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Examiners' report

A LEVEL

FURTHER MATHEMATICS A

OCR Level 3 Advanced GCE in Further Mathematics A

H245

For first teaching in 2017

Y541/01 Summer 2025 series

Version 1

Contents

Introduction

Our examiners' reports are produced to offer constructive feedback on candidates' performance in the examinations. They provide useful guidance for future candidates.

The reports will include a general commentary on candidates' performance, identify technical aspects examined in the questions and highlight good performance and where performance could be improved. A selection of candidate responses is also provided. The reports will also explain aspects which caused difficulty and why the difficulties arose, whether through a lack of knowledge, poor examination technique, or any other identifiable and explainable reason.

Where overall performance on a question/question part was considered good, with no particular areas to highlight, these questions have not been included in the report.

A full copy of the question paper and the mark scheme can be downloaded from Teach Cambridge.

Paper Y541 series overview

Many examples of excellent candidate work were seen across this paper, with most candidates making a good attempt at the majority of questions. Candidates should be encouraged to try answering the most challenging questions as candidates were often able to gain the early marks for some initial setup (e.g. noting the approximations to use in Question 10 (c)) even if they were not able to complete a full answer.

Candidates who did well on this paper generally:	Candidates who did less well on this paper generally:
• worked carefully and precisely across all questions • followed instructions such as 'show detailed reasoning' and included sufficient working to demonstrate their understanding of a method, even when using a calculator to evaluate • demonstrated understanding across the breadth of the specification for this paper.	• included partially developed solutions • did not fully address what each question was requesting – for instance, not going on to give a conclusion or explaining their answer where required • relied on a calculator without demonstrating understanding or justification in 'determine' or 'detailed reasoning' questions – meaning that their answers could not receive full credit, even if the final value were correct.

Question 1

1 In this question you must show detailed reasoning.

Vectors **a** and **b** are given by $\mathbf{a} = \begin{pmatrix} 2 \\ -4 \\ 3 \end{pmatrix}$ and $\mathbf{b} = \begin{pmatrix} -1 \\ 3 \\ -2 \end{pmatrix}$.

Determine, in either order

- **a.b**
- **a**×**b**. **[3]**

Most candidates answered this part very well, with the majority giving correct answers for both the required products. The question had the DR instruction so required candidates to show the method used to calculate both the dot and cross products, in order to demonstrate their understanding. Some candidates did not gain marks because they did not show any working for either product (gaining at most B1 under the special case). The most common error seen was sign errors in the calculations for the terms of the cross product.

OCR support

This OCR blog discusses the instruction 'in this question you must show detailed reasoning' and gives some further detail as to what candidates need to demonstrate to show their understanding.

Question 2 (a)

2 You are given that $-7-5\mathrm{i}$ is one root of the equation $x^3+10x^2+18x-296=0$.

(a) Write down another complex root of the equation $x^3+10x^2+18x-296=0$. **[1]**

Almost all candidates gave the correct answer here.

Question 2 (b)

(b) Using your answer to part **(a)**, express $x^3 + 10x^2 + 18x - 296$ as a product of a real linear factor and a real quadratic factor. **[3]**

Many candidates gave the correct factorisation here. The question gave a very specific instruction 'using your answer to part (a)' – which, in effect, meant that candidates needed use the given complex conjugate pair to establish a factorisation. Some candidates chose to go (as shown in the alternative method) via the product of roots, but the most common method seen was to multiply the factors arising from the known roots together to obtain a quadratic and then deduce the remaining linear factor. Some candidates (typically showing no working at all) did not show any evidence that they had used their answer to part (a) and therefore could score at most B1 under the special case. Candidates should remember to read the whole instruction given in a question carefully. Candidates who gave three linear factors (for the one real and two complex roots) could not score full marks unless they had also found the quadratic factor with real coefficients elsewhere in their working.

Question 3 (a)

3 Matrices **A** and **B** are given by $\mathbf{A} = \begin{pmatrix} 1 & -3 \\ 4 & 8 \end{pmatrix}$ and $\mathbf{B} = \begin{pmatrix} -3 & -3 \\ 1 & 2 \end{pmatrix}$.

(a) Find the matrix **AB**. **[1]**

The majority of candidates gave the correct answer here.

