right)^2$.
- The misconception identified in **2(b)** was seen again in this part.
- Many candidates made no attempt at this part.

Question 3

(a) **Comprehensive responses**

- Nearly all candidates recognised that if the number was divisible by 5, the final digit had to be 5.
- Many candidates used a simple visual representation, such as ^ ^ 5, to clarify the success criteria and listed beneath it the values that could be selected.
- Most candidates stated the required calculation clearly.

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Limited responses

- Some candidates did not apply the requirement that the values had to be greater than 200.
- Some assumed that digits could not be repeated.
- Some candidates attempted to calculate the possible outcomes for different first digits but did not apply a consistent approach throughout.
- Some candidates attempted to list all possible values, but not always in a logical order, resulting in values being omitted.

(b) **Comprehensive responses**

- Most candidates used clear labelling to identify the processes being considered.
- Identifying the possible outcomes for the final digit was generally the more successful approach.
- Many candidates used simple visual representations, often listing the possible digits for each position with one success criterion applied.
- Most candidates used a systematic approach to calculate the possible outcomes.

Limited responses

- Many candidates did not identify the scenarios that were being considered.
- Some candidates included values that were below 200.
- Some candidates identified suitable first digits but then generalised using 6P2 for the remaining two digits without applying the condition that the values had to be even.
- Many candidates did not set out their solutions clearly or logically, making it difficult to identify the process being attempted.

Question 4

(a) **Comprehensive responses**

- Almost all candidates stated clearly the un-simplified binomial approximation expression for the required success criteria.
- Many candidates included the values for each term, although this was not required.
- Most candidates stated the probability to at least 3 significant figures.

Limited responses

- Some candidates misinterpreted the success criteria and found P(8, 9).
- Some candidates omitted the binomial coefficient in each term.
- Some candidates attempted to use the normal approximation to the binomial distribution, although the required conditions were not met.
- Some candidates attempted to use a geometric distribution, which was not appropriate in this context.

(b) **Comprehensive responses**

- Almost all candidates stated un-simplified expressions for the mean and variance of the time taken to complete the task.
- Most candidates stated the normal standardisation formula with the correct values substituted.
- Most candidates showed the numerical calculation required to obtain the correct probability area.
- Most candidates stated the probability to 4 significant figures.

Limited responses

- Some candidates did not state un-simplified calculations for the mean and variance and consequently made errors in their calculations.
- Some candidates partially evaluated or omitted the normal standardisation formula.
- Some candidates did not recognise that discrete data was being considered and did not apply a continuity correction.
- Some candidates misinterpreted the success criteria and therefore applied an incorrect continuity correction.
- Some candidates did not provide the numerical calculation required to obtain the probability area.
- Some candidates confused the variance with the standard deviation.

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Question 5

(a) **Comprehensive responses**

- Almost all candidates showed the required calculation accurately.
- Many candidates included a tree diagram, which they then referenced throughout the question.

Limited responses

- Some candidates did not add the extra green pen to the box after Lui had selected a pen.
- Some candidates replaced the pen selected by Lui as well as adding the extra green pen.

(b) **Comprehensive responses**

- Most candidates identified the individual scenarios being considered and then calculated the probabilities in that order.
- Some candidates simplified the success criteria to P (Red, Red) + P (not Red, Red).
- Some candidates used a tree diagram to assist, often building on the diagram already used in their solution to **5(a)**.

Limited responses

- Many candidates did not identify the relevant scenarios and did not follow the order of information provided in the question.
- Some did not include P (Red, Red) in the success criteria.
- Many candidates used incorrect denominators carried forward from **5(a)**.

(c) **Comprehensive responses**

- Most candidates stated the general formula for conditional probability.
- Many candidates used their answer from **5(b)** to calculate the denominator.
- Some candidates calculated the numerator and then used this value to assist in calculating the denominator.
- Some candidates used their tree diagram to identify the required probabilities.

Limited responses

- Some candidates did not recognise the conditional probability request and simply calculated the probability that Lui's pen was red.
- Some candidates assumed the required denominator was P(Red) = $\frac{3}{10}$.

Question 6

(a) **Comprehensive responses**

- Almost all candidates followed the instruction for Hippos to be placed on the left.
- Most candidates ordered the leaves correctly with consistent spacing and vertical alignment.
- Some candidates made corrections to ensure that replacement values were correctly aligned.
- Most candidates included a non-symmetrical single key that included both the teams and the units.

Limited responses

- Some candidates did not order the leaves.
- Some candidates used a split stem, which was not appropriate for the data range.
- Some candidates used a single digit for the stem, for example ‘8’ instead of ‘18’.
- Many candidates omitted either the key or the units from the key.
- Some candidates did not align the leaves vertically.

(b) **Comprehensive responses**

- Most candidates identified the upper quartile and lower quartile values.
- Most candidates obtained the quartiles by finding the median of the upper and lower data sets.
- Almost all candidates evaluated the calculation accurately.

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Limited responses

- Many candidates did not identify the Upper or Lower Quartiles.
- Some candidates used the formula $\frac{n+1}{4}$ rather than finding the median of the upper or lower data range.
- Some candidates stated a data range, for example, $172-190$ rather than evaluating the difference.

(c) Comprehensive responses

- Most candidates found the total height of the Hippos and calculated the mean. They then increased this mean by 0.5 cm, obtained the new total height for the Hippos, and used this to calculate the height of the new player.
- Some candidates realised that if the mean increased by 0.5 cm, then the new player was 7.5 cm (0.5 cm × 15) taller than the injured player.

Limited responses

- Many candidates made arithmetical errors when calculating both the total height of the Hippos and the mean.
- Many candidates rounded values during their calculations rather than as a final step, leading to inaccurate results.
- Some candidates simply added 0.5 cm either to the height of the injured player or to the total height of the Hippos, misinterpreting the increase in the mean.

Question 7

(a) Comprehensive responses

- Most candidates formed 2 appropriate normal standardisation equations using μ and σ and z-values.
- Many candidates presented a clear algebraic solution to the simultaneous equations formed.
- Most candidates stated μ and σ to at least 3 significant figures.
- Some candidates included a simple normal distribution diagram to identify the probability regions given.

