

(https://intercom.help/kognity)



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Teacher view

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- The big picture
- Constructing diagrams
- Solving problems by sketching diagrams
- Bearings
- Angles of elevation and depression
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3. Geometry and trigonometry / 3.3 Applications of trigonometry



Notebook



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# The big picture

Early Egyptians and Babylonians knew about the ratios of sides of similar triangles but they did not use the concept of an angle; they only studied the side lengths of triangles.

Hipparchus of Nicaea of Hellenistic Anatolia (now Iznik, Turkey), a Greek astronomer and mathematician, also known as '*Father of the trigonometry*', was the first to use arithmetic techniques to calculate the trigonometric ratios for angles.

Once the concepts of angles and trigonometric ratios of angles had been introduced, people were able to apply them in many practical contexts, many of which are still used today.

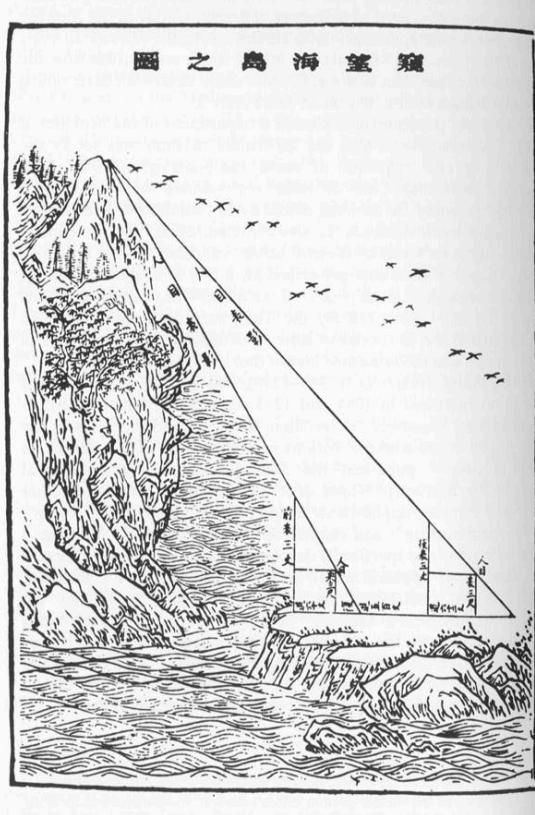
For example, forest surveyors use trigonometry to find the length of a river or boundaries of a forest; bearings are used to calculate the distances between locations on maps; and in oceanography the height of tides and waves are calculated by using angles of elevation and depression. An up-to-date application of trigonometry is the global positioning system (GPS) in a smartphone.

In this subtopic, you will be looking into the practical uses of trigonometry.

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Sea Island survey diagram

, first written by the Chinese mathematician Liu Hui during the Three Kingdoms era (220–280 CE).

Source: " [Sea island survey](https://commons.wikimedia.org/wiki/File:Sea_island_survey.jpg) ([https://commons.wikimedia.org/wiki/File:Sea\\_island\\_survey.jpg](https://commons.wikimedia.org/wiki/File:Sea_island_survey.jpg)) " by Liu Hui is in public domain.

More information

This is a diagram illustrating an ancient Chinese method of using trigonometry to survey a sea island. The image features a detailed drawing of a rocky island with a triangular shape overlaying it, representing the trigonometric calculations. The base of the triangle is along the shore, while one side extends up to the peak of the island. Several small annotations in Chinese script are placed along the sides of the triangle, indicating measurements or calculations. At the bottom left, waves are illustrated, suggesting the sea surrounding the island. Additionally, there are birds flying in the area above the triangle, providing a sense of perspective and scale.

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## Concept

There are many real-world applications of trigonometry including land surveys, bearings, angles of elevation and depression and GPS.

How could you use trigonometry to define the space around us?

How could the height of a distant object be estimated without physically measuring it?

How accurate are our calculations when the surface of Earth is not flat and the geometry you are using is for flat surfaces?

When making calculations and predictions based on the real world, it is often necessary to use modelling to reduce a complex shape into a system of triangles to enable trigonometry to be used.

3. Geometry and trigonometry / 3.3 Applications of trigonometry

# Constructing diagrams

## Labelling and drawing diagrams

In examinations, you will often be given a diagram of the question together with an explanation. Although these diagrams are not drawn to scale, they are helpful when solving a geometry problem.

In some cases, if you are not given a diagram you would benefit from sketching one as it would help you to spot the relationships.

## Example 1



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In triangle ABC,  $AB = 6.5 \text{ cm}$ ,  $BC = 4.2 \text{ cm}$  and angle  $BCA = 65.6^\circ$ .



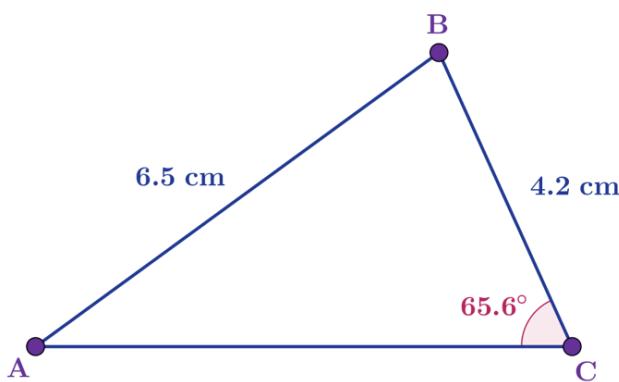
## Calculate the area of triangle ABC.

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### Solution

#### Steps

#### Explanation



More information

The image is a diagram of a triangle labeled ABC. The triangle has three sides: one side from A to B measuring 6.5 cm, one side from B to C measuring 4.2 cm, and the last side from A to C. The angle at point C is marked as 65.6 degrees. Each vertex is labeled with a letter and represented by a purple dot. The lengths of the sides are labeled in blue, and the angle at C is highlighted in red.

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$$c^2 = a^2 + b^2 - 2ab \cos C$$

$$6.5^2 = 4.2^2 + b^2 - 2 \times 4.2 \times b \times \cos 65.6^\circ$$

You can use the formula for the area of a triangle using the sine of the included angle,

$$\text{area of triangle} = \frac{1}{2}ab \sin C$$

When you sketch triangle ABC, you can see that the angle given is the included angle, so you will need to find the length of AC to be able to use this area formula.

$$b = 6.990 \dots \text{ cm}$$

As two sides and an angle are given, you can use the cosine rule to find the missing side length.

Use the GDC instructions provided below this table.

Don't round this value yet as you need it in the next calculation.



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Section

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Feedback



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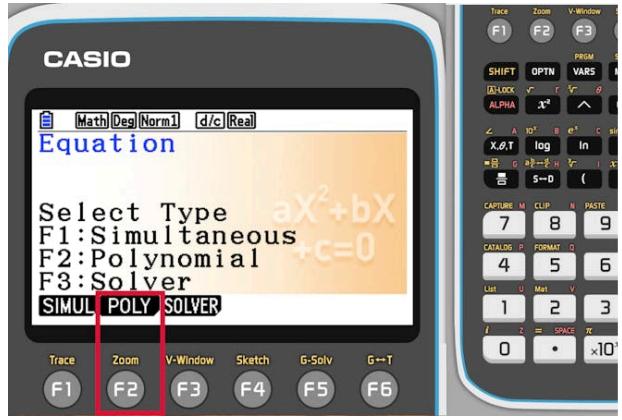
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$\text{area of triangle} = \frac{1}{2}ab \sin C$ $\text{area} = \frac{1}{2} \times 4.2 \times 6.990\ldots \times \sin 65.6^\circ.$ $\text{area} = 13.368\ldots$ $\approx 13.4 \text{ cm}^2$ (3 significant figures)		<p>Now that you have the side length needed, you can use the formula to find the area.</p>
	<p>Note that you can solve this problem by drawing the perpendicular from vertex <math>B</math> to the side <math>AC</math> and then finding the height using the given angle and side <math>AC</math>.</p> <p>The formula</p> $\text{area} = \frac{1}{2} \text{base} \times \text{height}$ <p>could then be used.</p>	

GDC instructions for finding  $b$ :



Student view

Step	Explanation
<p>In these instructions you will see how to use the polynomial equation solver to find the roots of the quadratic equation</p> $ax^2 + bx + c = 0$ <p>for</p> $a = 1$ $b = -2 \times 4.2 \times \cos(65.6^\circ)$ $c = 4.2^2 - 6.5^2$	
<p>Choose the equation solving mode.</p> <p>Press F2 to choose the polynomial root finder.</p>	

