ADDITIONAL MATHEMATICS

Paper 0606/12
Paper 12

Key messages

Candidates are advised to read each question carefully and ensure that the demands of the question are fully met. This includes ensuring that the final answer is given in the form required. Some candidates still appear to be unfamiliar with the form an exact answer should take. Decimal equivalents to an exact answer are not required. Candidates should also be familiar with the meanings of the command words used in this syllabus. Candidate should not rely on a calculator to take the place of working.

General comments

Many excellent scripts were seen, showing that most candidates were well prepared and able to show their knowledge of the syllabus objectives. There appeared to be no timing issues and candidates made the correct use of additional paper when the need arose.

Comments on specific questions

Question 1

(a) Nearly all candidates could obtain the correct amplitude.

(b) Nearly all candidates could obtain the correct period. Although the range of the function had been given in degrees, candidates were not penalised if they gave their answer in radians.

(c) It should be noted that when a sketch is required, the intercepts on both the horizontal and vertical axes are expected to be given. Whilst most candidates gave a correct intercept on the y-axis of 6, many candidates did not take the same care with the intercepts of $\pm 40°$, $\pm 80°$ and on the θ-axis. Candidates are also expected to take care with the end points of their graphs. In this question, the end points were maxima. Some candidates did not show this clearly in their sketch.

Question 2

(a) Nearly every candidate was able to apply the laws of logarithms correctly and to obtain a correct solution.

(b) Again, many correct solutions were seen, with most candidates initially making a correct change of base for one of the given logarithms. Errors occurred when some candidates mistook either $(\log_3 x)^2$ to be equal to $\log_3 x^2$, or $(\log_x 3)^2$ to be equal to $\log_x 3^2$. Some candidates chose to use a substitution for the logarithmic term, which was acceptable and highlighted the fact that a quadratic equation could be formed. Any correct exact solutions were acceptable. It is not necessary to include the decimal equivalent of exact answers as well. A few candidates erroneously discounted the negative solution that led to $3^{-1.5}$.

Question 3

Many completely correct solutions were seen. Most candidates were able to identify the key stages needed in the solution and apply them correctly. Some errors occurred when finding the gradient function of the curve C, but these errors did not stop candidates gaining subsequent method marks. It was essential however that the question was read carefully and the fact that exact coordinates were required, considered. This meant that all calculation should be in exact form. Some candidates were not able to gain some of the accuracy marks due to reverting to decimal form at some stage in their solution. Any correct exact form was acceptable although it was expected that the denominators of fractions did not contain fractions.

Question 4

(a) Many candidates did not obtain the correct range. Common errors included $f \geqslant 2$, $x > 2$ and $f > 3$. Candidates should be familiar with the asymptotic behaviour of exponential functions.

(b) An excellent response by nearly all candidates, showing a good understanding of how to obtain an inverse function.

(c) Although there were quite a few completely correct sketches, there were errors made by many candidates. Many sketched the graph of $y = 2 + e^{3x}$ and its inverse. Some sketched correct curves but omitted the intercepts on the axes. Some omitted the asymptotes or did not make them clear. A few candidates gave $y > 2$ and $x > 2$ as descriptions of the asymptotes. Many obtained the correct sketch of $y = 2 + e^{-3x}$ together with its asymptote but were unable to draw the reflection correctly to obtain the inverse function and its asymptote.

(d) An excellent response by most candidates, with all but a few using the correct order of operations for the composite function. Some errors did occur when dealing with the equation $\left(2 + e^{-3x}\right)^{\frac{3}{2}} = 8$, with candidates dealing with the index incorrectly. It should be noted that an answer of $x = \frac{\ln 2}{-3}$ was not acceptable as a final answer. Candidates were expected to continue and write this as $-\frac{1}{3}\ln 2$ or $-\frac{\ln 2}{3}$ or, of course the equivalent $\frac{1}{3}\ln\left(\frac{1}{x-2}\right)$. It is not necessary to give the decimal equivalent as well as the exact answer.