Limited responses

- Some candidates equated the normal standardisation expression to one of the probabilities given in the question.
- Many candidates used the normal distribution tables incorrectly and obtained a probability rather than the required z-value, for example using 0.80 to obtain 0.7881.
- Some candidates misinterpreted the probability area for 20% and used 0.524 instead of −0.524.
- Some candidates found only one of μ and σ.

(b) Comprehensive responses

- Most candidates stated both normal standardisation formulae with the correct values substituted.
- Some candidates interpreted the criteria appropriately and stated normal standardisation formulas $\pm\frac{0.6}{0.55}$.
- Most candidates showed the numerical calculation required to obtain the correct probability area.
- Most candidates stated a 4 significant probability for the success criteria.
- Many candidates showed the calculation required to obtain the expected number and then interpreted the decimal answer as a single integer value.

Limited responses

- Some candidates partially evaluated or omitted the normal standardisation formula.
- Some candidates incorrectly assumed that the probability area was symmetrical.
- Some candidates did not provide the numerical calculation required to obtain the probability area.

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- Many candidates did not calculate the expected number of leaves with lengths within 0.6 cm of the mean and instead stated only the probability.
- Many candidates indicated that their answer had been obtained by rounding or truncating a decimal value rather than by interpreting the result within the context of the question.

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MATHEMATICS

Paper 9709/53
Probability & Statistics 1

Key messages

What candidates did well

- Many candidates displayed good knowledge of the topics and showed good understanding of the methods required to solve probability/statistical problems.
- Good solutions were characterised by clear communication of the methods used.
- Good solutions highlighted success criteria alongside mathematical working to communicate the meaning of their solutions.
- Generally, solutions were given to the correct degree of accuracy – either exact or rounded to 3 significant figures.
- Most candidates used a ruler to construct an accurate diagram when required in the question that tested representation of data.

What candidates needed to improve

- When using working values to support further calculations, these should not be rounded prematurely. To justify a final answer correct to 3 significant figures, working values correct to at least 4 significant figures should be used calculations.
- Candidates should take care when rounding a number to 3 significant figures, especially when the first figure after the decimal point is a zero.
- Candidates should ensure they show all necessary working clearly and avoid giving answers unsupported by working.
- Candidates should ensure that they present only one solution for marking.

Comments on specific questions

Question 1

(a) **Comprehensive responses**

- Most candidates gave the correct answer of 0.0561 to the required degree of accuracy (3 significant figures).

Limited responses

- Some candidates appeared unsure of the difference between significant figures and decimal places and finished with an answer of 0.056.

(b) **Comprehensive responses**

- Most candidates completed this question successfully, with the shorter, more efficient method being the most popular.
- Some candidates used the longer, less efficient method and added their terms together to obtain the correct answer.

Limited responses

- Some candidates included an extra term in their calculation and therefore found the probability of obtaining a 5 on or before the 10th throw rather than before the 10th throw.

(c) **Comprehensive responses**

- Most candidates recognised the need to use the Binomial Distribution and did so successfully by clearly stating the unsimplified binomial expression.
- Most candidates stated the final probability to at least 3 significant figures.

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Limited responses

- Some candidates misinterpreted the success criteria and found only P(1) and P(2), or included P(0) in their calculation.
- Some candidates omitted the binomial coefficient in each term.
- A few candidates worked to only 3 significant figures throughout when finding P(1), P(2) and P (3) and added these values to obtain a final probability outside the acceptable range.

Question 2

(a) **Comprehensive responses**

- Most candidates correctly identified the core concept that $\sum P(X=x) = 1$ and set up an equation to solve for k.
- Most candidates calculated the value of k and then used it successfully to produce the four required probabilities.

Limited responses

- Some candidates gave responses that were not valid probabilities (values between 0 and 1) and/or gave four values that did not sum to 1.
- A few candidates did not identify the core concept that $\sum P(X=x) = 1$.

(b) **Comprehensive responses**

- Successful responses showed a clear method for calculating the mean of the distribution, E[X], and then used this value to calculate the variance, showing a full method.

Limited responses

- Some candidates extracted values directly from a calculator when calculating the mean of the distribution, giving no indication of the method used.
- A few candidates did not square the value of E[X] before subtracting it from $E[X^2]$.

Question 3

(a) **Comprehensive responses**

- Virtually all candidates used a sensible scale to draw their histogram.
- Most candidates used a ruler to construct the required histogram.
- Many candidates clearly labelled the axes correctly, including the unit of measurement (minutes) on the horizontal axis.

Limited responses

- Some candidates produced freehand attempts at their histogram.
- Some candidates did not label axes correctly or at all.
- A few candidates plotted the bars at 9.5, 14.5, etc., showing confusion between discrete and continuous data.

(b) **Comprehensive responses**

- Most candidates recognised that the mid-points of the intervals are needed to calculate an estimate of the mean.
- Most candidates set out the required calculation in a logical manner, often using a tabular approach.
- Most candidates interpreted their solution in the context of the question and gave an answer correct to 3 significant figures.

Limited responses

- Some candidates incorrectly used the upper- or lower-class boundary values in their calculation.
- A few candidates divided by the number of intervals rather than the number of candidates.
- Some candidates did not recognise that an answer of, say, 7.33 was unlikely to be a reasonable estimate of the mean of the given data.

(c) **Comprehensive responses**

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- Most candidates recognised the need to find 40% of 150 and then find the class interval containing the 60th candidates.
- Most candidates gave the required interval.

Limited responses
- Some candidates found 40% of 150, leaving their answer as 60 rather than identifying the required interval.

Question 4

(a) **Comprehensive responses**
- Most candidates produced a tree diagram of the correct form.
- Most candidates labelled the branches correctly with H(head), T(tail), R(red), B(blue) or G(green).
- Most candidates added the correct probabilities to their labelled branches.

Limited responses
- Some candidates produced an incorrect tree diagram with branches missing.
- A few candidates labelled part of their tree diagram with B(blue) when it should have been G(green).
- A few candidates gave probabilities that assumed replacement of the discs in Bag A and/or Bag B.

(b) **Comprehensive responses**
- Most candidates used their tree diagram probabilities to correctly identify the four scenarios in which discs of the same colour were obtained.
- Most candidates showed a full method for finding the summation of the probabilities of the 4 scenarios.

Limited responses
- Some candidates used only the Bag A and Bag B probabilities, without the H(head) or T(tail) probabilities, to identify the 4 correct scenarios.