## Section

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Feedback



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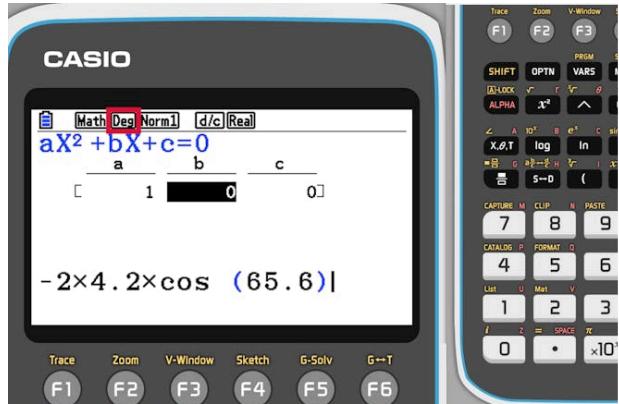
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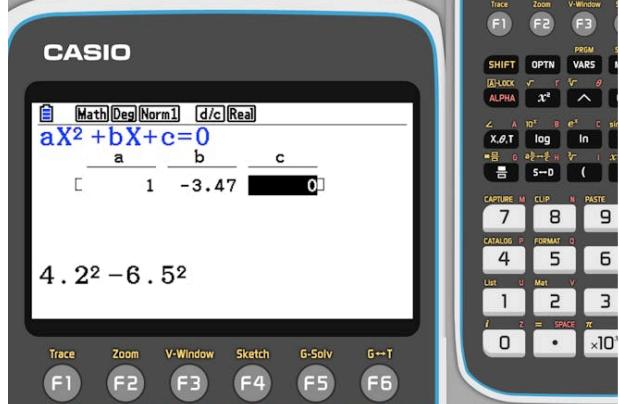
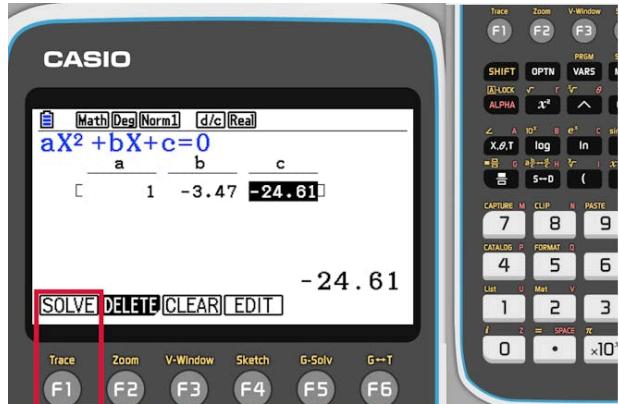
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Step	Explanation
<p>This is a quadratic equation, so press F1 to choose degree 2.</p>	
<p>You can enter an expression as the coefficient. Make sure your calculator is in degree mode so that you get the correct cosine value.</p>	



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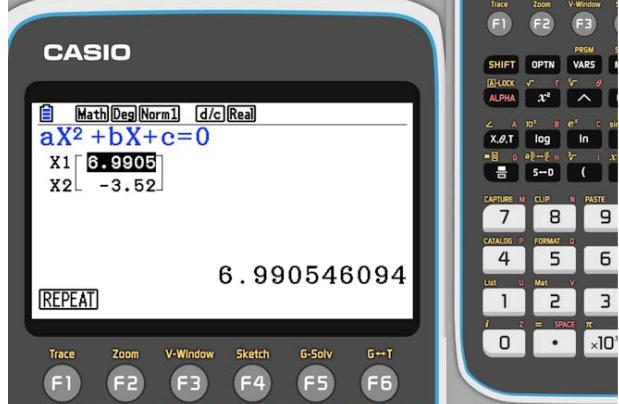
Step	Explanation
Note, that the expression you entered for $b$ is converted to a number.	
Once you entered all the coefficients, press F1 to solve the equation.	



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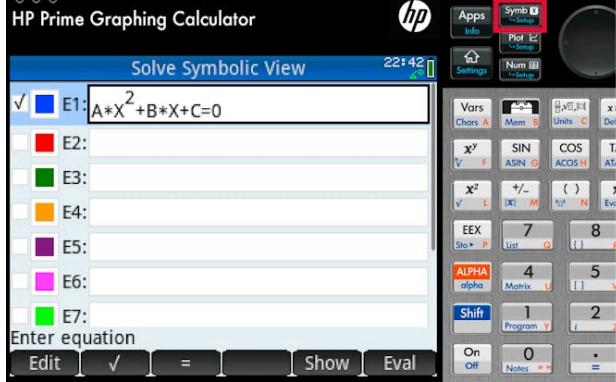
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Step	Explanation
<p>There are two solutions. In the context (<math>x</math> is the side length of a triangle), only the positive solution is meaningful.</p>	



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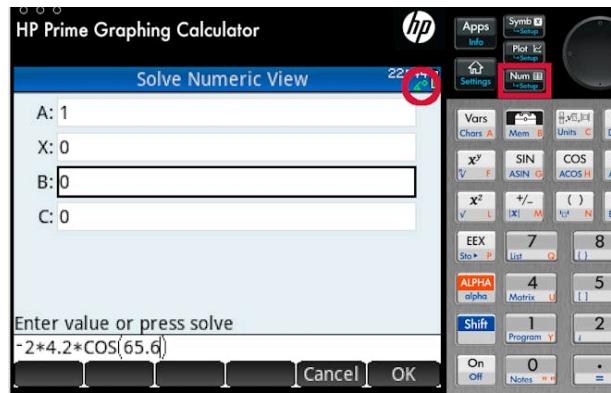
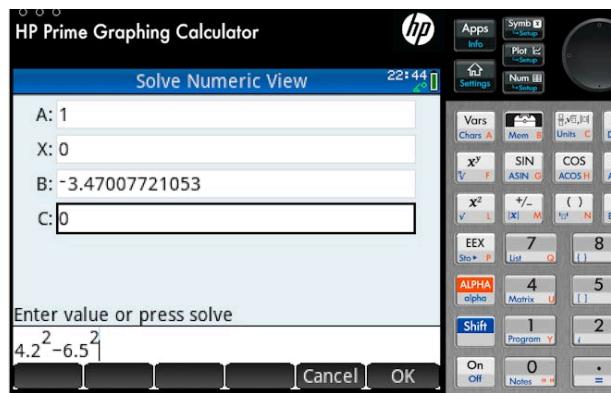
Step	Explanation
<p>In these instructions you will see how to use the polynomial equation solver to find the roots of the quadratic equation</p> $ax^2 + bx + c = 0$ <p>for</p> $a = 1$ $b = -2 \times 4.2 \times \cos(65.6^\circ)$ $c = 4.2^2 - 6.5^2$ <p>Choose the solver application. Some parts of the explorer application is also available in exam mode, you can experiment with it.</p>	
<p>In the symbolic view, enter the general form of a quadratic equation.</p>	



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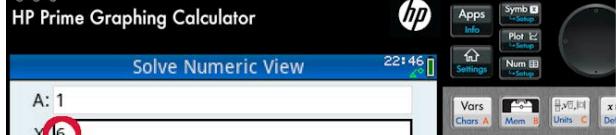
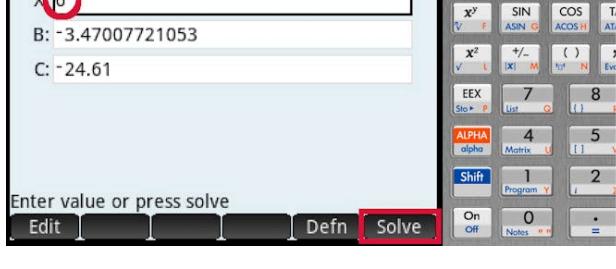
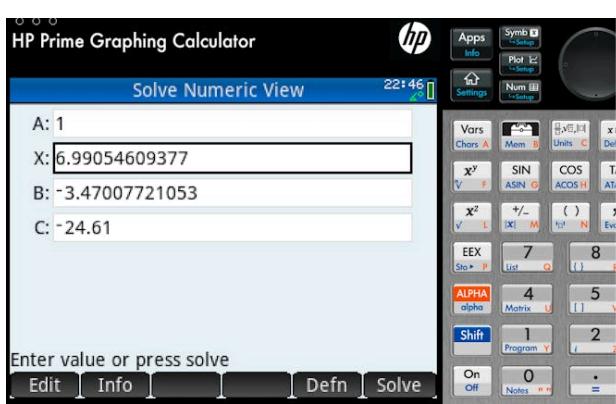
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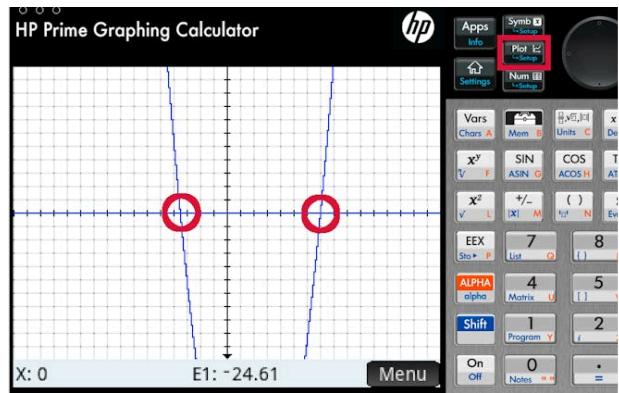
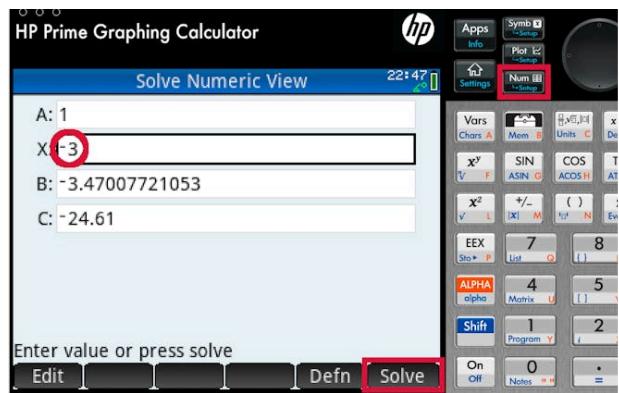
Step	Explanation
<p>Move to the numeric view to enter the coefficients.</p> <p>You can enter an expression as the coefficient. Make sure your calculator is in degree mode so that you get the correct cosine value.</p>	
<p>Note, that the expression you entered for <math>b</math> is converted to a number.</p>	