Question 5

(a) Most candidates applied appropriate differentiation and the factor theorem to obtain the correct values of a and b. Candidates should ensure that they carefully check their answers as answers of $a = -29$, $b = -513$ should alert candidates as to a possible error, especially when the resulting cubic equation does not factorise in **part (b)**.

(b) Provided a correct solution was obtained in **part (a)** most candidates obtained the correct quadratic factor of $5x^2 + 14x - 3$ and hence the correct solutions to the equation. Some candidates did not state the solutions of the equation after factorisation, highlighting the need to ensure that the demands of the question are met. Some candidates just wrote down the solutions to the equation, having clearly made use of their calculator. No marks were available in these cases as the question demand had stated that working needed to be shown. Candidates with incorrect values of a and b, were able to obtain the method mark if they had applied a correct approach.

(c) This question part was not really dependent on the two previous parts as a candidate with incorrect values of a and b could still obtain full marks by recognising that they needed to consider $\operatorname{cosec} 2\theta = -3$ only. If other trigonometric ratios were considered and erroneous answers obtained, then this was penalised in the last accuracy mark. Most candidates recognised that $\operatorname{cosec} 2\theta = -3$ and solved this accordingly. The main problem that some candidates had was with premature rounding when dealing with 2θ, this leading to inaccurate answers of 99.8° and 279.8°. Candidates need to be working to greater accuracy than that required by the final answer.

Question 6

(a) (i) Most candidates realised that they had to find the area under the velocity–time graph. There were errors in some of the calculations seen and occasionally ‘missing areas’.

(ii) Many correct answers were seen, with candidates correctly finding the gradient of the appropriate part of the velocity-time graph. Candidates with an incorrect answer to **part (i)** were able to obtain a method mark for correct use of their velocity.

(b) (i) Many completely correct solutions were seen, with candidates recognising the need to differentiate a product and make use of the chain rule. Errors usually involved the chain rule with missing terms of '2' or a missing index number. Again, it is not necessary to give a decimal answer as well as an exact answer.

(ii) Most candidates were able to state in some form or other that the velocity was always positive when $t > 0$, or that the velocity was never zero for $t > 0$. It was also acceptable to state that the acceleration was always positive for $t > 0$. Some candidates however thought, incorrectly, that because the particle was travelling in a straight line, its direction could not be changed.

Question 7

(a) Many correct solutions were seen. Very few candidates were unable to integrate the given function using the reverse chain rule and most were able to apply the limits correctly. For the final answer, it was expected that $\sqrt[3]{8}$ be evaluated as 2. Some candidates made copying errors with the power of $\frac{1}{3}$, highlighting the need to be careful and to also check any answers carefully. Any correct exact form was acceptable although it was expected that the denominators of fractions did not contain fractions.

(b) Most candidates recognised that $\int \frac{4}{2x+1}\,dx$ was a function of $\ln(2x+1)$, with the occasional error in the coefficient of $\ln(2x+1)$. Fewer candidates recognised that $\int \frac{8}{(2x+1)^2}\,dx$ was a function of $\frac{1}{2x+1}$ with the occasional error in the coefficient of $\frac{1}{2x+1}$. Provided the integral was in the required form, candidates were usually able to apply limits correctly and obtain accuracy marks where appropriate.

Question 8

(a) (i) Very few incorrect answers were seen.

(ii) Candidates are advised to write down their thought processes carefully when dealing with a question of this type. Many did just that, stating the cases they were considering, for example, starting with a 6 or an 8. Candidates are also advised to work out any permutations and combinations as they work through the question as correct work is sometimes difficult to identify when left in non-numerical form until the end of the question. Many correct solutions were seen, but in some cases, it was clear that candidates had forgotten to consider the number '9' when dealing with their strategies, even though they had correctly considered 9 numbers in **part (i)**.