(c) **Comprehensive responses**
- Most candidates recognised this as a conditional probability question.
- Most candidates knew they needed to apply the general formula $P(A \mid B) = \dfrac{P(A \cap B)}{P(B)}$.
- Many candidates showed a good understanding of how to calculate the conditional probability in the context given here.
- Good solutions were characterised by a logical approach that broke the questions down into three clearly explained steps.

Limited responses
- Some candidates quoted the general formula to for conditional probability without interpreting this in the context of the question and so did not communicate their method clearly.
- Some candidates did not show the method used for finding the numerator and denominator probabilities required to obtain the final answer.

Question 5

(a) **Comprehensive responses**
- Most candidates showed a clear understanding of the standardisation process required to solve this question using the Normal distribution.
- Some candidates used a sketch to support their thinking.
- Most candidates used tables correctly to find the two z-values and then used an appropriate calculation to find the required probability.
- Most candidates gave the final answer correct to at least 3 significant figures.

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Limited responses

- Some candidates did not show the appropriate given values substituted into a standardisation formula.
- A few candidates did not show the calculation from their z-values leading to the final answer.

(b) **Comprehensive responses**

- Most candidates gave the correct z-value from the given information.
- Most candidates used the standardisation formula with their z-value to form an equation in σ.

Limited responses

- Some candidates gave an incorrect z-value from the given information.
- A few candidates equated the standardising formula to a probability.

(c) **Comprehensive responses**

- Most candidates produced an estimate for the mean and variance from the given data.
- Many candidates correctly used a continuity correction in their standardisation formula.
- Some candidates used a sketch to establish which tail of the Normal distribution curve was required to obtain the final solution.
- Most candidates set their work out in a logical manner showing all steps clearly.

Limited responses

- Some candidates tried to use values from part **(b)** of the question to obtain the mean and variance required here.
- A few candidates used a calculator without indicating their method, for example, they standardised with the correct values without showing the standardisation formula.
- A few candidates confused variance with standard deviation and/or seemed unsure which to use in their standardisation formula.

Question 6

(a) **Comprehensive responses**

- The most common successful approach was to calculate the total number of arrangements with four S's together and subtract the number of arrangements with the S's together and O's the together.
- Some candidates were also successful using an approach that treated the 4 Ss as a single item and inserted the O's.
- Many candidates included a simple visual representation of the given conditions.

Limited responses

- Some candidates did not fully execute their chosen method, particularly when dealing with the repeating letters.

(b) **Comprehensive responses**

- Candidates who used a diagram to support their thinking were often successful in obtaining the values required to reach the correct solution.
- Most candidates used one of the standard methods, involving either mapping out the specific positions for the O's or treating the letters between the O's as a grouped item.

Limited responses

- Some candidates confused the relevant permutation calculations. The most common error was calculating $6!/4! \times 3!$ instead of multiplying by 3. Others used $({}^6P_4)/4! \times 3$ instead of multiplying by 3!, or completely forgot to multiply by the 3 configurations altogether.

(c) **Comprehensive responses**

- Most candidates recognised the need to set up different scenarios based on the condition given in the question at least 2 S's and at least 1 O.
- Most candidates showed the five correct scenarios.
- Most candidates showed unsimplified expressions when calculating the outcome for each scenario.

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Limited responses

- Some candidates only identified only four or fewer of the 5 required scenarios.
- Some candidates treated identical letters as distinct and so obtained many more outcomes than were possible.

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MATHEMATICS

Paper 9709/55
Probability & Statistics 1

Key messages

What candidates did well
- Most candidate demonstrated a good understanding of the questions and showed their working clearly.
- Most candidates were familiar with the formulae and processes and applied them with care.
- Candidates did particularly well with the final questions on Permutations and Combinations.

What candidates needed to improve
- Candidates need to take more care over graph work. Labels must always be clear and there must be evidence on the graph if it is used in further calculations.
- When answering questions on the Normal Distribution, candidates are advised to use a diagram to ensure that they find the correct probability area.
- Candidates should aim to find the simplest and most direct method to answer the question.
- Candidates should be careful not to prematurely approximate numbers that are to be used in further calculations
- Candidates should make sure that they read the question carefully and check that their answer makes sense.

Comments on specific questions

Question 1

(a) **Comprehensive responses**
- Most candidates displayed a sound knowledge of the standard deviation formula.
- Most candidates appreciated that coding, which only involved subtracting a constant, had no effect on the standard deviation of the original data.
- Most applied the formula correctly and obtained the correct value for the standard deviation.

Limited responses
- Some candidates confused Standard Deviation with Variance and omitted to take the square root at the final stage.
- Some incorrectly applied the Variance formula, most frequently omitting to divide 32460 by 60.
- Some candidates did not give a clear demonstration of how they had substituted the given values into the Standard Deviation formula.
- A few candidates attempted to decode the data, an approach which required complex algebra, and very few of these arrived at the correct final answer.

(b) **Comprehensive responses**
- Most candidates were clear on how the coding affected the mean.
- Many candidates used the approach of finding the total of the values (95.7×60) and equating it to $642 + 60c$.
- Some candidates realised that c could be found by finding the difference between the mean of x and the mean of $(x - c)$. This was a very efficient approach.

Limited responses
- A few candidates did not realise that the coding was applied 60 times when finding the total amount. This resulted in seeing an incorrect equation equivalent to $95.7 \times 60 = 642 + c$

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Question 2

(a) **Comprehensive responses**

- Many candidates produced a clearly labelled graph making full use of the space provided.
- They plotted points above the upper boundaries of the groups and drew a smooth curve, with a sharp pencil, from (0, 0) through the plotted points.

Limited responses

- Some candidates used a ruler to join the points.
- Some candidates did not start their curve at (0, 0).
- Some did not label their axes at all while others labelled the horizontal axis as 'time' without giving the units (seconds) as well.
- A few chose a small scale which made accurate plotting very complicated.
- A few allowed their graph to rise above 160 before the final point.

(b) **Comprehensive responses**

- Most candidates clearly indicated on their graphs how they had found the quartiles at cumulative frequency values of 40 and 120.
- Most knew to subtract their lower quartile value from their upper quartile value to find the interquartile range.

Limited responses

- Some disregarded the instruction to 'use your graph' and left no evidence on their graph of having done so.
- A few candidates mistakenly found a quarter and three quarters of the total time and took readings from t = 100 and 300.