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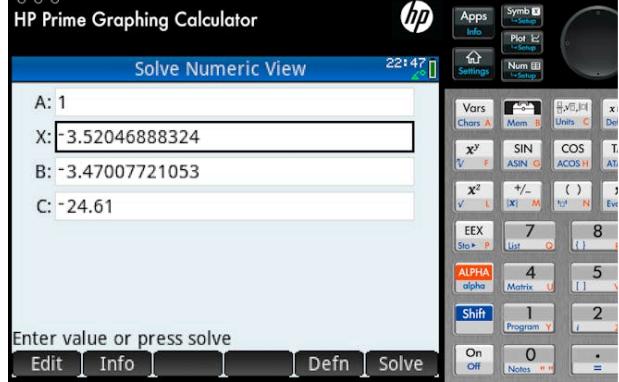
Step	Explanation
<p>Once the coefficients are entered, move to the row for <math>x</math> to tell the calculator that you would like to solve this equation for <math>x</math>.</p>	
<p>The calculator finds the solutions one at a time. Enter an <math>x</math>-value that you think is close to the solution. In this example, the diagram indicates, that the side length you are looking for is somewhere around the length of the longer given side.</p>	
<p>Once done, press solve.</p>	



Step	Explanation
<p>To find the other solution, open the plot view.</p> <p>You will see the graph of the quadratic. You can see that the solution you did not get earlier is negative, so it is not meaningful in this context (you are looking for the length of a side of a triangle).</p> <p>If you are still interested, make a note that this other solution is around <math>-3</math> and go back to the numeric view.</p>	
<p>In the numeric view, enter the new approximation for the solution and press solve.</p>	



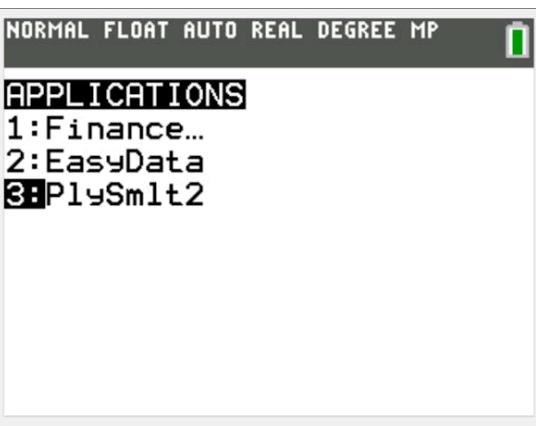
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Step	Explanation
The second solution is now displayed.	



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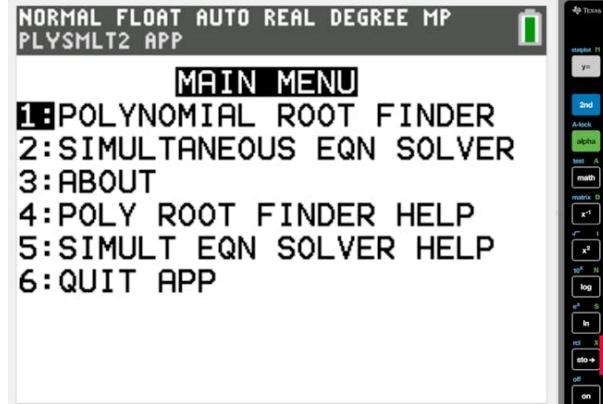
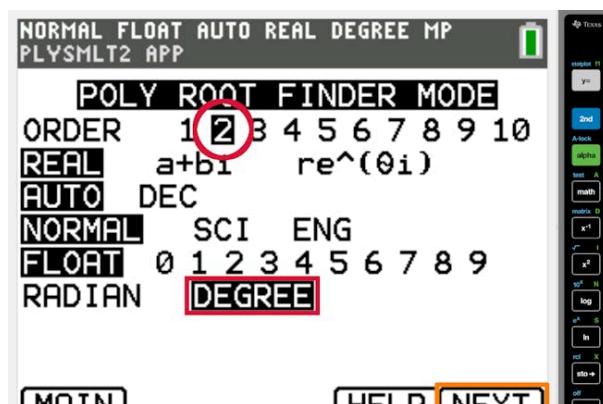
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Step	Explanation
<p>In these instructions you will see how to use the polynomial equation solver to find the roots of the quadratic equation</p> $ax^2 + bx + c = 0$ <p>for</p> $a = 1$ $b = -2 \times 4.2 \times \cos(65.6^\circ)$ $c = 4.2^2 - 6.5^2$	
<p>Open the list of applications.</p> <p>Open PlySmlt2, the polynomial equation solver application.</p>	



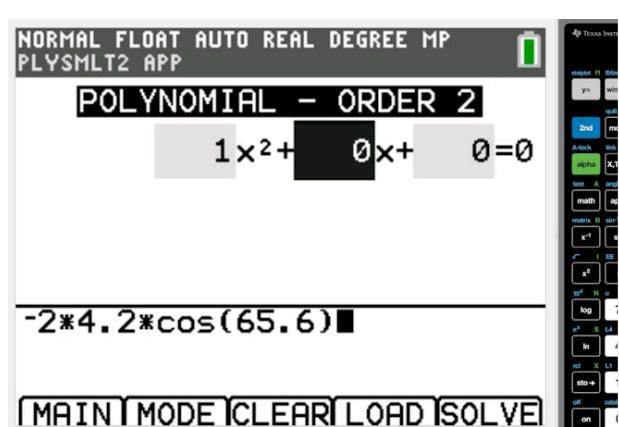
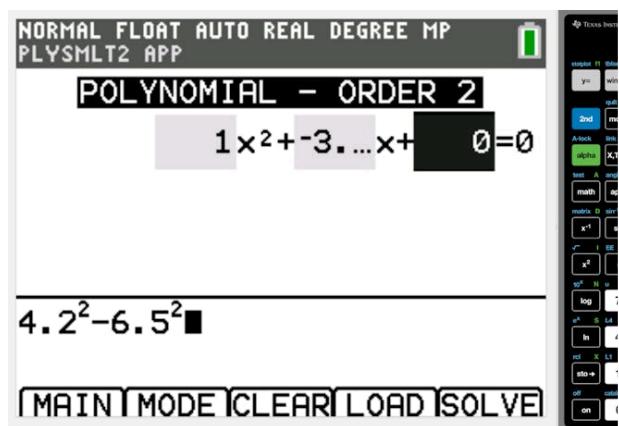
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Step	Explanation
You will need the polynomial root finder option.	
This is a quadratic equation, so choose order 2.  Make sure you choose degree mode so that you get the correct cosine value in the coefficient.  Once done setting the options, move to the next step by pressing the corresponding button under the screen.	