Question 3 (b)

(b) Verify that $\det(\mathbf{AB}) = \det(\mathbf{A}) \times \det(\mathbf{B})$. **[2]**

Most candidates scored both marks here, by correctly computing all three required determinants and verifying the required fact. A few candidates did not give a sufficient argument to show that they had verified the required fact, even though on this occasion the mark scheme allowed candidates to simply write $20 \times (-3) = -60$. Candidates reminded to make sure that they give a complete argument, even in low-tariff questions such as this. The conclusion (although mathematically trivial) is important so that candidates demonstrate clearly that they understand what they have shown, and how they have shown it.

Question 3 (c)

(c) Use matrices **A** and **B** to demonstrate that matrix multiplication is **not** commutative. **[2]**

The majority of candidates recognised that they needed to first compute **BA** here, and most did this correctly although, for those who did not, this undermined their demonstration leading to a mark of 0 in this part. As in part (b), candidates needed to clearly state a conclusion that showed what their working demonstrates, e.g. $\mathbf{AB} \neq \mathbf{BA}$. Most candidates did this adequately to score the second B mark, but some did not. The mark scheme allowed candidates to demonstrate non-commutativity through using a single element (correctly computed) but this was hardly seen.

Question 3 (d)

The transformation represented by matrix **A** is denoted by T.

(d) Show that the point $(2, -5)$ is **not** an invariant point under T. **[2]**

Most candidates appeared to know what was required here and correctly completed the required pre-multiplication of the vector by the matrix. However, in this part (compared to (b) and (c)) slightly more candidates did not give an appropriate conclusion, which meant that they did not score the second mark. Candidates needed to state that the point given by the vector they had found was different from the initial point (and hence, it is not invariant under T).

Question 3 (e)

(e) Find the matrix which represents the inverse transformation of T. **[2]**

Most candidates scored both marks here. The first mark was available for evidence that candidates understood that the matrix corresponding to the inverse transformation was the inverse of the matrix (and could be given for candidates who stated this fact or who made a clear attempt at an inverse matrix). The second was for having the required inverse fully correct, following through their determinant from part (b).

Question 4

4 In this question you must show detailed reasoning.

Determine the sum of all cube numbers from 216 to 512 000 inclusive. **[4]**

Most candidates answered this question well, correctly deducing the right limits and making correct use of the formula (which is given in the formula booklet) for the sum of cubes. This question had a DR instruction, indicating to candidates that they needed to show a complete method, with (ideally) every step of their working. This is not a restriction on the use of a calculator (e.g. to evaluate the final answer) but it means that solutions that did not show a full method could not score full marks – and the answer alone, without working, was scored 0. This was almost never seen. Many candidates correctly deduced the need to use an upper limit of 80 and applied the appropriate formula. A few candidates attempted to use 512000 as the upper limit (often accompanied by a subtracted term with the upper limit of 215 – which could score M1). Candidates who used their calculator to compute the entire sum in one step (without showing explicit use of the subtracted terms) could not score full marks.

The alternative method using composite sums was hardly seen.

Exemplar 1

4

$\sqrt[3]{216} = 6 \qquad \sqrt[3]{512000} = 10\sqrt[3]{512} = 80$

$\sum_{r=6}^{r=80} r^3 = \sum_{r=1}^{80} r^3 - \sum_{r=1}^{5} r^3$

$= \frac{1}{4} \times (80)^2(81)^2 - \frac{1}{4} \times 5^2(6)^2$

$= \cancel{10497375}$

$10497600 - 225$

$= 10497375$

This is a good example of a fully correct solution to Question 4, showing all of the required steps in the working and demonstrating good understanding and application of the method to reach the correct answer. 4/4

Question 5 (a)

5 In this question you must show detailed reasoning.

(a) Use an algebraic method to determine the two square roots of $-3+(4\sqrt{7})\,\mathrm{i}$.

Give your answers in the form $a+b\mathrm{i}$ where a and b are exact. **[5]**

This part was generally well answered. The question again had the DR requirement and specified that candidates should 'use an algebraic method' – this meant that direct computation (e.g. from a calculator or via polar form and De Moivre) was not sufficient. Most candidates were able to set up an appropriate pair of equations in a and b (while candidates were not required to use this notation, it was indicated in the question) and combine these to reach an appropriate quartic. Some candidates made an error in their elimination, typically resulting in a sign error in their quartic which often resulted in the values for a and b being swapped in their final answers.

