AS LEVEL

Exemplar Candidate Work

FURTHER MATHEMATICS A

H235
For first teaching in 2017

Y535/01 Summer 2018 examination series

Version 1

www.ocr.org.uk/mathematics
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Introduction

These exemplar answers have been chosen from the summer 2018 examination series.

OCR is open to a wide variety of approaches and all answers are considered on their merits. These exemplars, therefore, should not be seen as the only way to answer questions but do illustrate how the mark scheme has been applied.

Please always refer to the specification https://www.ocr.org.uk/qualifications/as-a-level-gce/further-mathematics-a-h235-h245-from-2017/assessment/#as-level for full details of the assessment for this qualification. These exemplar answers should also be read in conjunction with the sample assessment materials and the June 2018 Examiners’ report or Report to Centres available from Interchange https://interchange.ocr.org.uk/Home.mvc/Index

The question paper, mark scheme and any resource booklet(s) will be available on the OCR website from summer 2019. Until then, they are available on OCR Interchange (school exams officers will have a login for this and are able to set up teachers with specific logins – see the following link for further information http://www.ocr.org.uk/administration/support-and-tools/interchange/managing-user-accounts/).

It is important to note that approaches to question setting and marking will remain consistent. At the same time OCR reviews all its qualifications annually and may make small adjustments to improve the performance of its assessments. We will let you know of any substantive changes.
Question 1(i)

1. The points $A$, $B$ and $C$ have position vectors $6\mathbf{i} + 2\mathbf{j} + 4\mathbf{k}$, $13\mathbf{i} + 2\mathbf{j} + 5\mathbf{k}$ and $16\mathbf{i} + 6\mathbf{j} + 3\mathbf{k}$ respectively.

(i) Using the vector product, calculate the area of triangle $ABC$. [5]

Exemplar 1 5 marks

Examiner commentary
Short, clear, concise statements with accurate working.

Exemplar 2 5 marks

Examiner commentary
An alternate method. Whilst valid, there is a greater risk of numerical error. Also, as a less efficient method, there is a time penalty that might be costly over the duration of the examination.
Exemplar 3

4 marks

1(i) \[
\begin{align*}
A &= \begin{pmatrix} 6 \\ 2 \\ 4 \end{pmatrix}, &
B &= \begin{pmatrix} 13 \\ 2 \\ 5 \end{pmatrix}, &
C &= \begin{pmatrix} 16 \\ 6 \\ 3 \end{pmatrix} \\
\end{align*}
\]

\[
AB - b - a = \begin{pmatrix} 19 & 3 \\ 2 & 1 \end{pmatrix} - \begin{pmatrix} 6 \\ 4 \end{pmatrix} = \begin{pmatrix} 7 \\ 0 \end{pmatrix}
\]

\[
CB = b - c = \begin{pmatrix} 13 \\ 2 \\ 5 \end{pmatrix} - \begin{pmatrix} 16 \\ 6 \\ 3 \end{pmatrix} = \begin{pmatrix} -3 \\ -4 \\ 2 \end{pmatrix}
\]

\[
\begin{pmatrix} 7 \\ 0 \\ 1 \end{pmatrix} \times \begin{pmatrix} -3 \\ -4 \\ 2 \end{pmatrix} = \begin{pmatrix} 4 \\ -8 \\ -2 \end{pmatrix} \sqrt{4^2 + (-17)^2 + (-28)^2} \approx 108.9
\]

\[
\frac{108.9}{2} = 54.5 \text{ units} \quad \text{AU}
\]

Examiner commentary

All correct work but careless oversight of the need to take a square-root has cost this candidate a mark here. Moreover, in (ii), the final mark is CAO so this slip has cost them a second mark later on.
Examiner commentary

This candidate starts well but then attempts to do two steps at once (namely, a vector product and a magnitude) and has thus confused a vector quantity for a scalar and lost most of the marks here.
Question 1(ii)

1 (ii) Hence find, in simplest surd form, the perpendicular distance from \( C \) to the line through \( A \) and \( B \). [3]

Exemplar 1 3 marks

Examiner commentary

Notice how even a most basic sketch diagram has helped this candidate to decide what to do to answer the question.