(b) Candidates who thought clearly about the different scenarios and wrote them down first tended to have more success. The mark allocation should guide candidates and suggests that more than one calculation is required. Of the candidates that completed the solution correctly, most opted for the first method in the mark scheme. An error in one case only meant that a candidate could obtain a method mark. The alternative method was less popular and less successful, with candidates having to perform an extra step in their calculations. Candidates needed to have at least two correct cases when attempting this method in order to obtain at least one method mark. Again, candidates are also advised to work out any permutations and combinations as they work through the question as correct work is sometimes difficult to identify when left in non-numerical form until the end of the question.

Question 9

(a) (i) Most candidates identified the first term and the common difference correctly and were able to form a correct equation using the sum of an arithmetic progression. The process of simplification of this equation was easier if candidates wrote the common difference as $3\lg\theta$ rather than $\lg\theta^3$. Candidates who did this were usually more successful at obtaining the correct resulting quadratic equation. Those who equated indices tended to make more sign errors. Many correct solutions were seen although it should be noted that a candidate with an incorrect quadratic equation would not obtain a method mark for the solution of this equation unless full working was seen. It is preferable to use a calculator for checking purposes only. Some candidates identified that as $\lg\theta$ was a common factor throughout, they could deal with an equivalent arithmetic progression with a common difference of 3, a first term of 2 and a sum of 4732. This was an acceptable method.

(ii) Many correct answers were seen. It should be noted that this part was not dependent on **part (i)** and many candidates who did not complete **part (i)** successfully were able to obtain the mark in this part.

(b) (i) Most candidates correctly identified $\frac{1}{3}$ as the common ratio. To obtain both marks it was essential that candidates state a correct reason for their answer of there being a sum to infinity, for example $|r| < 1$, $\left|\frac{1}{3}\right| < 1$, $-1 < r < 1$ or $-1 < \frac{1}{3} < 1$.

(ii) Most candidates were able to write down the correct unsimplified *n*th term of $\left(\lg\phi^3\right)\left(\frac{1}{3}\right)^{n-1}$.

Although many were able to simplify correctly to obtain the required answer, some candidates were unable to manipulate the indices correctly.

(iii) Candidates with a correct answer to **part (ii)** were usually able to obtain the correct answer of 10. Some candidates chose to go back and use their unsimplified *n*th term and evaluate the value of ϕ correctly.

(c) Provided the answers to **parts (a)** and **(b)** were equated and then like vectors equated, most candidates were able to obtain at least two method marks. Sign errors and arithmetic slips meant that few correct solutions were seen.

(d) Very few candidates were able to obtain the accuracy mark associated with this part of the question due to previous errors.

ADDITIONAL MATHEMATICS

Paper 0606/22
Paper 22

Key messages

It is important that candidates read each question carefully, interpreting any key statements and using all the information given.

Candidates also need to show full method so that marks can be awarded should an error be made in the accuracy of a solution.

Attention should be given to the instructions on the front page of the examination paper. Candidates should ensure that their answers are given to at least the accuracy required in a question. When no particular accuracy is asked for, candidates should ensure that they follow the instructions on the front page.

When solving trigonometric equations with angles in radians, candidates should work in radians rather than converting from degrees to radians in the final step. Converting from degrees often introduces an approximation error. It is also important that candidates check their calculator is in the appropriate mode at the start of each question involving angles and trigonometric expressions.

Candidates should also make sure that they refer to the list of formulae given on page 2 of the examination paper when needed.

General comments

Most candidates were well-prepared for this examination. They were able to successfully recall and apply techniques in order to solve problems. Many candidates offered complete and correct solutions, with all necessary method shown. Most candidates attempted to answer all questions.

Candidates needed to state expressions unambiguously. Brackets should be used to ensure that terms cannot be misinterpreted. This was required, for example, in **Question 4(b)(i) and Question 5** in this examination.