Most candidates who reached a quartic solved it correctly, although candidates should bear in mind that, under a DR instruction, a full method for reducing to a quadratic and solving analytically should be shown. Of these, candidates typically identified the right values (because *a* and *b* are both real). However, many candidates did not pair these values correctly – often assuming that the result would be a conjugate pair and giving $2 \pm \sqrt{7}i$ which was not correct for the final mark.

Candidates are reminded to follow the instructions in the question carefully (while there are other ways to calculate the square roots of a complex number, this question was specifically asking for an algebraic method), show all the steps in their working, and to check their final answers carefully.

Exemplar 2

5(a)

Let the roots be denoted as

$(a+bi)$ where $a, b \in \mathbb{R}$

$\Rightarrow (a+bi)^2 = -3+4\sqrt{7}\,i$

$a^2 + 2abi - b^2 = -3 + 4\sqrt{7}\,i$

Equate real and imaginary parts

$a^2 - b^2 = -3 \qquad a^2 = b^2 - 3$

$2ab = 4\sqrt{7}$

$ab = 2\sqrt{7}$

$b = \dfrac{2\sqrt{7}}{a}$

$a^2 - \dfrac{28}{a^2} = -3 \qquad a^4 + 3a^2 - 28 = 0$

let $a^2 = u$

$u^2 + 3u - 28 = 0$

$\cancel{u = \dfrac{-3 \pm \sqrt{57}}{2}}$

$\cancel{\therefore a = \pm\sqrt{\dfrac{-3\pm\sqrt{37}}{2}}}$

$(u+7)(u-4) = 0$

$u = -7$ or $u = 4$

As $a^2 = u$, $u \geq 0$ if $a \in \mathbb{R}$ $\therefore$

$u = 4 \quad a = \pm 2$

$a = \pm 2$

$\therefore b = \dfrac{2\sqrt{7}}{\pm 2} = \pm\sqrt{7}$

when $a = 2$, $b = \sqrt{7}$

when $a = -2$, $b = -\sqrt{7}$

$\therefore \boxed{\begin{array}{c} 2+\sqrt{7}\,i \\ -2-\sqrt{7}\,i \end{array}}$

This is an excellent example of a fully correct solution, showing good algebraic working – including an appropriate explanation for discounting the other possible roots to the quartic in *u*. The correct square roots are seen assembled at the end, clear following from correct work. This response was given 5 marks.

Question 5 (b)

(b) State the relationship between the two arguments of the two square roots found in part **(a)**. **[1]**

Around half of candidates answered this part correctly, with some candidates going further than the explanation required and giving an equation which related the two arguments. Many candidates. perhaps as a result of the same misconception identified in (a), assumed that the two square roots would be conjugates and so gave answers such as 'they are opposite' or 'same magnitude, different sign' which were not correct. The question specified a relationship about the arguments, so other connections between the two square roots (e.g. 'reflection in…') were not sufficient to score the mark here.

Question 6 (a)

6 One of the regions bounded by two polar curves, C_1 and C_2, is used to model the face of a flat earring.

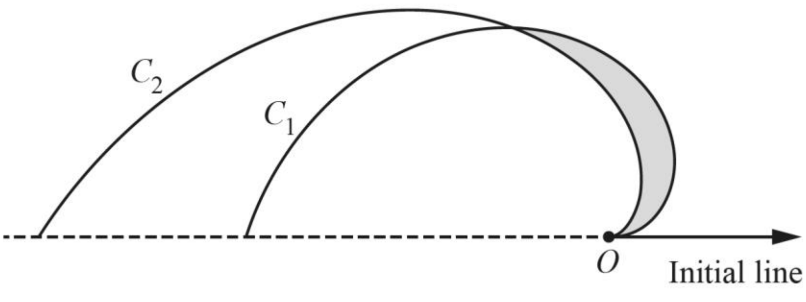
The polar equations of C_1 and C_2 are

$C_1: r = 2\theta$

$C_2: r = \theta^2$

where $0 \leqslant \theta \leqslant \pi$.

The curves C_1 and C_2 are shown in the diagram below with the region used to model the earring shaded.



You are given that C_1 and C_2 intersect at the pole O.