Question 3

(a) **Comprehensive responses**

- Most candidates considered the outcomes from the three drink options and formed a 3-term probability expression using the given probabilities and the variable x.
- Nearly all candidates equated their probability expression to 0.505
- Many candidates included a clear algebraic solution of the equation to find the value of x.

Limited responses

- Some candidates mistakenly summed the three probabilities of having cake when combined with different drinks and equated them to 1.
- for example, $0.25 + 0.4 + x = 1$ giving $x = 0.35$
- A few candidates equated their correct sum of three products to 1 instead of 0.505
- That is, $0.2 \times 0.25 + 0.35 \times 0.7 + 0.45x = 1$

(b) **Comprehensive responses**

- Most candidates demonstrated a clear understanding of the Conditional Probability formula.
- Most knew to divide the probability of Jules having juice and not cake (0.35×0.6) by the probability that she does not have cake ($1 - 0.505$).
- Many candidates used an unnecessarily long method to find the probability that she does not have cake ($0.2 \times 0.75 + 0.35 \times 0.6 + 0.45 \times 0.3$). If this was calculated accurately, it had no impact on the final answer.

Limited responses

- Some who knew and used the Conditional Probability formula did not explain the derivation of the probability of Jules having juice and not cake and presented 0.21 as their numerator without showing the product 0.35×0.6.
- A few did not appreciate the Conditional nature of the probability and gave their final answer as the probability of having juice and not cake, $0.35 \times 0.6 = 0.21$.

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Question 4

(a) **Comprehensive responses**

- Most candidates recognised the need for the Binomial Distribution with n =9 and p = 0.8.
- Most candidates successfully subtracted the probability of 7, 8 and 9 residents shopping at the local store from 1.
- Some candidates chose the longer method of adding the probabilities of 0, 1, 2, 3, 4, 5 and 6 residents shopping at the local store.

Limited responses

- Some candidates who added the probabilities of 7, 8 and 9 residents shopping at the local store did not go on to subtract the total from 1.
- Some candidates only subtracted the probabilities of 8 and 9 residents shopping at the local store and omitted 7.
- A few candidates who chose the longer method did not include the probability of no residents shopping at the local store.
- A few candidates tried to use a Normal approximation to the Binomial.

(b) **Comprehensive responses**

- Most candidates understood that a Normal approximation to the Binomial was required and calculated the correct mean and variance, 96 and 19.2.
- Most candidates produced a correct standardisation expression using 96 as the mean and $\sqrt{19.2}$ as the standard deviation and included the continuity correction 90.5.
- Most candidates found the correct area for P (X > 90), that is, greater than 0.5.

Limited responses

- Some candidates used the Variance instead of the standard deviation in their Standardisation expression.
- Some omitted the continuity correction, and a few used the continuity correction in the wrong direction (89.5).
- A few candidates subtracted the correct answer from 1.
- A few candidates prematurely approximated the value of the standard deviation which resulted in an inaccurate final answer.
- A few candidates multiplied their final answer by 120, mistakenly thinking that they had been asked to estimate the number of residents who shop at the local store.

Question 5

(a) **Comprehensive responses**

- Most candidates produced an accurate probability distribution table for X, the difference between the two numbers on the spinner.
- Some used a sample space diagram to calculate the probabilities of the four possible differences between the two number, 0, 1, 2 and 3 while others used lists or calculations.

Limited responses

- Some candidates did not take account of the difference between two identical numbers being zero. They produced a table with only three values of X, that is, 1, 2 and 3.
- A few made mistakes in their calculations and produced fractions with denominators other than 16, 8 or 4.
- It was good to see that some candidates working with incorrect probabilities did try to ensure that they summed to 1.

(b) **Comprehensive responses**

- Most candidates were familiar with the formula needed to find the Variance of X. They derived the value of E(X) showing their working clearly and used that in the follow-on calculation of the Variance, showing all stages of their working.
- Most gave the answer in fraction form and those who used the decimal form knew to give the exact answer (0.9375) even if they went on to round it to 3 significant figures later.

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Limited responses

- Some candidates forgot to square the E(X) in their Variance calculation.
- A few candidates showed no evidence of their working even though they produced the correct final answer.
- A few candidates did not follow the instruction on the front of the paper that only 'non-exact' numerical answers should be given correct to 3 significant figures and gave 0.938 as their final answer without previously stating that the answer was either 15/16 or 0.9375.

(c) **Comprehensive responses**

- Most candidates recognised the geometric distribution and knew to multiply the probability of 'not a difference of 3' by itself 6 times before they multiplied by the probability of 'a difference of 3'.
- A few candidates used an alternative method. They correctly subtracted the probability of 'not 3' raised to the power of 7 from the probability of 'not 3' raised to the power of 6.

Limited responses

- A few candidates misunderstood the question and used combinations to find the probability that the difference of 3 could occur once in the first seven spins.
- A very small number of candidates embarked on a lengthy calculation to find the sum of the probabilities of a difference of 3 on each of the first six spins and then subtract this from 1. Consideration of the demand of the question would have indicated that this was not an appropriate method.

(d) **Comprehensive responses**

- Most candidates recognised the need for the binomial distribution.
- They knew to find the probability of a difference of 3 occurring twice in the first 6 spins and then to multiply that result by the probability of 3 on the 7th spin.

Limited responses

- Some candidates did not take account of the fact that there was more than one way of there being a difference of 3 twice in the first 6 spins and omitted the Combination term (6C2).
- A few others omitted the second step of the calculation and did not multiply by the probability of 3 on the 7th spin.
- A few candidates included their answer to the previous part of the question in their product.

Question 6

(a) **Comprehensive responses**

- Most candidates standardised correctly for both values of mass (412 and 424) which resulted in z-values –1.25 and 0.625.
- Most candidates used the tables to find the correct probabilities associated with these z-values and combined the probabilities correctly: phi (0.625) – {1 – phi (1.25)} to find the correct area.

Limited responses

- A few candidates used a continuity correction when standardising.
- Some candidates did not find the correct area, the most common error being to calculate phi (1.25) – phi (0.625).

(b) **Comprehensive responses**

- Most candidates found the correct probability of a box having a mass more than 245 grams.
- Many candidates used the tables correctly to find the z-value associated with their probability and equated it to a standardisation formula

Limited responses

- Some candidates equated their standardisation formula to a probability, usually after using the tables the wrong way round.
- Some candidates made errors while rearranging their equation involving a z-value and a standardisation formula.
- Some candidates used a negative z-value which resulted in a negative value for sigma.