Exemplar 2 1 mark

Examiner commentary

Although the magnitude of one relevant vector has been calculated, the lack of a simple diagram has meant that this candidate has struggled to make any further progress on this part.
Examiner commentary

This candidate has produced a diagram, but overlooked the obvious use of “half-base-times-height” to solve the problem.
Question 2(i) and (ii)

2 The surface with equation \( z = 6x^3 + \frac{1}{3}y^2 + x^2y \) has two stationary points.

(i) Verify that one of these stationary points is at the origin. [4]

(ii) Find the coordinates of the second stationary point. [5]

Exemplar 1

4 marks

\[
\begin{align*}
2(i) & \quad \frac{\partial z}{\partial x} = 18x^2 + 2xy \\
& \quad \frac{\partial z}{\partial y} = 2y + x^2 \\
\Rightarrow \quad \frac{\partial^2 z}{\partial x^2} &= 36x \\
\Rightarrow \quad \frac{\partial^2 z}{\partial y^2} &= 2 \\
\Rightarrow \quad \frac{\partial^2 z}{\partial x \partial y} &= 2x
\end{align*}
\]

\[
\begin{align*}
\text{at origin:} & \quad x = 0, \quad y = 0 \\
\Rightarrow \quad 18x^2 + 2xy &= 0 \\
\Rightarrow \quad 2y + x^2 &= 0 \\
\Rightarrow \quad x^2 &= -\frac{2}{3}y \\
\Rightarrow \quad x &= \pm \sqrt{-\frac{2}{3}y} \\
\end{align*}
\]

\[
\begin{align*}
z &= 6(0)^3 + \frac{1}{3}(0)^2 + (0)^2(0) \\
\Rightarrow \quad z &= 0
\end{align*}
\]
Examiner commentary

The working here is solid and correct. Note, however, that there is a lot more working than is necessary to answer the question; indeed, this work covers much of the work required in part (ii) – in fact, when you look at (ii), you see that almost all of this work has been repeated, wasting valuable time.

Exemplar 2

3 marks

Examiner commentary

If you look at the portion of work presented for part (i), you will see that this candidate has earned no marks. Fortunately, despite this failure to grasp what was being asked of them, they have then gone on to do the necessary working in their work for (ii). It is important to be very clear as to what is being asked and then to undertake the necessary steps to do it. It is not always the case that marks can be earned if the candidate’s work makes it clear that they do not know what has been asked of them.
Examiner commentary

The lack of the factor "2" when differentiating $x^2y$ (w.r.t. x) has lost this candidate a mark both here and at the end of (ii), the final mark of which is a CAO.
Examiner commentary

It might seem a fine distinction, but you will see that the solution here shows that $f_x = f_y$ when $x = y = 0$ rather than that they are both, individually, zero. This mistake has then confused the candidate into a panicky bit of working in (ii) as it has led to an awful bit of division work in line 3.
Question 3

3 Given that $n$ is a positive integer, show that the numbers $(4n+1)$ and $(6n+1)$ are co-prime. [3]

Exemplar 1

3 marks

Examiner commentary

Though correct, there is still a warning to be issued at this point. This method (a use of what is called the Euclidean Algorithm) is not only off-syllabus but it is principally a method for finding the hcf of two numbers; how it applies to algebraic expressions is rather less obvious and it thus represents something of a gamble to deploy it in an examination setting. In order to be credited full marks it was necessary, as in this exemplar, to provide an effective explanatory note.

Exemplar 2

3 marks

Examiner commentary

This is much more the work expected from that which is actually on-syllabus, and it is extremely well explained as well as correctly presented.
Examiner commentary

Not only is the work presented in a strange order here (the conclusion is given before any working to support it), there also seems to be a confusion as to how to reason it properly. Note that the right ingredients are all there – the correct multiples of $(4n+1)$ and $(6n+1)$ are noted but then not subtracted. It may be that this candidate does indeed understand what is needed, but they have not performed the key step of subtracting the two multiples in order to get the answer 1. In order to gain the final mark, however, they would still have had to explain why the 1 gives the asked for conclusion. Many candidates thought that getting a numerical answer to their chosen linear combination of $(4n+1)$ and $(6n+1)$ meant that this was the hcf required rather than just a multiple of it. The conclusion that $h \mid 1 = h = 1$ follows since the greatest number that divides 1 is, of course, 1 itself.
Question 4(i), (ii), (iii) and (iv)

4 The group $G$ consists of a set of six matrices under matrix multiplication. Two of the elements of $G$ are

$$A = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix} \quad \text{and} \quad B = \begin{pmatrix} 1 & -1 \\ 0 & -1 \end{pmatrix}.$$ 

(i) Determine each of the following:
   - $A^2$ [2 marks]
   - $B^2$ [2 marks]

(ii) Determine all the elements of $G$. [4 marks]

(iii) State the order of each non-identity element of $G$. [3 marks]

(iv) State, with justification, whether $G$ is
   - abelian [2 marks]
   - cyclic.