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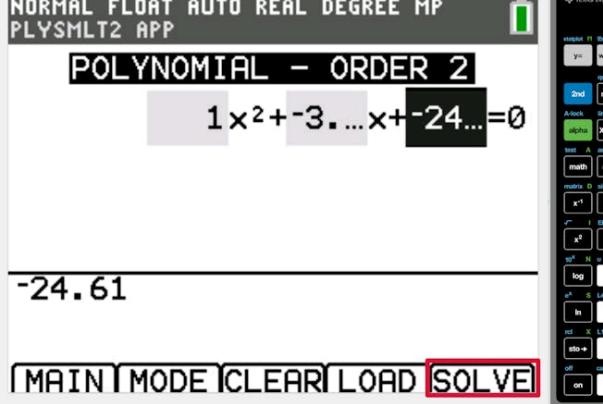
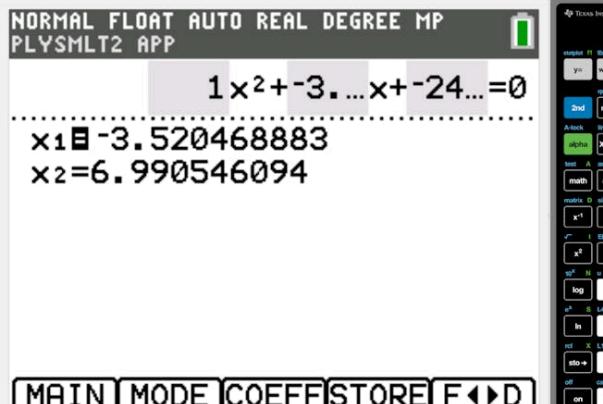
Step	Explanation
You can enter an expression as the coefficient.	 



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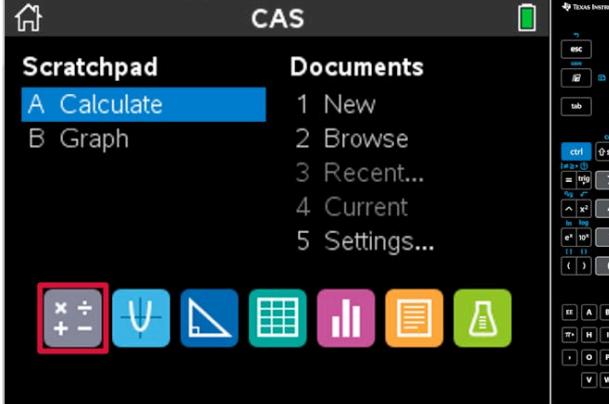
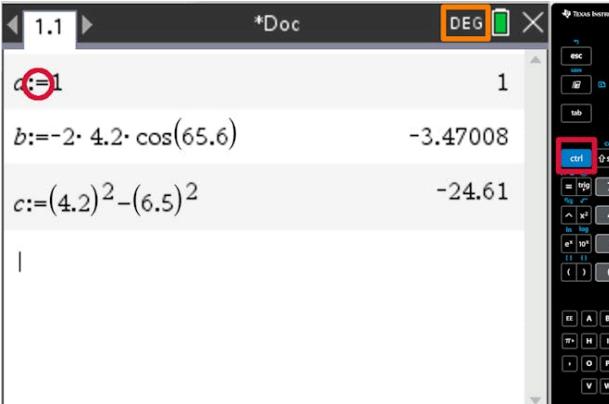
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Step	Explanation
<p>Once you entered all the coefficients, press the button under the screen that corresponds to the solve option.</p>	 <p>The calculator screen shows the following steps:</p> <ul style="list-style-type: none"> <li>Mode settings: NORMAL FLOAT AUTO REAL DEGREE MP PLYSMLT2 APP</li> <li>Equation input: POLYNOMIAL - ORDER 2 <math>1x^2 + -3...x + -24... = 0</math></li> <li>Solution output: -24.61</li> <li>Calculator menu bar: MAIN MODE CLEAR LOAD SOLVE</li> </ul>
<p>There are two solutions. In the context (<math>x</math> is the side length of a triangle), only the positive solution is meaningful.</p>	 <p>The calculator screen shows the following steps:</p> <ul style="list-style-type: none"> <li>Mode settings: NORMAL FLOAT AUTO REAL DEGREE MP PLYSMLT2 APP</li> <li>Equation input: <math>1x^2 + -3...x + -24... = 0</math></li> <li>Solutions output: <math>x_1 = -3.520468883</math> <math>x_2 = 6.990546094</math></li> <li>Calculator menu bar: MAIN MODE COEFF STORE F4 D1</li> </ul>



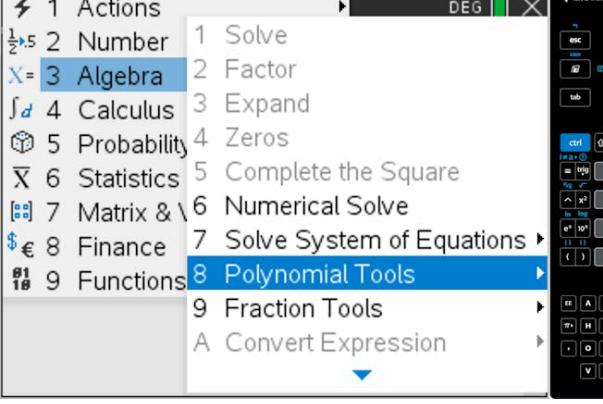
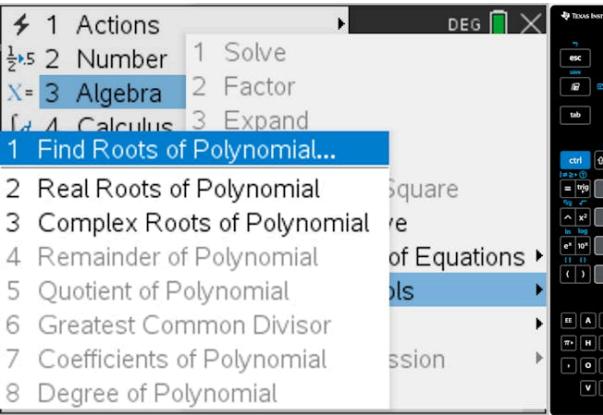
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Step	Explanation
<p>In these instructions you will see how to use the polynomial equation solver to find the roots of the quadratic equation</p> $ax^2 + bx + c = 0$ <p>for</p> $a = 1$ $b = -2 \times 4.2 \times \cos(65.6^\circ)$ $c = 4.2^2 - 6.5^2$ <p>Start with opening a calculator page.</p>	
<p>You can use variables to store the coefficients.</p> <p>Make sure you use the assigned equal.</p> <p>Make sure your calculator is in degree mode so that you get the correct cosine value in the definition of <math>b</math>.</p>	 <pre> a:=1 b:=-2*4.2*cos(65.6) c:=(4.2)^2-(6.5)^2 </pre>



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Step	Explanation
<p>You can access the polynomial root finder through the menu system ...</p>	 <p>The screenshot shows the TI-Nspire CX CAS calculator's main menu. The 'Algebra' icon (a blue X=) is highlighted. The menu items are:</p> <ul style="list-style-type: none"> <li>1 Actions</li> <li>2 Number</li> <li><b>3 Algebra</b></li> <li>4 Calculus</li> <li>5 Probability</li> <li>6 Statistics</li> <li>7 Matrix &amp; V</li> <li>8 Finance</li> <li>9 Functions</li> <li>8 Polynomial Tools</li> <li>9 Fraction Tools</li> <li>A Convert Expression</li> </ul>
<p>... choose the polynomial root finder option.</p>	 <p>The screenshot shows the TI-Nspire CX CAS calculator's Algebra menu. The 'Find Roots of Polynomial...' option (1) is highlighted. The menu items are:</p> <ul style="list-style-type: none"> <li>1 Actions</li> <li>2 Number</li> <li><b>3 Algebra</b></li> <li>4 Calculus</li> <li>1 Find Roots of Polynomial...</li> <li>2 Real Roots of Polynomial</li> <li>3 Complex Roots of Polynomial</li> <li>4 Remainder of Polynomial</li> <li>5 Quotient of Polynomial</li> <li>6 Greatest Common Divisor</li> <li>7 Coefficients of Polynomial</li> <li>8 Degree of Polynomial</li> </ul>



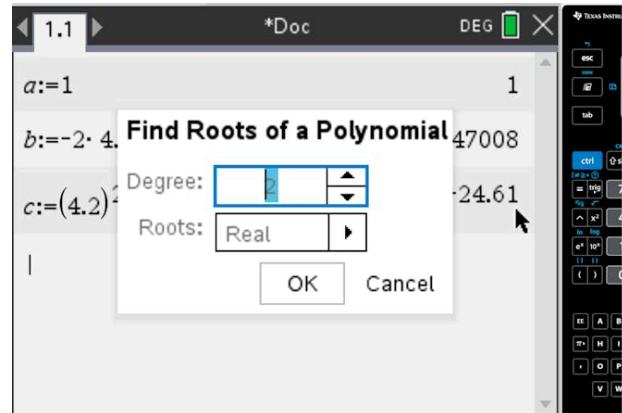
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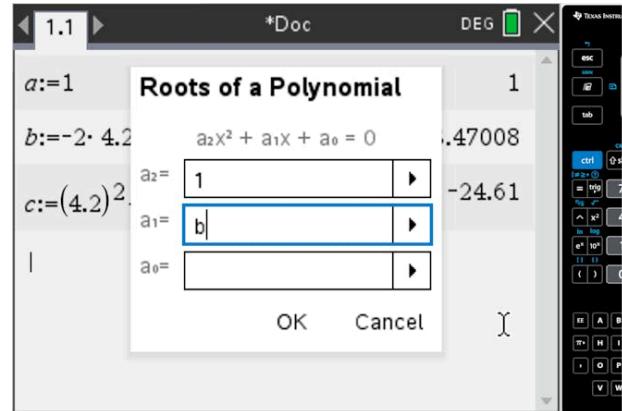
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Step	Explanation
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This is a quadratic equation, so choose degree 2.