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(c) **Comprehensive responses**

- Most candidates standardised correctly using the terms in μ.
- Most candidates eliminated μ from their standardisation formula to find the z-value (0.8).
- Many candidates used their tables correctly to find the probability that Z > 0.8

Limited responses

- Some candidates did not know how to eliminate μ from their standardisation expression.
- A few candidates found the incorrect area, usually P (Z < 0.8).
- A few candidates used 0.8 as a probability and worked with its associated z-value (0.842)
- A few candidates mistakenly thought that P (Z > 0.8) is the same as P (Z < 0.2)

Question 7

(a) **Comprehensive responses**

- Most candidates understood and answered this question well.
- There were two contrasting strategies with equally valid approaches:
- To subtract the number of arrangements with both three As and two Ns together (6!) from the total number of arrangements with the three As together (7! /2!)
- To multiply the number of arrangements with the 3 As together without any Ns (5!) by the number of ways the Ns can be inserted separately (6C2)

Limited responses

- Using the first method, a few candidates thought that the total number of ways with the three As together was 9! /2!3!
- Again, using the first method, a few forgot about the two Ns and thought the total number of ways with the three As together was 7!
- Using the second method a few candidates though the order of the Ns mattered and multiplied by 6P2

(b) **Comprehensive responses**

- Most candidates understood the question well.
- Most candidates knew that they needed to find the number of ways that four letters could be positioned between the two Ns and then to divide by the total number of ways the nine letters could be ordered.
- Most candidates multiplied the number of ways the letters other than Ns could be arranged (7! /3!) by 4, the number of possible positions for the block of two Ns with four letters in between.
- Many candidates then divided this total (3360) by the total number of ways the nine letters could be arranged (9! /3!2!)

Limited responses

- Many candidates did not remember to find a probability and presented the number of ways that four letters could be positioned between the Ns as their final answer.
- Some candidates did not realise that there were 4 ways to position the block of two Ns with four letters in between.
- A few candidates made the question far more complicated by considering the number of As in the four letters between the Ns. This longer method was far more complicated and was more prone to errors and slips.

(c) **Comprehensive responses**

- Most candidates produced a clear table of the four possible groupings of the As and Ns.
- Most candidates calculated the number of ways that each scenario could occur.
- Most candidates totalled the number of ways for the four correct scenarios

Limited responses

- A few candidates worked with the correct numbers and did not explain their method clearly, if at all.
- Some candidates identified the correct groupings and made errors in trying to calculate the number of ways each scenario could occur, often multiplying the Combinations instead of adding them.

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- Some candidates only identified three scenarios, often omitting the grouping with the As in the group of 3 and the Ns in the group of 2.

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MATHEMATICS

Paper 9709/61
Probability & Statistics 2

Key messages

What candidates did well
- Candidates who were well prepared for the examination showed good mathematical knowledge across a range of topics.
- Mathematical notation was generally used correctly.

What candidates needed to improve
- There was an error in **Question 3(b)** where the question asked for the largest value instead of the smallest value. This has been corrected in the published version of the paper.
- Candidates should answer in the context of the question when required to do so.
- Candidates should give clear and logical solutions.
- Errors should be crossed out and answers rewritten rather than written over.
- Candidates should show sufficient working to justify answers.
- Candidates should ensure that final answers are given correct to 3sf.
- Candidates should use the correct format when stating the conclusion to a hypothesis test.

Comments on specific questions

Question 1

Comprehensive responses
- N (584,396.9) was used.
- Candidates carried out two standardisations, for 550 and 600.
- The area between 550 and 600 was correctly found.

Limited responses
- Many candidates incorrectly used the distribution N (58.4, 6.3^2) given in the question.
- Some candidates used $s/\sqrt{10}$ when standardising.
- Some candidates did not use an appropriate method to find the area between 550 and 600.

Question 2

(a) **Comprehensive responses**
- Candidates identified that a one-tailed test was required.
- The correct hypotheses were stated.

Limited responses
- Some candidates used μ or x or λ instead of p in their hypotheses.
- Some candidates used the number of dolls instead of a probability.
- Some candidates omitted ‘probability’ or ‘p’ in their hypotheses.

(b) **Comprehensive responses**
- Candidates answered in the context of the question.
- Candidates clearly stated the conclusion that would have been made and the actual outcome required for a Type II error.

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Limited responses
- Some candidates did not answer in the context of the question.
- Candidates did not always make clear the conclusion being made and the actual outcome.

(c) **Comprehensive responses**
- Candidates used Bin (50,0.12).
- Candidates stated and evaluated a correct Binomial expression for P (<3).
- Candidates showed good accuracy in numerical work.

Limited responses
- Some candidates omitted a term when calculating P (≤3).
- Some candidates only calculated P (3).
- Some candidates calculated P (>3).

Question 3

(a) (i) **Comprehensive responses**
- Candidates stated a Poisson distribution with correct parameter.

Limited responses
- Some candidates omitted the parameter.
- Some candidates stated the parameter but did not identify the distribution as Poisson.
- Some candidates stated a distribution other than the Poisson distribution.

(ii) **Comprehensive responses**
- Candidates stated a normal distribution with the correct parameters.
- Candidates fully justified their choice using the context of the question.

Limited responses
- Some candidates chose a distribution other than the Normal distribution for the approximation.
- Some candidates gave incorrect parameters.
- Some candidates did not fully justify their approximation and stated $\lambda>15$ rather than in context (i.e. $\lambda=25>15$).

(iii) **Comprehensive responses**
- Candidates used N (25,25).
- Candidates correctly applied a continuity correction when standardising.
- Candidates found the correct area, (<0.5).

Limited responses
- Some candidates standardised using their normal distribution.
- Some candidates did not use the correct continuity correction.
- Some candidates found an area greater than 0.5 rather than less than 0.5.

(b) Due to an issue with **Question 3(b)**, full marks have been awarded to all candidates for this question to make sure that no candidates were disadvantaged.

Question 4

(a) **Comprehensive responses**
- Many candidates correctly and convincingly showed that E(X) was equal to 2.8.

Limited responses
- Some candidates did not use an appropriate method to find E(X).