(a) Find the other point of intersection of C_1 and C_2. Give your answer in polar coordinates. **[2]**

Almost all candidates were able to compute the required value $\theta = 2$ corresponding to the point of intersection. Some candidates did not discount the value $\theta = 0$ which, on this occasion, the mark scheme allowed – even though the question specified 'the other point of intersection'. A small number of candidates didn't go on to find the corresponding value of $r = 4$, or gave their polar coordinates the wrong way around which meant that the second mark could not be awarded.

Question 6 (b)

(b) In this question you must show detailed reasoning.

Determine the area of the face of the earring. **[4]**

Most candidates made a good start in this part, correctly recognising the limits and form of the integral they needed to evaluate. The majority of candidate responses showed a clear, full method here – which was appropriate to the DR instruction. Some candidates made errors in the computation (often when applying the limits) or had their terms the wrong way around – resulting in a correct, but negative answer (which could be recovered for full marks if the answer were given as the required positive value). A number of candidates subtracted the two curves before squaring, i.e. attempting $\int (2\theta - \theta^2)^2$ which was not correct.

Question 7 (a)

7 In this question you must show detailed reasoning.

(a) Express $\dfrac{-4x^2+5x-17}{x^3-x^2+3x-3}$ in partial fractions. **[6]**

Most candidates correctly factorised the denominator and identified the two (one linear, one quadratic) denominators for the partial fractions form, scoring M1A1. This question also had the DR requirement, so candidates needed to proceed with a full method to reach the correct answer, with correct working shown. Many fully correct answers were seen, although some candidates took a 'shortcut' by not showing the likely existence of an *x* term in the numerator of the second term (*B* in the mark scheme).

Question 7 (b)

(b) Hence determine the exact value of $\displaystyle\int_{\sqrt{3}}^{3} \frac{-4x^2+5x-17}{x^3-x^2+3x-3}\,\mathrm{d}x$. **[4]**

This part was generally well answered, with almost all candidates showing clear working in accordance with the DR instruction. Most candidates correctly identified the appropriate integral for both of their partial fractions (in ln and tan-1 respectively) and went on to substitute the given limits correctly. A small number of candidates did not fully simplify their answer, e.g. by not combining two separate ln terms, or made an error in doing so, meaning that they could not be awarded the final A mark.

Question 8 (a)

8 A function $f(x)$ is defined by $f(x) = x\sinh 2x$.

(a) Prove by induction that $\dfrac{d^{2n} f}{dx^{2n}} = 4^n(x\sinh 2x + n\cosh 2x)$ for $n \geqslant 0$ where $\dfrac{d^0 f}{dx^0}$ is defined as being equal to $f(x)$. **[6]**

Many candidates made a good attempt at this induction question, with the majority demonstrating understanding of how to correctly set out the steps needed.

For the induction setup overall, most candidates attempted to give the right basis case for $n = 0$ (as $n \geq 0$ was specified in the question). Some candidates gave the correct working here, but did not conclude this case – this mark could be recovered if the conclusion (e.g. 'true for $n = 0$') was included in their overall conclusion. A small number of candidates gave the base case for $n = 1$, which did not score the B mark, but the final conclusion mark could be recovered if they gave their overall conclusion correctly in terms of $n = 1$.

For the intermediate working, candidates needed to make the inductive assumption and differentiate twice to show that the required form was reached for $n = k + 1$. This work was generally done well, although some candidates appeared to have tried to reverse-engineer from the conclusion and ended up with inconsistent working. Candidates are of course encouraged to understand 'where they need to get to' (and many wrote this down, identified as 'target' or similar – which is absolutely permissible), but if candidates are using that conclusion to determine their intermediate steps then they should make sure that all of these steps are correct and consistent so that the proof remains valid.

A few candidates missed the need to differentiate twice, perhaps confusing $2(k + 1) = 2k + 2$. Some candidates (perhaps misunderstanding the standard, notation used) attempted to multiply by the second derivative rather than differentiating twice.

Most candidates appeared to understand what is needed in a conclusion to the induction process, although a few did not show the importance of the implication $n = k \Rightarrow n = k + 1$ – for instance stating 'true for $n = k$ and $n = k + 1$' which was not sufficient to score the final mark.