It was expected that candidates would have a good understanding of how to use similarity and ratio. Many candidates demonstrated this in **Question 2** and **Question 3(a)** respectively. It was also expected that candidates would be aware that, when stating a numerical answer as a fraction, the denominator of the fraction given as the final answer should not be negative. When the denominator of a fraction was negative, it was considered that the fraction was still a calculation rather than a value. This was necessary in **Question 6** and **Question 7(a)** in this examination.

Many candidates presented their work in a clear and logical manner. Some candidates sensibly used additional paper and neatly indicated the number of each question on the additional pages. It was helpful when candidates who did this added a comment in the answer space in their main script to indicate that their answer was written, or continued, elsewhere. Many candidates used sheets of additional paper headed Rough Work. Candidates should be aware that rough jottings written in various orientations, haphazardly on the page are difficult to attribute. If work is written on additional sheets of paper, even if it is considered by the candidate to be rough work, it should be numbered and written neatly so that it can be marked as part of the solution if needed.

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

Comments on specific questions

Question 1

(a) The majority of candidates were able to solve the equation successfully. Most of these candidates formed a pair of linear equations rather than a quadratic equation. A few candidates discarded the negative solution. This was not condoned. A small number of candidates applied an incorrect order of operations and attempted to solve $2|8 - 4x| + 5 = \pm 25$.

(b) Again, candidates performed well in this part of the question with a good proportion giving fully correct solutions. Some candidates lost the final mark, often from offering a final answer of $1 < x < 2.5$. Candidates who used a sketch graph to confirm the solution set were more commonly correct. Algebraic manipulation skills were usually good with very few candidates making slips when rearranging the inequality in the first step of the solution. A small number of candidates made sign errors when solving the quadratic equation or inequality to find the critical values.

Question 2

Many candidates were able to use their knowledge of similar triangles successfully in this question. Most candidates demonstrated sufficient method to indicate they had not used a calculator. Many candidates offered a full and detailed solution using simple scale factors, rationalising and simplifying correctly. Some candidates formed and solved simultaneous equations in a and b. Many of these candidates were also successful, although some did not show sufficient detail of the solving of their equations to earn full credit. A few candidates made sign slips in the final step. Some candidates needed to take a little more care when expanding brackets. Candidates who chose to work with the areas of the triangles were rarely successful and usually did not use the correct area factor or did not show enough detail. Candidates who worked with decimals needed to read the question more carefully.

Question 3

(a) This part of the question was well answered with the majority of candidates finding the correct, simplified vector. A few candidates earned a mark for a correct, unsimplified vector. Those candidates who offered an incorrect vector commonly made a direction error or misinterpreted the ratio as $AP : AB = 1 : 3$.

(b) Candidates found this part of the question to be more challenging. Good responses began by correctly finding the unit vectors in each direction and then multiplying these by the given magnitudes. Most then stated the correct vector **q** + **r**, found its magnitude and formed the correct unit vector. A few candidates made an arithmetic slip when forming **q** + **r**. A few other candidates stated the correct vector **q** + **r** but did not continue to find the unit vector. These candidates may have improved if they had reread the question before progressing to the next question. Weaker responses often offered either **q** + **r** as the sum of the given direction vectors, $\begin{pmatrix}1\\2\end{pmatrix}$, and ignored the given magnitudes or multiplied the given direction vectors by $12\sqrt{5}, \dfrac{1}{12\sqrt{5}}, 15\sqrt{2}$ or $\dfrac{1}{15\sqrt{2}}$ and then attempted to add these.