Exemplar 1

2 marks

4 marks

3 marks

2 marks
Examiner commentary

(i) This question was answer well by the majority of candidates. Note that the use of the command word 'Determine' does indicate that some written justification is needed (to show an understanding of the notation), even if the actual answer is to be found using the matrix functionality of a calculator.

(ii) This candidate has correctly listed all six elements. Just to note then that, with time such a crucial factor, it would have been simpler and easier to label them in terms of the given matrices $A$ and $B$.

(iii) Clearly stated orders for each non-identity element of the group.

(iv) The second part of the question is answered here from knowledge of syllabus item 8.03i, relating to the structures of groups of small order. Well done.

Exemplar 2

3 marks

\[4(ii)\]

\[
\begin{align*}
A &= (0 \, 1) & B &= (1 \, -1) \\
A^2 &= (1 \, 0) & B^2 &= (1 \, 0) \\
AB &= (0 \, -1) \cdot (1 \, -1) = (0 \, 1) \\
BA &= (0 \, -1) \cdot (0 \, -1) = (0 \, 1)
\end{align*}
\]

2 marks

\[4(iii)\]

\[
\begin{align*}
A & \text{ has order } 2. \quad \text{(B1)} \\
B & \text{ has order } 2. \quad \text{(B1)} \\
AB & \text{ has order } 3. \quad \text{(B1)} \\
BA & \text{ has order } 3. \quad \text{(B1)}
\end{align*}
\]
Examiner commentary

By failing to consider further products (e.g. ABA) in (ii), this candidate has missed the crucial sixth element of the group. This has lost them a mark in (ii) and a mark in (iii). Though they have belatedly looked at both ABA and BAB in (iv), no marks have been earned retrospectively since the opportunity has passed to list this extra matrix in the previous two parts. Moreover, having shown them equal in (iv), the candidate now thinks this is justification for a claim of abelian-ness when, in fact, they should be noting that AB and BA are not equal so the group cannot be abelian.

Exemplar 3

2 marks
**Examiner commentary**

This candidate has made an incorrect statement of the orders of two of the group's elements in (iii), which has then led to the use of a correct statement in (iv), but not one that applies in this particular situation. Given that calculators may be used to check powers of matrices; candidates should be encouraged to check working.

**Exemplar 4**

1 mark

**Examiner commentary**

The whole thrust of the question was leading towards a consideration of the orders of elements; so “the group has no generator because there is no element of order 6” would have been the full answer (and not just the statement that the group has no generator as given in this exemplar).

**Exemplar 5**

0 marks

**Examiner commentary**

This candidate has confused “abelian” and “cyclic”.
Question 5(i)

For integers $a$ and $b$, with $a \geq 0$ and $0 \leq b \leq 99$, the numbers $M$ and $N$ are such that

$$M = 100a + b \quad \text{and} \quad N = a - 9b.$$

(i) By considering the number $M + 2N$, show that $17 | M$ if and only if $17 | N$. [4]

Exemplar 1

Examiner commentary

Although the correct initial result has been established, as requested, it has not then been used. In itself, this is not a particular problem. However, this candidate has only proved one direction of implication of an “if and only if” (\(\iff\)) proof.