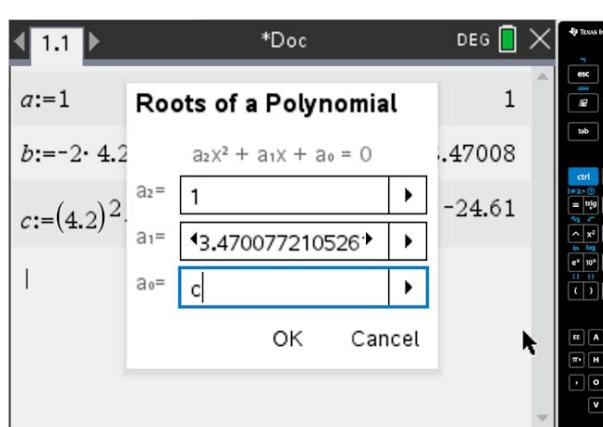
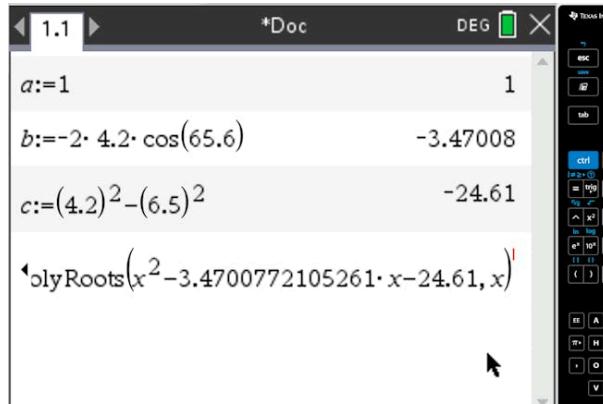


You can enter the names of the coefficients instead of typing in the full expression again.



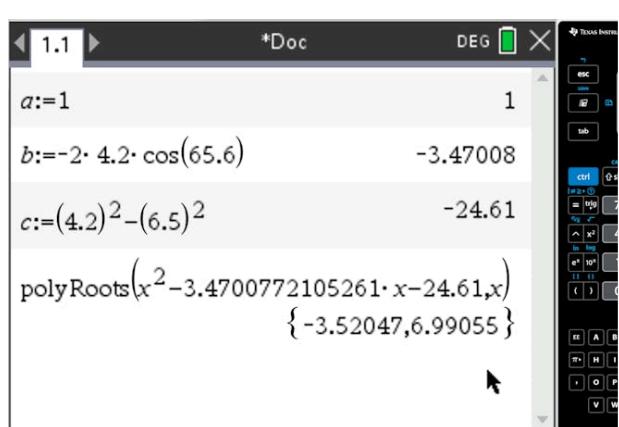
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Step	Explanation
<p>Note, that the expression you entered for <math>b</math> is converted to a number.</p>	
<p>The command is now put on the calculation screen. If you remember the format, you can type this in directly. If you do this, you can use the names <math>a</math>, <math>b</math> and <math>c</math> instead of the values. Press enter to see the solutions.</p>	

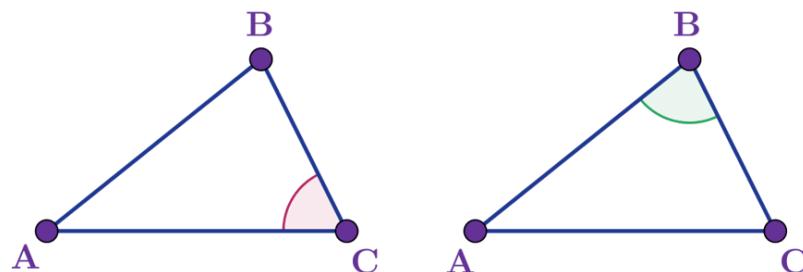


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Step	Explanation
<p>There are two solutions. In the context (<math>x</math> is the side length of a triangle), only the positive solution is meaningful.</p>	 <pre> 1.1 *Doc DEG a:=1 b:=-2·4.2·cos(65.6) c:=(4.2)<sup>2</sup>-(6.5)<sup>2</sup> polyRoots(x<sup>2</sup>-3.4700772105261·x-24.61,x) {-3.52047, 6.99055} </pre>

### ✓ Important

When labelling angles using three letters, the letter in the middle is the vertex of the angle. For example the vertex of angle ABC is B.



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The image shows two side-by-side triangles labeled ABC. In the first triangle on the left, there is an emphasis on angle C, highlighted with a pink area. The vertices are marked A, B, and C from the bottom left to bottom right. In the second triangle on the right, angle B is highlighted with a green area, indicating the angle at vertex B. The orientation and labels remain consistent across both triangles, emphasizing the relation between the internal angles of a triangle and showing the highlighted angles at each specific vertex. This description aligns with the text provided beneath the image that denotes angle equivalencies:  $\angle C = \angle BCA = \angle ACB$  and  $\angle B = \angle ABC = \angle CBA$ .

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$$\angle C = \angle BCA = \angle ACB \quad \angle B = \angle ABC = \angle CBA$$

### ① Exam tip

Make sure that your calculator is set to working in degrees when solving triangles and check that your answer looks sensible.

## Example 2



ABCD is a quadrilateral  $AB = 40\text{ m}$ ,  $BC = 50\text{ m}$ ,  $CD = 71\text{ m}$ ,  $AD = 30\text{ m}$  and the angle  $DAB = 90^\circ$ .

X  
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Find the area of quadrilateral ABCD. Give your answer correct to 1 decimal place.



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Step	Explanation
	Draw the diagram of the quadrilateral. You can start at any point and follow either clockwise or anticlockwise to mark the vertices.
	Draw the diagonal $DB$ to divide the quadrilateral into two triangles.
$\text{area } ABCD = \text{area } (DAB) + \text{area } (DBC)$	
$\text{area } (DAB) = \frac{1}{2} \times 40 \times 30$ $\text{area } (DAB) = 600 \text{ m}^2$	Using area = $\frac{1}{2}$ base $\times$



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Step	Explanation
$DB^2 = 30^2 + 40^2$ $DB = 50 \text{ m}$	You will need to find more information about triangle $ABC$ in order to find angle $C$ . You can use Pythagoras' theorem to find the length $DB$ .
$\cos C = \frac{50^2 + 71^2 - 50^2}{2 \times 50 \times 71}$ $\angle C = \cos^{-1} \left( \frac{50^2 + 71^2 - 50^2}{2 \times 50 \times 71} \right) = 44.765\ldots^\circ$	Use this length and the cosine rule in triangle $DBC$ .
$\text{area } (DBC) = \frac{1}{2} \times 50 \times 71 \times \sin 44.765\ldots^\circ$ $\text{area } (DBC) = 1249.95\ldots \text{ m}^2$	Using the formula $\text{area of triangle } = \frac{1}{2} \times \text{base} \times \text{height}$
$\text{area } ABCD = 600 + 1249.95\ldots$ $= 1850.0 \text{ m}^2 \text{ (1 d. p.)}$	Therefore, adding both triangle areas, $\text{area } ABCD = \text{area } (DAB) + \text{area } (DBC)$

## ✓ Important

When labelling polygons, start from any point and follow either a clockwise or anticlockwise direction.

# 2 section questions ^



Student view

Question 1





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In triangle ABC, AB =  $x$  cm, AC =  $2x$  cm, BC = 10 cm and angle BAC =  $60^\circ$ .

Calculate the value of  $x$  correct to 3 significant figures. Do not give the units with your answer.