Question 4

(a) (i) Candidates found this question to be reasonably challenging. Most candidates were able to differentiate $\cos x$ correctly. A small number of candidates were able to differentiate $3\sin^2 x$ correctly. Many candidates gave $6\cos x$ as the derivative of this term. A few candidates rewrote $3\sin^2 x$ as $3 - 3\cos^2 x$ before they differentiated. This was not necessary and did not make the solution simpler. A good proportion of candidates with the correct derivative, or a derivative of acceptable structure, went on to multiply by $\dfrac{\cos x}{\sin x}$ or to replace $\dfrac{\sin x}{\tan x}$ by $\cos x$. Most of these correctly derived $3(1 + \cos^2 x)$. A few candidates did not show sufficient detail or made a slip in working and did not earn the final mark. In weaker responses, candidates misinterpreted $y + \cot x \dfrac{dy}{dx}$ and also attempted to differentiate $\cot x$. A number of candidates stated $k = 3$ following incorrect working.

(ii) Candidates with fully correct solutions to **part (a)(i)** usually gave correct solutions to this part. Occasionally, some solutions were omitted, commonly the negative values or the values derived from $\cos^{-1}\left(-\sqrt{\frac{1}{3}}\right)$. Candidates who found angles in degrees first and then converted to radians often made premature approximation errors. This was not condoned and is not a recommended method of solution for this reason. Candidates sometimes made other rounding errors. They need to be aware that they should write down an accurate value to more than 3 significant figures before they round their final answer. This ensures that marks can still be given should rounding errors then be made. Candidates who stated the answer $k = 3$ following incorrect working in **part (a)(i)** were not given full credit in this part. Candidates who used values of k that gave negative values for $\cos^2 x$ should have returned to their solution to **part (a)(i)** to find any errors they had made. Commonly, however, candidates who used values such as $k = 6$, simply rewrote the $\sqrt{-\frac{1}{3}}$ that resulted as $-\sqrt{\frac{1}{3}}$.

(b) (i) A fair number of fully correct derivatives were seen. Some candidates omitted to include brackets where they were necessary writing, for example, $1-\frac{1}{2\sqrt{x}}\sec^2\left(x-\sqrt{x}\right)$. A few candidates offered a derivative that was a product including $\sec^2\left(x-\sqrt{x}\right)$ but were unable to differentiate $x-\sqrt{x}$ correctly. Commonly, an answer of $-\frac{1}{2}x^{-\frac{1}{2}}\sec^2\left(x-\sqrt{x}\right)$ was offered in these cases. Some candidates offered $\left(1-\frac{1}{2\sqrt{x}}\right)\sec^2 x\left(x-\sqrt{x}\right)$. The inclusion of the extra and incorrect x was not condoned. Weaker responses typically rewrote $\tan\left(x-\sqrt{x}\right)$ as $\tan x-\tan\sqrt{x}$ before differentiating or treated $\tan\left(x-\sqrt{x}\right)$ as a product of 'tan' and '$x-\sqrt{x}$' and applied the product rule.

(ii) Credit in this part of the question depended on a correct solution to **part (b)(i)**. A small number of candidates gave fully correct solutions, including the constant of integration, which needed to be included for full credit. A reasonable proportion of candidates were able to manipulate the expression they had found, or the expression they were integrating in this part, to a form from which the answer to this part could be deduced. This was a necessary part of the solution. Many of these candidates went on to offer an answer of $2\tan\left(x-\sqrt{x}\right)$ with no constant of integration. Some candidates made a slip in thinking and gave the answer $\frac{1}{2}\tan\left(x-\sqrt{x}\right)$ following otherwise correct work. In the weakest responses, candidates made no attempt to link their solution to **part (b)(i)**.

Question 5

The majority of candidates followed the instruction to differentiate. Most candidates were able to differentiate $\ln 3x$ as $\frac{3}{3x}$, although on occasion one of the 3s was omitted. The majority of candidates used a correct structure for the quotient rule. Occasionally the product rule was attempted. This was acceptable providing candidates used appropriate functions. Some candidates attempted to simplify their derivative prior to substituting $x = 1$. This sometimes resulted in errors and loss of accuracy. When the derivative was not shown correctly at any stage, evidence of substitution of 1 into the candidate's derivative needed to be seen. Candidates should be aware that this is a key step in the method and should be shown. Some candidates were clearly using their calculator to find $\left.\frac{\mathrm{d}}{\mathrm{d}x}\left(\frac{x}{\ln 3x}\right)\right|_{x=1}$ as the correct answer was sometimes seen following an incorrect derivative. This was not accepted. A few candidates confused $(\ln 3x)^2$ with $\ln 3x^2$ at some stage. Weaker responses sometimes used of $1+h$ instead of 1 or instead of h or applied the product rule to inappropriate functions.