Exemplar 2

Examiner commentary

This candidate has lost a mark through lack of clarity when establishing the initial result, by failing to be explicitly clear about the fact that $102 = 6 \times 17$. While this may seem harsh, much of the number theory work is about demonstrating things that may seem obvious. Indeed, the whole of part (ii) is to do with the application of an algorithmic process rather than simply the question of whether the given number is a multiple of 17.
Examiner commentary

This solution is almost entirely correct, establishing the initial result AND then using it properly in the one direction of the proof, even though the clear statement that 102 is a multiple of 17 appears embedded within the expression for 2N. As far as proof goes, this would be better presented if the candidate had said something like “Suppose that $M = 17m \ldots$”, with a similar intro to the second, $=\ldots$ part. The final mark has been lost only as a result of carelessness. One may well argue that the sign of the 34 is irrelevant to the issue of divisibility, but even small slips in the numerical working are likely to be penalised, since incorrect numbers almost invariably do affect such matters, so it is important to be entirely correct – as a rule, “lucky” errors should receive no more credit than “unlucky” ones.
Question 5(ii)

(ii) Demonstrate step-by-step how an algorithm based on the result of part (i) can be used to show that 2058376813901 is a multiple of 17. [4]

Exemplar 1

Examiners commentary

If you examine this you will see that two marks have been lost by this candidate simply by failing to write the relevant zero at the end of the first stage of the process. As with the final comment on 5(i), although the 0 at the end of a number has no bearing on the divisibility by 17, it represents a mis-application of the algorithm, which leads to the loss of the final mark also. While this may seem a tad harsh, remember that a calculator could still have been used to do the numerical bits and so there really is no excuse for having lost these marks here.
Examiner commentary

This is rather puzzling working … taking off only the one final digit (when the question is quite clear that it should be two) and then multiplying by 5 instead of 9 before subtracting to complete each step. Nonetheless, it has been possible to award one M(ethod) mark for the full application of an algorithm of this kind through to a conclusion.

It is worth pointing out that several candidates offered a completely different algorithmic process for establishing divisibility by 17, one that was off-syllabus. Given that this question asks for a specific application of an algorithm based on the results of part (i), such approaches would also be limited to a maximum mark of 1.
Exemplar 3

Examiner commentary

This solution starts well, correctly identifying the “a” and “b” necessary for the implementation of the first stage of the algorithm, but the candidate then forgets to multiply the b by 9 and effectively starts again with the $M + 2N$ idea from part (i). Note the appearance of the statement $b = -\frac{1}{7}$, at which point (given that we are working with integers here) alarm bells should have been going off.
Question 6(i)

6 The Fibonacci sequence \( \{F_n\} \) is defined by \( F_0 = 0, F_1 = 1 \) and \( F_n = F_{n-1} + F_{n-2} \) for all \( n \geq 2 \).

(i) Show that \( F_{n+5} = 5F_{n+1} + 3F_n \) \[3\]

Exemplar 1

This solution neatly illustrates the “layered” way that the single Fibonacci definition (each term being the sum of the previous two) can be applied to the changing subscripts; the end result then takes the form of a factor tree, a simple (number theoretic) idea drawn from candidates’ earlier mathematical experiences.
Exemplar 2

Examiner commentary

Another completely correct derivation of the required result, but rather lengthier. The line-by-line approach is as good as the approach of the first example, and the use of bracketed terms to show where each term leads to on the next line is also a good strategy. It is interesting to note that this candidate works their way “up” the Fibonacci chain before actually completing the proof by working back “down” – the correct outcome can be achieved either way round but the reader must realise that valuable time may have been spent here, as it is not a terribly efficient approach.
Examiner commentary

This candidate starts well, noting several of the same cases as the previous candidate had. The lack of a clear strategy for putting them all together has led to confusion between adding terms and adding subscripts.
Question 6(ii)

(ii) Prove that $F_n$ is a multiple of 5 when $n$ is a multiple of 5.  

Exemplar 1  

Examiner commentary  

Despite the odd appearance of a proof of part (i)'s result in the middle of the page, this is a good, solid induction proof. The baseline case is established very concisely and there is a clearly stated induction hypothesis. We must then jump the part (i) result (which, incidentally earned the candidate all of part (i)'s marks, despite being in the wrong place) to read the rest of a very concise piece of induction work, running (ignoring the interruption) to a mere seven lines. The candidate fails to produce what I refer to as the induction "round up", which explains the logic of the proof as a way of completing the proof.
Examiner commentary

Although the question does not explicitly require an inductive proof (in fact, please see the published mark-scheme for a viable alternative using modular arithmetic) most candidates recognised that this question was set up perfectly for its use. In this case, the candidate has set out the baseline case correctly but then confused the assumption that an $F_n$ term is a multiple of 5 with an assumption of part (i)'s result, which was intended to be used in an entirely different way in the proof.
**Question 7(i)(a), (i)(b), (ii)(a), (ii)(b), (iii), (iv) and (v)**

7. The ‘parabolic’ TV satellite dish in the diagram can be modelled by the surface generated by the rotation of part of a parabola around a vertical z-axis. The model is represented by part of the surface with equation $z = f(x, y)$ and $O$ is on the surface.