(b) **Comprehensive responses**
- Candidates stated and used N (2.8,1.16/300)
- Candidates formed a correct equation in ‘k’ using a correct z-value.
- Candidates correctly solved the equation for k.

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Limited responses
- Some candidates used 1.16 rather than 1.16/300.
- Some candidates used a probability in their equation rather than a z-value.
- Some candidates did not form an equation of the correct form.

(c) Comprehensive responses
- Candidates gave a correct explanation showing an understanding of the Central Limit Theorem.

Limited responses
- Some candidates did not give sufficiently precise reasons.
- Many candidates stated 'it' was normally distributed without specifying whether 'it' referred to X or the population distribution.
- Some candidates did not demonstrate a full understanding of the Central Limit Theorem.

(d) Comprehensive responses
- Candidates identified a two-tail test was required.
- Candidates stated the hypotheses.
- Candidates carried out standardisation and made the required comparisons.
- Candidates gave a conclusion in context using appropriate non-definitive language.

Limited responses
- Some candidates incorrectly used X or $\overline{X}$ in their hypotheses.
- Some candidates attempted a one-tail test.
- Some candidates confused the variance and the standard deviation when standardising.
- Some candidates did not give a clear comparison, and some used an incorrect z-value or area.
- Some gave invalid comparisons, for example comparing a z-value with an area.
- Some candidates did not give conclusions in context using an appropriate degree of uncertainty.

Question 5

(a) (i) Comprehensive responses
- Candidates used Po (2.5) to find the required probability.
- Candidates stated the full Poisson expression.
- Candidates showed good numerical accuracy.

Limited responses
- Some candidates included an extra term in their Poisson expression.
- Some candidates calculated P (1) and P (3) rather than $P(1 \leq X \leq 3)$.
- A small number of candidates did not show enough working to justify their answer.

(ii) Comprehensive responses
- Candidates stated an equation of the correct form.
- Candidates correctly solved the equation using logarithms.
- Candidates found the required probability.

Limited responses
- Some candidates made sign errors often caused by omitting brackets.
- Some candidates made errors when using logarithms.

(b) Comprehensive responses
- Candidates used Po (4).
- Many candidates found P (2) using a Poisson distribution.
- Candidates used sufficient accuracy to convincingly show the given result.

Limited responses
- Some candidates used a normal approximation.
- Some candidates did not find P (2) to the required 4dp or greater accuracy.

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- Some candidates did not successfully show that the given value and their calculated value were the same to 2dp but different to 3dp.
- Some candidates found P (2) but did not attempt the final step required by the question.

Question 6

(a) **Comprehensive responses**

- Candidates attempt to integrate f(x).
- Candidates used the correct limits.
- Candidates equated the integral to 1.
- Candidates solved the equation to show that $\lambda = 3$.

Limited responses

- Some candidates were unable to integrate $e^{-\lambda x}$ correctly.
- Some candidates did not successfully rearrange their equation to show that $\lambda = 3$.
- Some candidates did not equate their integral to 1.

(b) **Comprehensive responses**

- Candidates stated and attempted a correct method to find E(X).
- Candidates successfully carried out integration by parts.

Limited responses

- Some candidates stated the method but did not attempt the integration.
- Some candidates omitted factors of 8/7 or 24/7.
- Some candidates did not fully justify their answer.

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MATHEMATICS

Paper 9709/62
Probability & Statistics 2

Key messages

What candidates did well
- Many candidates demonstrated good mathematical knowledge across a range of topics.
- Mathematical notation was generally used correctly.
- Solutions were generally well presented.

What candidates needed to improve
- Candidates should show sufficient method to justify answers.
- Candidates should use the formulae provided when appropriate.
- Candidates should read questions carefully and ensure that all aspects of the question are addressed.
- Errors should be crossed out rather than written over.
- Candidates should ensure that the final answers are accurate to 3sf by keeping intermediate working to at least 4sf.
- Candidates should use the correct format when stating the conclusion to a hypothesis test.

Comments on specific questions

Question 1

Comprehensive responses
- Many candidates used correct formulae to calculate unbiased estimates of the population mean and variance.
- Numerical accuracy was generally good.
- Many candidates showed full working.

Limited responses
- Some candidates confused the formulae for calculating the unbiased estimate of the variance.
- Some candidates used an incorrect formula and calculated the biased variance rather than the unbiased variance.

Question 2

Due to a series specific issue with this question, full marks were awarded to all candidates for this question to make sure that no candidates were disadvantaged.

Question 3

(a) **Comprehensive responses**
- Many candidates selected a one-tail test.
- Many candidates stated correct hypotheses.

Limited responses
- Some candidates used p rather than μ or λ.
- Some candidates used the term ‘mean’ rather than ‘population mean’.

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(b) **Comprehensive responses**

- Many candidates used Po(2.4).
- Numerical accuracy was generally good.
- Many candidates showed full Poisson expressions.
- Many candidates fully justified their answers.

Limited responses

- Some candidates did not show full Poisson expressions when justifying their answers.
- Some candidates calculated point probabilities only, rather than using an appropriate method.
- Some candidates used a normal distribution.

(c) **Comprehensive responses**

- Many candidates used their previous calculations in part **(b)** to state the probability of a Type I error.

Limited responses

- Some candidates did not use their previous calculations and instead stated the significance level as the probability of a Type I error.
- Some candidates gave answers greater than 0.05.
- Some candidates stated what was meant by a Type I error rather than stating its probability.

Question 4

(a) **Comprehensive responses**

- Many candidates used Po(3.8).
- Many candidates showed the full Poisson expression.
- Numerical accuracy was generally good.
- Many candidates reached the correct answer.

Limited responses

- Some candidates omitted terms from, or included extra terms in, their Poisson expression.
- Some candidates made numerical errors.

(b) **Comprehensive responses**

- Many candidates used correct Poisson expressions.
- Many candidates used a correct formula for the required conditional probability.
- Many candidates found the correct numerator and denominator.
- Many candidates maintained sufficient accuracy throughout.

Limited responses

- Some candidates identified the correct denominator for the conditional probability.
- Some candidates did not fully understand the requirements for calculating the numerator.
- Some candidates did not attempt to find a conditional probability.

(c) **Comprehensive responses**

- Many candidates used N (170,170).
- Many candidates correctly standardised using a continuity correction.
- Many candidates found an area less than 0.5.