Question 8 (b)

(b) Using the formula given in part **(a)**, determine the exact value of the coefficient of x^8 in the Maclaurin series for $x\sinh 2x$. **[3]**

Most candidates made a good attempt at this part, typically scoring the first mark for selecting an appropriate derivative from the form in part (a) and substituting $x = 0$. Some candidates went on to evaluate this incorrectly (e.g. assuming that $4\cosh 0 = 0$) but this mark could still be awarded for a correct form. Some candidates identified this result (typically 1024) as their final answer, which was not correct. However, many went on to use the correct form for the Maclaurin series term to find the required answer. Candidates needed to give this in an exact form, although the scheme on this occasion allowed answers that were the whole 'term' i.e. $\frac{8}{315}x^8$ rather than just the coefficient $\frac{8}{315}$. The question was 'determine' so candidates needed to provide justification for their answer, by demonstrating correct working leading to their answer - especially because of the relationship with part (c) here.

Question 8 (c)

(c) Use the Maclaurin series for e^x to verify your answer to part **(b)**. **[3]**

This part was less well answered than (b), with many candidates scoring only the first B1. The minority of candidates who correctly used the Maclaurin series for e^x often went on to receive all 3 marks for correct work and verification. Notice that parts (b) and (c) were, in effect, asking candidates to find the same result via two different routes. This provided candidates with a useful (and explicitly requested) opportunity to verify their answers were correct. Candidates should be reminded to make sure that they have provided sufficient working in each part to show that they have found the result twice and demonstrated understanding of both routes. In other words, simply writing down the same answer in both parts would not score.

Question 9 (a)

9 When light hits a certain photo-sensitive cell, at time $t = 0$, there is an electrical response in the cell which is denoted by $y(t)$ where both y and t are measured in suitable units. A student wishes to model this response, y.

In an attempt to model y, the student sets up the differential equation

$$\frac{d^2y}{dt^2} + 6\frac{dy}{dt} + 9y = 10e^{-3t} \quad (*)$$

which is subject to the following conditions.

- $y = 0$ when $t = 5$
- $y \geqslant 0$ for all $t \geqslant 0$

(a) By substituting into a suitable differential equation, **verify** that $y = (A + Bt)e^{-3t}$ is a complementary function of the differential equation (*). **[2]**

Most candidates answered this part well, correctly differentiating the given complementary function twice and substituting into the LHS of the ODE to obtain 0. A few candidates set up the substitution correctly but did not show that 0 was reached. The scheme did not require candidates to explicitly cancel or combine terms, but a conclusion was needed for the second mark. A few candidates incorrectly concluded that this form would $= 10e^{-3t}$. Candidates who instead solved the auxiliary equation could not gain either mark; the question gave a clear instruction that this should be verified by substituting.

Question 9 (b)

(b) Determine the particular solution for y in terms of t. **[8]**

Many candidates provided good work in this part, with quite a few scoring the first 6 marks. Some candidates did not immediately identify the correct form for the particular integral (note that the first 3 M marks could be awarded, provided it started with a polynomial in t), and sometimes took more than one attempt ('escalating' by starting with αte^{-3t} and then working up to, e.g. $\alpha t^2 e^{-3t}$). Some candidates did not 'spot' the required form and tried more general forms – this was permissible, provided that they went on to deduce that the additional coefficients were 0. Many candidates were able to correctly use the first condition to find an equation in A and B (having combined their terms to find a general solution), but very few candidates scored the final two marks for correctly using the positivity condition to deduce a second condition and thus find the values of A and B. Some candidates deduced, perhaps by using their calculator, the correct values of A and B without showing working to demonstrate this – which could score B1 under the special case, following the first 6 marks.

Question 9 (c)

(c) Using your answer to part **(b)**, find the value of y immediately after the light hits the cell. **[1]**

Most candidates who had obtained an appropriate particular solution in part (b) made an appropriate attempt here by substituting in $t = 0$. This mark could be scored as follow-through, provided a particular solution without remaining unknown coefficients had been reached.

Question 9 (d)

The cell can be considered to be operating properly if $y < 4$ when $t = 1$.

(d) Discuss whether the cell can be inferred to be operating properly. **[2]**

Here, candidates needed to substitute $t = 1$ to find the value of y from their particular solution and then comment on whether this meant the cell could be inferred to be operating properly. Around half of candidates made an attempt here. The inference here is that the value obtained from the model (for the correct particular solution) is very close to the threshold value of 4, so candidates should ideally have commented on this – and the potential for it to be within the margin of error of the model.