5.77

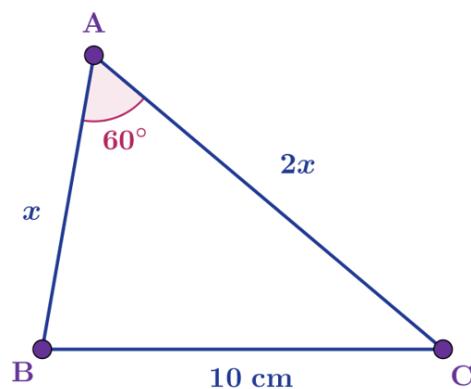


### Accepted answers

5.77, 5.77

### Explanation

Sketch the diagram:



More information

You are given 3 sides and an angle, so you can use the cosine rule in triangle ABC:

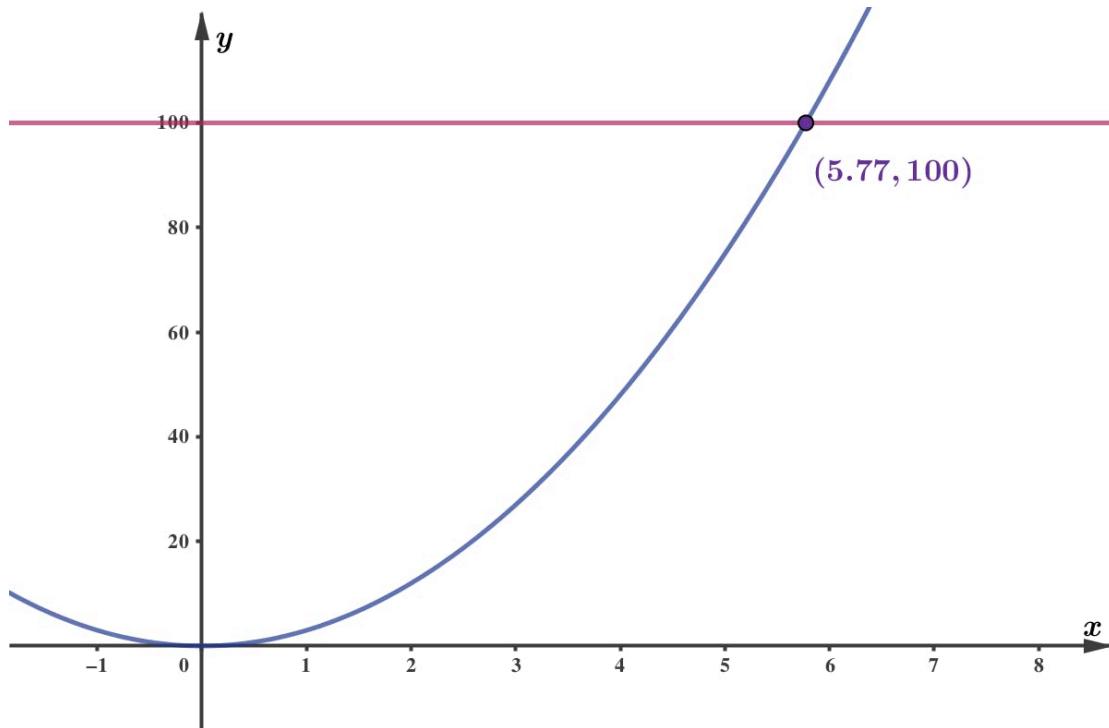
$$10^2 = x^2 + (2x)^2 - 2 \times x \times 2x \times \cos 60^\circ$$

Using the calculator,  $x = 5.7735\dots = 5.77$  cm (3 significant figures)



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More information

## Question 2



In quadrilateral ABCD, angle DAB =  $71^\circ$ , angle DBA =  $30^\circ$ , angle BDC =  $45^\circ$  and angle BCD is acute.

If AD = 11 cm and CB = 18 cm find the size of angle C.

Give your answer to 3 significant figures without the degree symbol.

54.8



### Accepted answers

54.8, 54,8

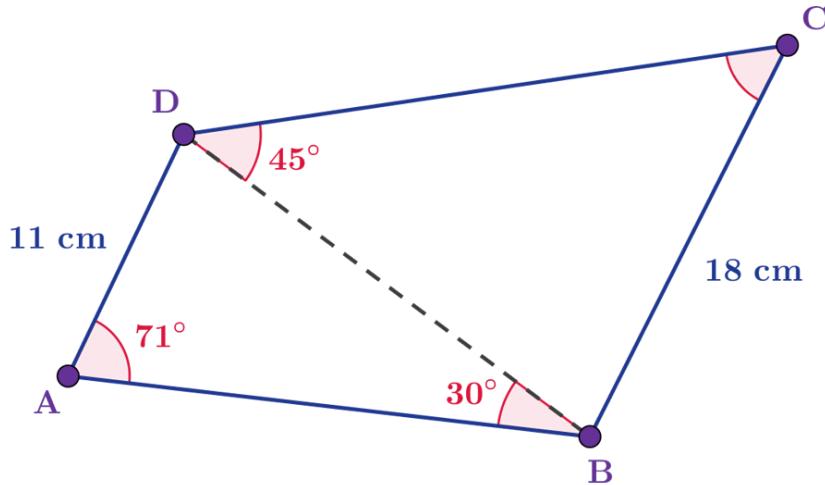
### Explanation

Draw the diagram and label it with the given values.



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More information

You can use the sine rule to find the side DB in triangle ADB

$$\frac{DB}{\sin 71} = \frac{11}{\sin 30}$$

$$DB = 20.801\dots \text{ cm}$$

Using the sine rule to find angle C in triangle DBC

$$\frac{\sin C}{20.8} = \frac{\sin 45}{18}$$

$$\text{angle } C = \sin^{-1} \left( \frac{20.801\dots \times \sin 45}{18} \right)$$

so angle  $C = 54.8^\circ$  (to 3 significant figures).

3. Geometry and trigonometry / 3.3 Applications of trigonometry

## Solving problems by sketching diagrams

**Section**

Student... (0/0)

Feedback

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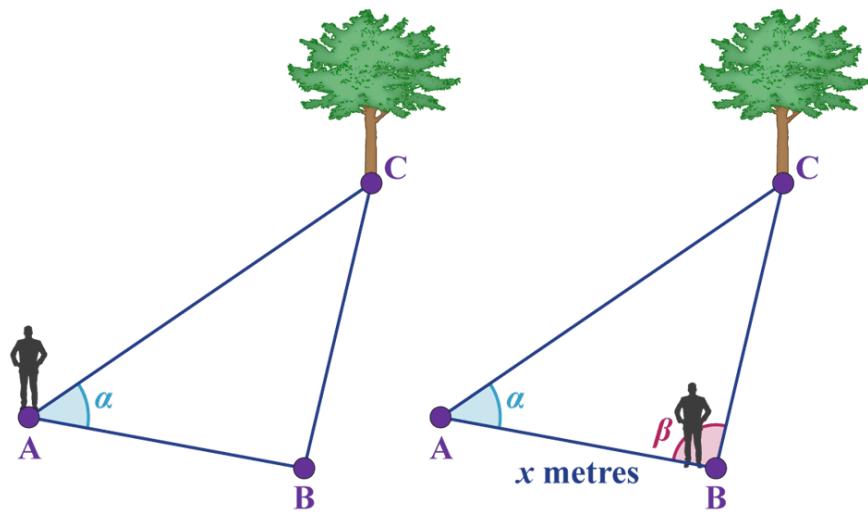
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# Finding the distance without actually measuring

Have you ever noticed a building, a hill or a landmark at a distance and wondered how far away it is? Did you know that you can use trigonometry to find the distance to the landmark without actually having to walk there?

The method for calculating the distance without physically measuring it is called triangulation, which is a method widely used by land surveyors.

A surveyor measures the viewing angle to a landmark from a distance, then walks along a straight line and measures the distance walked and the new viewing angle.



More information

The image shows a diagram illustrating how a surveyor measures angles to a landmark from two different positions. On the left, a surveyor at point A measures angle  $\alpha$  to a tree at point C. On the right, the surveyor has moved to point B, a distance  $x$  meters away from point A, and measures a new angle  $\beta$  to the same tree at point C. The diagram visually represents how these measurements relate to the positions of the surveyor and the tree, helping in calculating distances and angles through triangulation.