Limited responses

- Some candidates omitted a continuity correction, or used an incorrect one.
- Some candidates found areas greater than 0.5.

Question 5

(a) **Comprehensive responses**

- Many candidates used a correct expression for the width of the confidence interval.
- Many candidates equated this to 0.165.
- Many candidates used Z=1.96
- Many candidates rearranged the equation to form a three-term quadratic equation in x or p.
- Many candidates correctly solved this and gave the two values of x as integers.

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Limited responses
- Some candidates did not give their final answers as integers.
- Some candidates gave final answers for *p* rather than *x*.
- Some candidates used (p-1) rather than (1-p) in their expression.
- Some candidates made factor-of-10 errors when forming and rearranging the equation.
- Some candidates used σ in their confidence interval formula and made no further progress.

(b) Comprehensive responses
- Many candidates found and solved a correct equation.

Limited responses
- Some candidates made factor-of-2 errors.
- Many candidates were unable to find the required equation.

Question 6

(a) Comprehensive responses
- Many candidates stated correct hypotheses.
- Many candidates fully showed the standardisation used to find the test statistic.
- Many candidates made a clear and valid comparison of z-values (or areas).
- Many candidates made a conclusion in context using appropriate language.

Limited responses
- Some candidates did not give conclusions in context using the appropriate level of uncertainty.
- Some candidates made invalid comparisons, for example comparing a z-value with an area.
- Some candidates used a two-tail test.

(b) Comprehensive responses
- Many candidates stated that the Central Limit Theorem was not needed.
- Many candidates gave a correct explanation demonstrating understanding of the Central Limit Theorem.

Limited responses
- Some candidates did not provide sufficiently precise explanations.
- Many candidates stated that 'it' was normally distributed without specifying that 'it' referred to T or the population distribution.
- Some candidates incorrectly thought that the Central Limit Theorem was needed.
- Some candidates did not demonstrate a dull understanding of the Central Limit Theorem.

(c) Comprehensive responses
- Many candidates stated a correct equation or inequality.
- Many candidates correctly rearranged the equation or inequality to find n.
- Many candidates gave the correct range.

Limited responses
- Many candidates made errors with inequality signs.
- Some candidates used the incorrect sign for the z-value.
- Some candidates made algebraic errors rearranging their equation or inequality.
- After reaching n>62.9 some candidates did not then deduce that n≥70.

Question 7

(a) Comprehensive responses
- Many candidates correctly found the value of a.
- Many candidates integrated $xf(x)$ and using 'a' to find $E(X)$.

Limited responses
- Some candidates found $E(X)=a^3/6$ but did not substitute the value of 'a'.

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(b) **Comprehensive responses**

- Many candidates clearly stated a correct equation to find the median.
- Many candidates correctly carried out the integration.
- Many candidates obtained a three-term quadratic equation.
- Many candidates solved this rejected one value with a valid reason.

Limited responses

- Some candidates did not give a fully correct reason for rejecting the solution $m=\sqrt{2}+1$.

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MATHEMATICS

Paper 9709/63
Probability & Statistics 2

Key messages

What candidates did well
- Many candidates demonstrated secure knowledge of the syllabus content and presented their solutions clearly.
- Candidates demonstrated competence in questions that required the direct application of mathematical processes.

What candidates needed to improve
- Candidates should work to a sufficient degree of accuracy when giving non-exact answers to three significant figures.
- Full working should be shown.
- Errors should be crossed out rather than being written over.
- Candidates would benefit from further practice in interpreting contexts and forming equations to solve problems.

Comments on specific questions

Question 1

Comprehensive responses
- Most candidates used the correct z-value.
- Many candidates used the correct expression for a confidence interval.

Limited responses
- Some candidates used a z-value of 0.834 because of incorrect use of statistical tables.
- Some candidates used an incorrect expression for a confidence interval, mixing probabilities and values.

Question 2

(a) **Comprehensive responses**
- Many candidates gave fully correct solutions.

Limited responses
- Some candidates omitted hypotheses.
- Some candidates omitted the parameter from their hypotheses, for example, $H_0 = 0.3$.
- Some candidates did not give the probability to three significant figures.
- Some candidates did not state their conclusion in context.

(b) **Comprehensive responses**
- Some candidates stated the correct answer.

Limited responses
- Many candidates did not give their answer to three significant figures as instructed in the question.
- Many candidates did not realise that all that the required answer was the probability already calculated in part **(a)**.

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- Many candidates assumed that the significance level had to be a commonly used value, such as 2% or 1%.
- Some candidates omitted the percentage sign and gave an answer of 3.55.

Question 3

Comprehensive responses
- Some candidates used the area of a triangle to find *a*.
- Many candidates used integration to find *a*, either by integrating f(x) and equating the result to 1, or by integrating $xf(x)$ and equating the result to 2.
- Most candidates used the correct method to find the variance.

Limited responses
- A few candidates did not subtract 2^2 from $E(X^2)$ when calculating the variance.
- Some candidates using an integration method to find *a* made errors when determining f(x).

Question 4

(a) **Comprehensive responses**
- Some candidates gave correct answers involving several conditions.

Limited responses
- Many candidates failed to give context in their responses.

(b) **Comprehensive responses**
- Most candidates were able to calculate the probability correctly.

Limited responses
- A few candidates included an extra term in their calculation.
- A few candidates made an error multiplying 3.2 by 3 or omitted this step.

(c) **Comprehensive responses**
- Many candidates were able to calculate the conditional probability correctly.

Limited responses
- Some candidates just found P (X = 5) and did not recognise that a conditional probability was required.
- Some candidates attempted to calculate a conditional probability but made errors in their calculation $\dfrac{P(X=5)\times P(X\geq 4)}{P(X\geq 4)}$.
- A few candidates had an inaccurate final answer due to premature rounding.

(d) **Comprehensive responses**
- Many candidates produced fully correct solutions.
- Most candidates realised that a normal approximation was needed.

Limited responses
- Some candidates did not use a continuity correction.

Question 5

(a) **Comprehensive responses**
- Most candidates used a correct formula for the unbiased estimate of variance.

Limited responses
- Very few incorrect answers were seen.
- A few candidates omitted to state the mean.

(b) **Comprehensive responses**
- Many fully correct solutions were seen.

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- Candidates either compared z-values or probabilities when conducting the test.