Question 10 (a) and (b)

10 **(a)** Find $\frac{1}{2}e^{-u}$ as a percentage of $\sinh u$ for the following values of u.

- $u = 2$
- $u = 5$ **[1]**

(b) Find, as a percentage of $\sinh u$, the difference between $\sinh u$ and $\cosh u$ for the following values of u.

- $u = 2$
- $u = 5$ **[1]**

These first two parts were well answered, with most candidates giving a correct answer to both parts. No working was required as the questions were 'Find' questions – so the result of the calculation is all that candidates were expected to offer. These parts gave candidates an indication of the approximations to consider using in part (c). Some numerical slips were seen, and place value errors (especially in the smaller values) were not uncommon.

Question 10 (c)

A function f is defined for all integers n by $\mathrm{f}(n) = \sinh(0.01n) - 5\cosh(0.005n) - 9\tanh n$.

(c) **In this question you must show detailed reasoning.**

With the help of suitable approximations, use an algebraic method to determine the smallest value of n for which $\mathrm{f}(n) > 100$. You should **verify** your answer, once found, by direct calculation. You may assume that the required value of n is large. **[6]**

Very few candidates scored full marks on this final question, although many candidates made a good attempt. This question asked candidates to select and use suitable approximations for large *n*. Parts (a) and (b) gave candidates a 'hint' as to what these approximations might be – but alternatives were not excluded. The main method seen in the scheme (using exponentials) was most common, although a small number of candidates chose instead to use $\sinh x \approx \cosh x$ as shown in the alternative method. Either of these methods was acceptable, provided that candidates used more than one approximation and gave a full algebraic method to show how the required value was reached. For the final mark, candidates needed to verify that the value they had found (573 if correct) was indeed the 'smallest value of *n*'. This required them to demonstrate (by 'direct calculation' as noted in the question) by showing a pair of values either side of the threshold.

The DR instruction is not a restriction on candidates' use of their calculator and candidates are encouraged to make use of its functionality here to help them check their working. However, this question gave a specific instruction and so candidates who found the value directly, e.g. by using their calculator's 'solve' functionality, without using approximations, could not be awarded the marks for this working. The mark scheme under both methods specifically required candidates to show a full analytical method for manipulating and solving their inequality or resulting equation.

Some candidates used hyperbolic trigonometric identities to manipulate the given function, or an inequality including that function, or used the full exponential forms to reach, for instance a quartic in e^u. The marks could only be awarded once a suitable approximation was used. For example, working in the full exponential forms could be recovered if candidates then assumed that the e^{-u} terms would tend to 0 for large *n*. However, again, even though a precise answer can be found by using a calculator's numerical solve function (and without using any approximations) this was not enough to gain credit.

Candidates should be reminded – especially when a DR instruction applies – to make sure that they are following the instructions for each question in full.

Exemplar 3

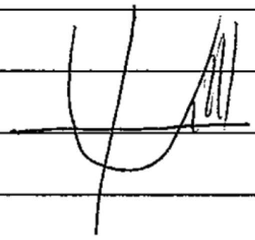
10(c) $f(n) \approx \frac{1}{2}e^{0.01n} - \frac{5}{2}e^{0.005n} - 9$ for large n

let $e^{0.005n} = u$

$100 < \frac{1}{2}u^2 - \frac{5}{2}u - 9$

$200 < u^2 - 5u - 18$

$0 < u^2 - 5u - 218$



$u > 0 \Rightarrow u > \frac{5+\sqrt{5^2+4(218)}}{2}$

$u > \frac{5+\sqrt{897}}{2} \approx 17.5$

$e^{0.005n} > 17.5$ $\quad 17.5 > 1$

$0.005n > 2.86$ $\quad \Rightarrow \ln 17.5 > 0$

$n > 572.13$

$n = 573$ is the smallest

$n = 573$

$f(573) = 100.97 > 100$

$f(572) =$

This is an example of a very good solution to Q10(c) – the candidate has used reasonable approximations to reach a correct inequality and reduced this to a solvable form. They solve this correctly to deduce the appropriate boundary value. However, although they offer one calculation step to verify this, they fail to complete the final calculation required, f(572), which means their verification is incomplete, so they are unable to score the last accuracy mark as they have not demonstrated that 573 is the **smallest** value of n for which the condition holds. 5/6

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