Student view

[Generated by AI]



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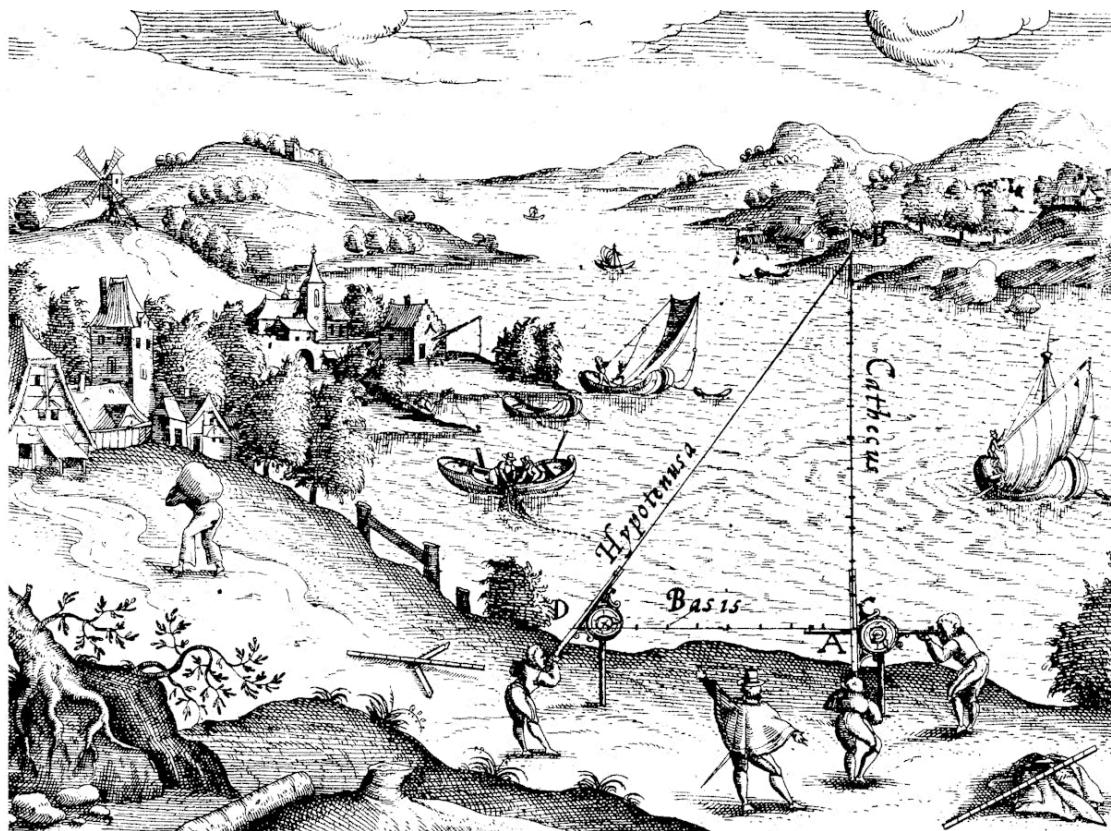
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Measure the viewing angle to the tree. Measure the distance walked and the new viewing angle.

Once you have the two base angles and the length of the base, you can solve the triangle.

## ★ Definition

In surveying, the tracing and measurement of a series of triangles in order to work out how far away distant objects are is called triangulation. This is usually done by measuring the base angles of a triangle and the distance between the vertices of the base. Trigonometry can then be used to work out the required distances.



16th century triangulation

Source: " CD006-Triangulation 16th century ([https://commons.wikimedia.org/wiki/File:CD006-Triangulation\\_16th\\_century.png](https://commons.wikimedia.org/wiki/File:CD006-Triangulation_16th_century.png)) " by Hulsius is in public domain.



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The image is an illustration from the 16th century, depicting a triangulation process used for measurement. The landscape features hills, trees, buildings, and a body of water. In the foreground, there are several figures positioned strategically with measurement tools. Two lines labeled 'Hypotenusa' and 'Cathetus' are drawn between the figures, showing the angles and sides of a triangle used in the measurement. Another line, labeled 'Basis,' forms the base of the triangle. The illustration includes various details such as boats on the water, distant hills, and small windmills on the far-left hill.

[Generated by AI]

## Example 1



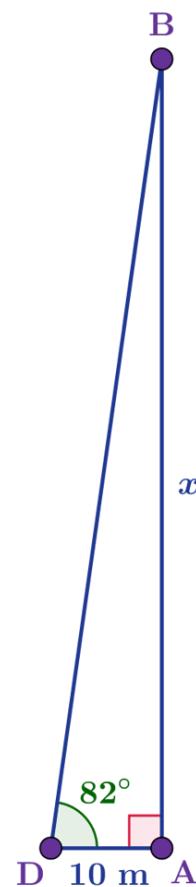
In the picture above, river surveyors in France are using triangulation to find the width of the river Seine. Angle  $D = 82^\circ$ , the length of the base  $DA = 10 \text{ m}$  and the angle  $A = 90^\circ$ . What is the width of the Seine to the nearest metre?

The diagram below shows what you know about triangle DAT.



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②

$$\tan 82 = \frac{x}{10}$$

$$x = 10 \times \tan 82 = 71.15 \dots = 71 \text{ m to the nearest metre}$$

### ⚠ Be aware

The width of the river is the perpendicular distance from D to A , not the hypotenuse of the triangle.

### 🌐 International Mindedness

✖

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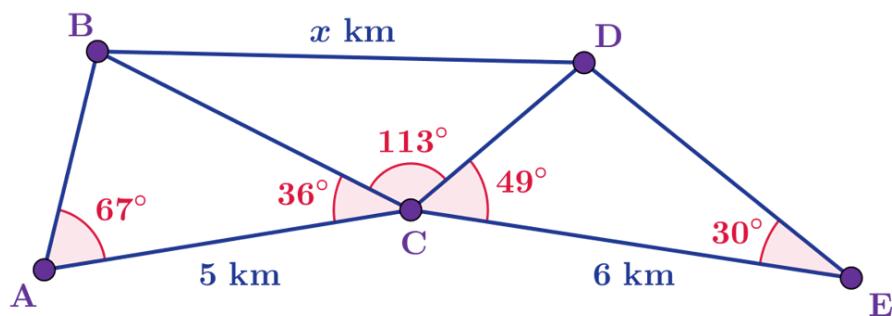
Between 1816 and 1855, the astronomer F.G.W. Struve used triangulation to map the region of land between the Arctic Sea and the Black Sea — a distance of over 2800 km. The chain includes 265 main station points and 258 main triangles. This study was the first accurate measurement of a long segment of a meridian which then helped with the development of Earth sciences and topographic mapping. You can find more information about this path, which was added to the UNESCO world heritage list in 2005, here in this [link](https://www.maanmittauslaitos.fi/en/about-nls/themes/struve-geodetic-arc). ↗ (<https://www.maanmittauslaitos.fi/en/about-nls/themes/struve-geodetic-arc>)

## Example 2



A land surveyor, measures the initial angle to a distant tree as  $67^\circ$ . She walks 5 km and measures the angle to the same tree from the base line to be  $36^\circ$ . She measures the angle between the viewing lines to both of the landmarks as  $113^\circ$ . She then walks 6 km along the base line CE, where the base angles are  $49^\circ$  and  $30^\circ$ . You can see her sketches in the diagram below.

Find the distance between the two landmarks B and D to the nearest km .



More information

This diagram illustrates a geometric shape consisting of lines connecting five points: A, B, C, D, and E. The lines form two triangles: ABC and CDE. The line segment AB measures 5 km, BD is represented as  $x$  km, and DE measures 6 km. The angles of triangle ABC at A and B are  $67^\circ$  and  $36^\circ$  respectively, with the angle

Student view



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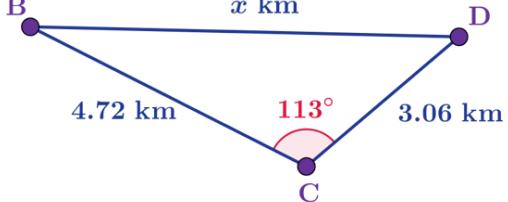
at C being  $113^\circ$ . Triangle CDE has angles at C and E of  $49^\circ$  and  $30^\circ$  respectively. The diagram is used for calculating distances and angles between marked points.

[Generated by AI]

Steps	Explanation
<p>Triangle BAC:</p> $\text{angle B} = 180 - (67 + 36) = 77$	<p>There are three triangles one of the side lengths of triangle BCD in which only the angle to side BD is given can find the sides BC and the length of BD can be found using the cosine rule.</p>
$\frac{BC}{\sin 67} = \frac{5}{\sin 77} = \frac{BC}{\sin 67}$ $BC = \frac{5 \times \sin 67}{\sin 77}$ $BC = 4.7235\dots$	<p>You can find BC using the cosine rule.</p> <p>Don't round your answer in the memory of your calculator.</p>
$\text{angle D} = 180 - (30 + 49) = 101^\circ$	



Student view

Steps	Explanation
$\frac{DC}{\sin 30} = \frac{6}{\sin 101}$ $DC = \frac{6 \times \sin 30}{\sin 101}$ $DC = 3.056\dots$	<p>You can find DC using the rule.</p> <p>Don't round your answer in the memory of your calculator.</p>
	<p>In triangle BCD:</p> <p>As you have two sides and an included angle, you can use the cosine rule to find the missing length.</p>
$x^2 = 4.72^2 + 3.06^2 - 2 \times 4.72 \times 3.06 \cos 113^\circ$ $x = 6.552\dots = 7 \text{ km (to the nearest km)}$	<p>Using the cosine rule</p> $c^2 = a^2 + b^2 - 2ab \cos C$

## ① Exam tip

Do not round your answers for  $BC$  and  $DC$  to the nearest km. Only round the final answer, the length of  $DB$ , to the nearest km. Otherwise you might lose A (accuracy) marks because of early rounding.