Question 6

Candidates generally found this question to be straightforward. A good number correctly integrated e^{2-4x} and went on to show the correct substitution of the limits and the correct, exact answer. A few candidates did not give the answer in simplified exact form at any point, giving only a decimal answer. Some candidates offered the integral as $\frac{1}{4}e^{2-4x}$ or similar. A small number of candidates differentiated and this was not condoned. Most candidates attempted the correct strategy of integrating e^{2-4x} between the limits –0.25 and 0.5. A few candidates, however, included an extra area which they added or subtracted. This was also not condoned.

Question 7

(a) The majority of candidates were able to earn the first mark for the elimination of one unknown. Almost all candidates chose to eliminate x. Most candidates rearranged correctly to form a correct three-term quadratic equation in x^2. Some candidates used a substitution such as $u = x^2$ with great success. Candidates needed to choose a letter for this purpose with care as, those who chose to use $x = x^2$ or $y = x^2$ for their substituted unknown, often confused themselves. A good number of candidates stated $x^2 = 6$ and many discarded the negative value at or just before this point in their solution. A small number of candidates incorrectly rewrote $\sqrt{-\frac{1}{2}}$ as $-\sqrt{\frac{1}{2}}$. Candidates who gave decimal values for their coordinates sometimes rounded the y-coordinates to 2 decimal places rather than 3 significant figures. Weaker responses often either omitted to multiply all terms by x^2 when simplifying or offered an equation that had not been rearranged to a form from which solutions could be found, such as $2x^2(2x^2 - 11) = 12$. Commonly the solution then continued with $2x^2 = 12$ and on occasion $2x^2 - 11 = 0$. Other weak responses offered more than two pairs of coordinates or only one pair of coordinates.

(b) This part of the question required a length to be found and given in a specific, exact form. Some candidates were able to do this successfully. Other candidates gave an exact answer in a different form, such as $\sqrt{\frac{80}{3}}$. As calculator use was allowed in this question, these candidates would most likely have improved if they had used their calculator appropriately to complete the solution.

Weaker responses typically indicated an incorrect formula for finding the length required, commonly $\sqrt{(x_1 - x_2)^2 - (y_1 - y_2)^2}$ was attempted.

Question 8

(a) Almost all candidates attempted to plot the correct points and many were able to draw a sufficiently accurate line.

(b) A good proportion of candidates used the correct linear relationship and found the values of A and b to the required accuracy. A few candidates omitted to round the values as requested. Some candidates made errors when reading points from their line. Other candidates used base e rather than base 10 for their logarithms, but this was not common. A few other candidates confused A and b but this was also not common. Weaker responses typically did not use the graph in any way and candidates used the exponential equation to find values of A and b. This meant they could gain little credit.

(c) Again a good proportion of candidates were able to find an acceptable value of x. Some used the graph, others used either the linear or exponential form of the equation. All these methods were acceptable. A few candidates arrived at values of x that clearly did not fit the data and these may have improved if they had considered the graph or the original set of data given.

Question 9

(a) Candidates found this part of the question more challenging than **part (b)**. Some candidates were able to form a correct expression for the perimeter of the logo and simplify it correctly. A reasonable number of these formed a correct expression for the area and simplified it to the given answer, showing sufficient detail which included the expansion of $(16 - 4.5x)^2$. Candidates needed to take care in this as the required expression for the area was given in the question. Common errors made when finding the perimeter were to double all the radii, to use $ED = 2$, to only sum the arc lengths or to omit one or more length. Common errors when finding the area were to omit to halve $r^2\theta$ in all three cases or to omit to square $16 - 4.5x$. Candidates working with incorrect expressions for the area may have improved if they had checked their expression for the perimeter more carefully. Some candidates were clearly trying to adjust the perimeter they had found to 'fit' the answer rather than find their error. In their attempts to do this, they usually introduced further errors.