The point $P$ is on the rim of the dish and directly above the x-axis.

The object, $B$, modelled as a point on the z-axis is the receiving box which collects the TV signals reflected by the dish.

![Diagram of a parabolic dish]

(i) The horizontal plane $\Pi_1$, containing the point $P$, intersects the surface of the model in a contour of the surface.

   (a) Sketch this contour in the Printed Answer Booklet. [1]
   (b) State a suitable equation for this contour. [1]

(ii) A second plane, $\Pi_2$, containing both $P$ and the z-axis, intersects the surface of the model in a section of the surface.

   (a) Sketch this section in the Printed Answer Booklet. [1]
   (b) State a suitable equation for this section. [1]

(iii) A proposed equation for the surface is $z = ax^2 + by^2$. What can you say about the constants $a$ and $b$ within this equation? Justify your answers. [3]

(iv) The real TV satellite dish has the following measurements (in metres): the height of $P$ above $O$ is 0.065 and the perimeter of the rim is 2.652. Using this information, calculate correct to three decimal places the values of

   - $a$ and $b$,
   - any other constants stated within the answers to parts (i)(b) and (ii)(b). [4]

(v) Incoming satellite signals arrive at the dish in linear “beams” travelling parallel to the z-axis. They are then ‘bounced’ off the dish to the receiving box at $B$.

   - On the diagram for part (ii)(a) in the Printed Answer Booklet draw some of these beams and mark $B$. [2]
   - If the values of $a$ and $b$ were changed, what would happen?
Exemplar 1

7(i)(a)

\[ (x-p)^2 + (y-r)^2 = r^2 \]

1 mark

7(i)(b)

\[ (x-a)^2 + x^2 + y^2 = r^2 \]

1 mark

7(ii)(a)

1 mark

7(ii)(b)

\[ z = a - x^2 \]

1 mark
7(iii) They are both positive, so the surface is all above the or on the plane $0$. At the surface is always in the positive $z$-axis.

7(iv) Let $0.065 = \frac{ax}{x} \rightarrow \frac{ax}{x} = 1 \rightarrow 2 = 2.652$ and $2 = 2.652$ $\rightarrow \frac{2}{2.652} \rightarrow r = 0.752$

7(v) if $a$ and $b$ were changed, instead of $ax$ and $cy$, point $B$ would move down, end of $y$ dead, it would move up.
Examiner commentary

This is an excellent set of answers – clear statements, concisely given. In the diagram for (ii) (a), with the lines asked for in (v), it would be helpful to have arrows on the incoming beams of light to show where they are being reflected to the receiver at B but some b.o.d. has been allowed. For both diagrams, in (i) (a) and (ii) (a), the relevant axes have been labelled and the role of the origin is deducible, despite the rough nature of the sketches, one of a contour and one of a section of the surface. These sketches show how it is possible to get the marks without having to spend a great deal of time on them.

The reasoning in (iii) is good, particularly as this candidate has been guided by the number of marks which have been allocated to it – most candidates did not offer three points (points or reasons to justify them) and thus did not earn all 3 marks available.

The one lost mark, in part (iv), is as a result of an extra factor of 2 that has appeared in proceedings; all the other calculations need to refer to the constants introduced in previous parts’ answers. It is worth noting that specifically chosen values earlier on would have ruined the chances of getting many marks in (iv).

Exemplar 2

1 mark

1 mark

1 mark

1 mark
Examiner commentary

Notice the choice of specific values for the constants in (i) and (ii) parts (b). Whilst acceptable here, the possible calculations in (iv) have been pre-empted and thus the marks are very unlikely to be earned.

The answer to (iii) contains just the one point (albeit with a supporting reason) while there are three marks offered. The fact that $a$ and $b$ must be equal should follow from the candidate’s own suggestion in (i) (a) of a circle.