Limited responses

- Some candidates omitted hypotheses.
- Some candidates omitted the parameter from their hypotheses, for example, $H_0 = 41.5$.
- Some candidates did not state their conclusion in context.
- A few candidates gave a conclusion that implied a two-tailed test, for example, 'there is insufficient evidence that the mean length of the snakes is not 41.5'.

(c) Comprehensive responses

- Most candidates answered correctly.

Limited responses

- A few candidates gave the correct reason but did not state that a Type I error was not possible.

(d) Comprehensive responses

- Many candidates produced fully correct solutions.

Limited responses

- Some candidates did not realise that they needed to start by finding a critical vale and consequently made limited progress.
- A few candidates, using the correct method, prematurely approximated their critical value, leading to an inaccurate final answer.

Question 6

(a) Comprehensive responses

- Most candidates were able to combine the distributions and calculate the probability correctly.

Limited responses

- A few candidates subtracted the variances when combining the distributions.
- A few candidates confused variance and standard deviation and used $0.07^2 + 0.08^2$ as the variance.

(b) Comprehensive responses

- Some candidates successfully combined the distributions and completed the calculation to find the correct value of m.
- Most candidates were able to give the expected value of the total mass as 64.5 m.
- Many were able to find the correct z-value of ±0.524.

Limited responses

- Some candidates omitted to square 1.5 when finding the combined variance.
- Some candidates omitted to square m when finding the combined variance.
- A few candidates used an incorrectly signed z-value.
- A few candidates used a z-value of 0.525.

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MATHEMATICS

Paper 9709/65
Probability & Statistics 2

Key messages

What candidates did well
- Many candidates showed good mathematical knowledge across a wide range of topics.
- Mathematical notation was generally correctly used.
- Solutions were generally well presented.

What candidates needed to improve
- Candidates should read questions carefully and extract the relevant information and then reread the question when they have completed their solution to ensure that all the requirements have been fulfilled.
- Candidates should show sufficient method to justify answers, particularly on questions that require a given answer to be shown.
- Candidates need to keep to at least 4sf accuracy during working to ensure a final answer is accurate to 3sf.
- Errors should be crossed out rather than being written over.

Comments on specific questions

Question 1

(a) **Comprehensive responses**
- Many candidates stated the correct distribution, along with its parameters.

Limited responses
- Some candidates stated the correct distribution without parameters.
- A few candidates stated the parameters and did not mention the distribution.

(b) **Comprehensive responses**
- Many candidates stated the correct distribution, along with its parameter.

Limited responses
- Some candidates stated the correct distribution without parameters.

(c) **Comprehensive responses**
- Many candidates wrote the correct expression for the probability, evaluated all the relevant terms and obtained the correct answer.

Limited responses
- Some candidates omitted the term $e^{-0.5} \times \frac{0.5^2}{2}$.
- A few candidates used an incorrect distribution, $N(0.5, 0.499)$ or $B\left(250, \frac{1}{500}\right)$.

(d) **Comprehensive responses**
- Many candidates applied the continuity correction well and obtained an area consistent with their working.

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Limited responses

- Errors when standardising included an incorrect or no continuity correction.

Question 2

Comprehensive responses

- Most candidates calculated mean and variance correctly.
- Standardising with their values was generally done well.

Limited responses

- Some candidates squared 2 and/or 3 in the calculation of the variance.

Question 3

(a) **Comprehensive responses**

- Many candidates set up a correct equation in a or p and obtained the correct answers.

Limited responses

- Some candidates used an incorrect value for z.
- A few candidates mixed up a and p.

(b) **Comprehensive responses**

- Many candidates multiplied 0.94 by itself.
- Some candidates obtained a correct expression for the denominator.
- Many candidates attempted to divide two probabilities.

Limited responses

- Many candidates did not correctly calculate the probability that at least one interval contains the true value of p.

(c) **Comprehensive responses**

- Many candidates successfully calculated unbiased estimates of the population mean and variance.

Limited responses

- Some candidates confused the two formulae for the unbiased estimate of the variance.
- A few candidates found the biased variance rather than the unbiased variance.

Question 4

(a) **Comprehensive responses**

- Most candidates correctly and convincingly showed that the median of X was $\frac{a}{\sqrt{2}}$.
- Some candidates used direct proportionality and a combination of linear and area scale factors to calculate the median.

Limited responses

- Some candidates considered $f(x) = kx + c$ with $c \neq 0$.

(b) **Comprehensive responses**

- Most candidates performed a correct integration of $x \times f(x)$, including limits.

Limited responses

- Some candidates integrated $f(x)$ instead of $x \times f(x)$.

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Question 5

(a) **Comprehensive responses**

- Many candidates used the correct distribution $B(40,0.2)$.
- Sufficient working was shown by most candidates.

Limited responses

- Some candidates calculated $P(X \leqslant 4)$ instead of $P(X < 4)$.

(b) **Comprehensive responses**

- Most candidates realised that their answer to **part (a)** was also the answer to this question part.

Limited responses

- Some candidates stated that the probability of a Type 1 error was 0.

(c) **Comprehensive responses**

- Many candidates used the correct distribution $B(40,0.05)$.
- Sufficient working was shown by most candidates.

Limited responses

- Some candidates used an incorrect distribution.
- Some candidates calculated $P(X \leqslant 4)$ instead of $P(X < 4)$.

Question 6

(a) **Comprehensive responses**

- Many candidates performed the standardisation correctly.

Limited responses

- Some candidates did not divide 6.9 by $\sqrt{25}$.
- Some candidates found the wrong probability area.

(b) (i) **Comprehensive responses**

- Many candidates provided a conclusion that was in context, not definite, and without contradictions.
- Most candidates stated the hypotheses correctly and carried out a correct comparison.

Limited responses

- Many candidates stated the hypotheses in terms of the 'mean wingspan', instead of the 'population mean wingspan', or μ.
- Some candidates performed a one-tail test instead of a two-tail test.
- Some candidates performed a two-tail test, and an incorrect comparison, for example, they compared $\frac{5}{3}$ with 1.645 or 0.0478 with 0.05.

(ii) **Comprehensive responses**

- Some candidates provided the correct answer with a comprehensive explanation.

Limited responses

- Some candidates were not familiar with how to approach this question.
- Many candidates realised that the Central Limit Theorem was not needed, and provided an incomplete explanation, for example, one with no reference to the population of wingspans.

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