(b) Candidates were much more confident in this part of the question and many earned all the marks available. Almost all candidates correctly differentiated the expression for A with respect to x. Most candidates were able to equate this to 0 and solve to find the correct value of x. A small number of candidates made some slips in solving leading to inaccurate values of x. A few candidates omitted to find the minimum possible area of the logo although most candidates did attempt to find this area, and many of these did so correctly. Those few candidates who made slips in finding the area usually miscopied expressions or values.

Question 10

(a) A reasonable number of candidates offered fully correct solutions. Most of these proceeded as expected and stated equations using the information given and the coefficients of the first and second terms of the expansion. Most candidates knew or found ${}^{n}\mathrm{C}_1$ to be n. Those who did not were unable to make progress. As the relationship that they needed to demonstrate did not involve b, it was expected that candidates would eliminate b as a second step and then simplify the terms in a which remained. This approach was the simplest method of showing the required result. Again, candidates needed to take care not to make slips in their working, and show sufficient detail at each stage, as the answer had been given. A few candidates used alternative approaches, involving many more steps before the elimination of b, with more varied success. Some candidates made method errors when eliminating b. A common error was to replace a^{n-1} with b^{4-1}. Many candidates stated that $a = b$ or that $n = 4$ in this part and made no progress. Some candidates verified that $n = 12$ and $a = 4$ satisfied the given equation. This was not credited.

(b) Candidates found this part of the question the most challenging. A small number of neat, concise and fully correct solutions to the problem were seen. The most successful and straightforward approach involved forming another equation using the third term of the expansion and the information given. It was necessary for candidates to know or derive ${}^{n}\mathrm{C}_2$ to be $\frac{n(n-1)}{2}$ in this equation. Some candidates were unable to convert ${}^{n}\mathrm{C}_2$ as needed and made no progress. The simplest next step was to eliminate b and simplify that which remained. Some candidates did not manage to eliminate b successfully. Other candidates made slips when simplifying what remained. The result shown to be true in **part (a)** could then be used to form an equation in terms of n only. This could then be simplified and solved to find n. The values of a and b followed. Other methods were attempted and, although some were successful, many were less successful and much more complicated. The candidates who made no progress with **part (a)** also made no progress in this part of the question. Some responses were poorly presented and difficult to credit.

Question 11

This question assessed candidates' understanding of connected rates of change. A good number of candidates demonstrated excellent problem-solving skills in this question and earned full marks. Candidates needed to form a correct expression for the surface area in terms of r only. Many candidates did this. They then needed to recognise that $\frac{\mathrm{d}S}{\mathrm{d}r} = 6$ and equate this to $16\pi r$. Candidates who correctly differentiated their expression for the surface area could be credited for this step providing their expression for the surface area was a multiple of πr^2. A few candidates differentiated their expression for S in terms of r but labelled the derivative $\frac{\mathrm{d}S}{\mathrm{d}t}$. This usually resulted in $16\pi r = 6\frac{\mathrm{d}r}{\mathrm{d}t}$ and an attempt to find an expression for $\frac{\mathrm{d}r}{\mathrm{d}t}$. A recovery from this was rarely seen. Some candidates correctly stated $r = \frac{6}{16\pi}$ but then incorrectly simplified this as

$\frac{3}{8}\pi$ and so lost the final mark for an incorrect value of *S*. A few candidates made a premature approximation error, using a value of *r* that did not give a sufficiently accurate decimal value of *S*. In the weakest responses, candidates were unable to correctly state an expression for *S* that was dimensionally correct. Commonly the volume was stated, rather than the curved surface area.