Although this candidate did not score fully on these previous parts, they were able to secure the final part (v) marks.
Exemplar 3

7(i)(a) $y = z$  

1 mark

7(i)(b) $z = r$  
$\rho = f(x, y)$

1 mark

7(ii)(a) $z = F(x, 0)$  
$\gamma$ goes through origin

1 mark

7(ii)(b) $y = 0$

1 mark
Exemplar Candidate Work

7(iii)

- a must be real and cannot be negative or 0.

- b must be real and cannot be negative or 0.

\[ a^2 \] is always positive.

\[ y^2 \] is always positive.

1 mark

7(iv)

- \[ P = (0, 0.065) \]

- \[ Q = (-0.422, 0.0065) \]

\[ a = 2.65 \] and \[ b = 0 \]

\[ 0.844 = 0.422 \]

\[ 0.422 = 0.178a \]

\[ a = 0.365 \]

\[ b = -0.422 \]

1 mark

7(v)

If the values of \[ a \] and \[ b \] were changed, the receiver signals very not all hit the receiver (B)

1 mark
Examiner commentary

This candidate has to be applauded for some sensible answers. Even though they are uncertain as to the nature of the curve required in (i) (a), they clearly know the general appearance of a contour’s equation, which thus earns the mark in (i) (b). Then, in (ii), their sketch for (a) has been qualified with the added comment that shows which of the two curves they wish to be considered; this is, again, followed in (b) by a valid general statement of the equation of a section, despite their obvious uncertainty about what curve they have drawn in (a). In part (iii), many candidates either identified that both must be positive, or that they must be equal, but as in this example, seldom were both seen. Having failed to identify that $a=b$ in part (iii) not all marks could be gained in part (iv). In part (v), with the request to draw onto (ii) (a)’s diagram “some of these beams”, they have only drawn one and this has lost them a very easy mark.

Exemplar 4

0 marks

Exemplar 0 marks

Exemplar 0 marks

Exemplar 0 marks
Examiner commentary

The curves sketched in (i) and (ii) (a) are correct in one sense (a circle and part of a parabola); however, the axes noted in (i) (a) should be the $x$- and $y$-axes and the parabola in (ii) (a) should have its vertex at the origin, though this too would not have been credited the 1 mark since, again, the wrong axes have been marked on the diagram. A noteworthy point is that, without any axes indicated at all, these two marks could have been credited since it would have been assumed they were the correct ones; as it happens, the candidate has clearly shown they are the wrong ones and so such generosity (b.o.d.) cannot be offered.

Another matter raised here is that the circle equation offered in (i) (b) is apparently not centred at the origin but the slightly wobbly circle in (i) (a) might still be taken to be the correct one by the marker. From a candidate’s point of view, however, one should not give the marker reason to make a judgement on whether it is the circle it is supposed to be or not as the call may not go the way one might hope for.
In (iii), the candidate almost gets to say that $a$ and $b$ are positive but only ends up saying they are non-negative; the difference may be slight but further mathematicians should be well versed in making careful and precise statements and should not expect to get away with vagueness in either their descriptions or reasoning.

In part (iv), it can again be seen that unhelpful earlier answers (either too vague or too specific, or just incorrect or inappropriate) can make it inherently difficult to follow-through in a useful way. On this occasion, even with a given form in (iii) for the surface, this candidate has little prospect of gaining marks for suitable working.

Finally, in part (v), there are two marks, one of which is for drawing “some beams” hitting the dish and arriving at $B$ but the receiver seems to have been drawn on the surface of the dish. Then, for the comment, a sensible observation has been made in one sense, though the lack of specificity (the dish could actually be shallower, depending upon the values chosen for the constants) has made it impossible to reward. More to the point, there is a context to be considered within this modelling question, and the candidate has overlooked the thrust of this very final part of the question, which is clearly all about the box $B$.

Overall, there are a lot of minor oversights for one question but they have resulted in this candidate credited with almost no marks on it.

**Examiner commentary**

In (ii) (a), it is not actually clear that this curve isn’t a circle, but the mark would have been given if it had passed through the origin as it could have been taken as a parabola. This lack of clarity is not helped by a circle equation being offered for (ii) (b), though this would not have led to a withdrawal of any mark that had been given for (a) had the curve been assumed to be part of a parabola.
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