## झ The Theory of Knowledge

Trigonometry and geometry rely a great deal on representation. How accurate are visual representations in regard to the knowledge they provide? Watch the video below on the problem of maps and representing a three-dimensional object in a two-dimensional space.



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## 1 section question ^

### Question 1



A surveyor who wants to determine the width of a river, starts his measurements at point E.

Angle CED =  $31^\circ$ . He walks 20 m along the line DE and measures the angle CDG =  $54^\circ$ .

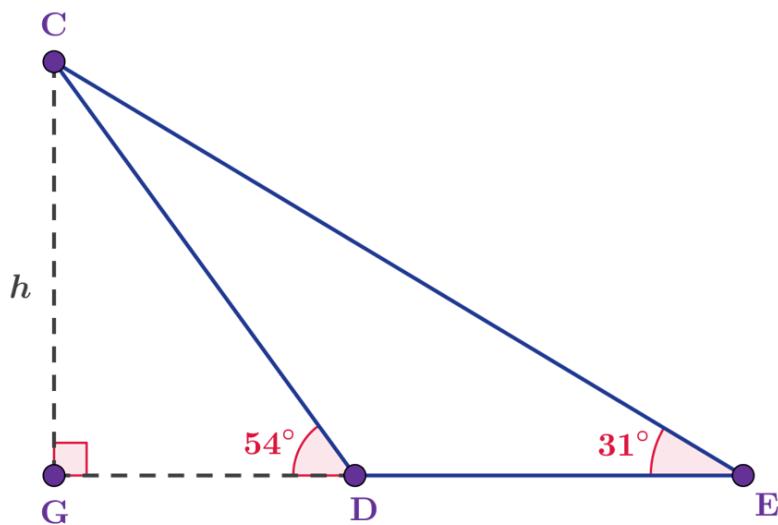
What is the width of the river (CG) to the nearest metre?

You do not need to give the units with your answer.



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More information

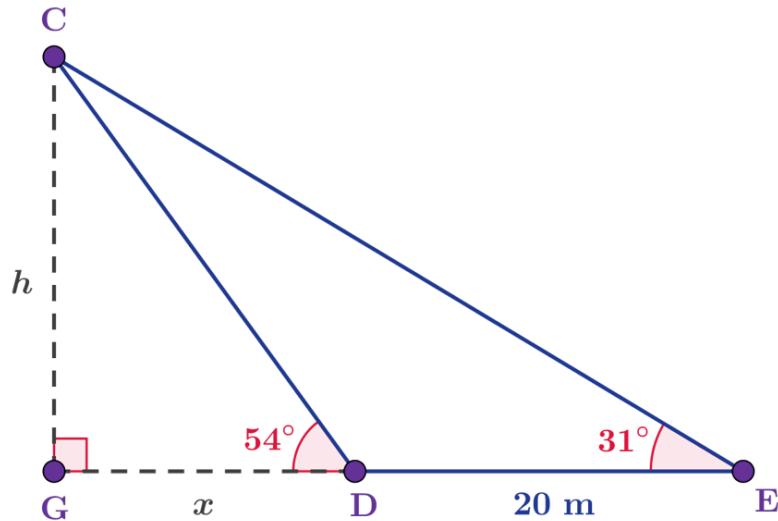
21



### Accepted answers

21, 21m, 21 m

### Explanation



More information

Using triangle CGE,  $\tan 31 = \frac{h}{x + 20}$

$$h = (x + 20) \tan 31$$



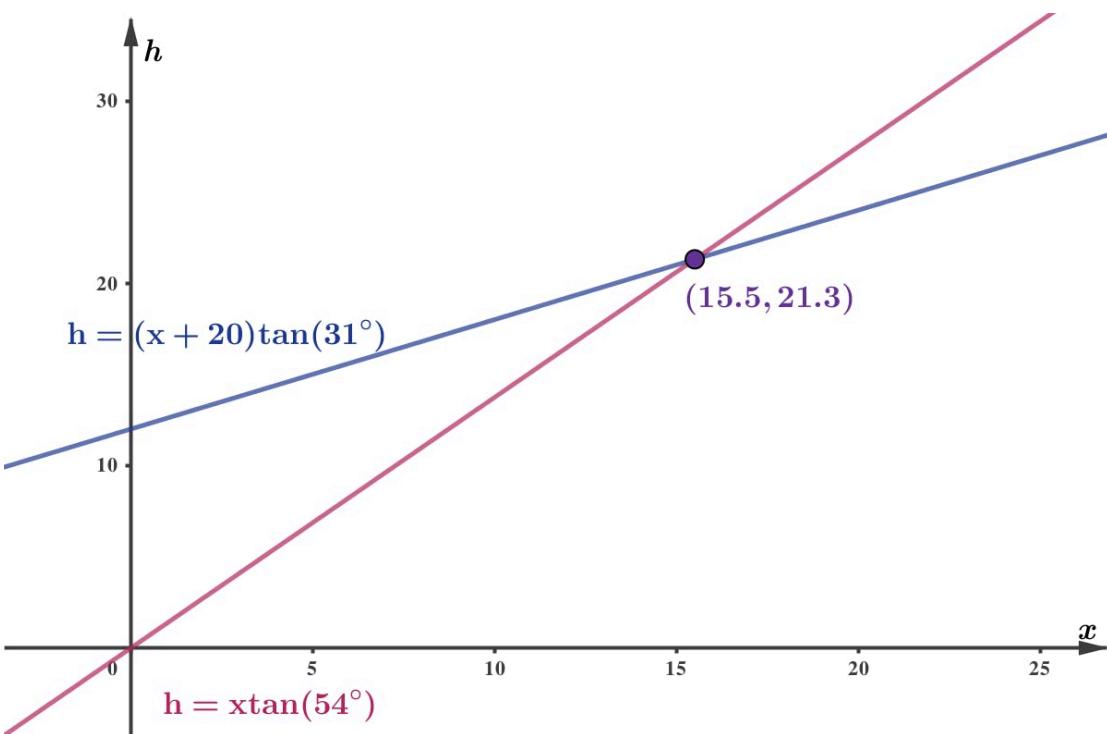
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Using triangle CDG,  $\tan 54 = \frac{h}{x}$



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Using a calculator



More information

$x = 15.5$  and  $h = 21.3 = 21$  m to the nearest metre.

3. Geometry and trigonometry / 3.3 Applications of trigonometry

## Bearings

Section

Student... (0/0)

Feedback

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## Compass directions

There are four main compass directions: north, south, east and west. The north–south line is perpendicular to the west–east line. The directions half way between are named north–east, south–east, south–west and north–west.

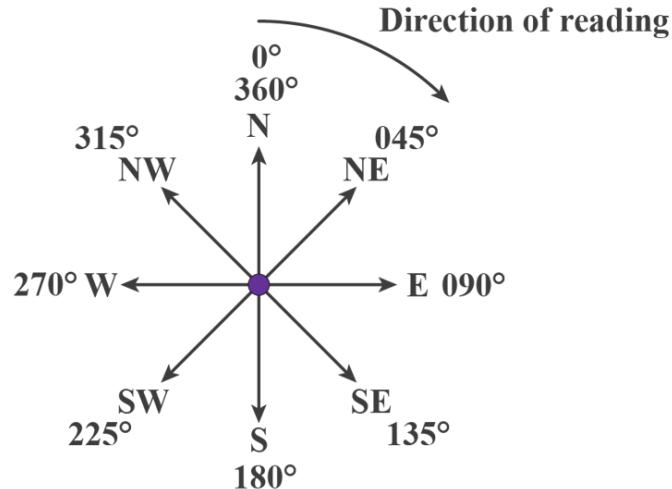


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Compass angles are always measured clockwise from north and they are written as 3-digit bearings. For example, north–east is  $045^\circ$  and north–west is  $315^\circ$ .

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More information

This image is a diagram of a compass rose showing the cardinal and intercardinal directions with their corresponding angles. At the center is a purple circle. Eight arrows emanate from the center pointing towards north, north-east, east, south-east, south, south-west, west, and north-west. Each direction is marked with its bearing angle: North (N) is labeled as  $0^\circ/360^\circ$ , North-East (NE) as  $045^\circ$ , East (E) as  $090^\circ$ , South-East (SE) as  $135^\circ$ , South (S) as  $180^\circ$ , South-West (SW) as  $225^\circ$ , West (W) as  $270^\circ$ , and North-West (NW) as  $315^\circ$ . There is also an arrow labeled 'Direction of reading' indicating clockwise movement starting from the north.

[Generated by AI]

## ☆ Definition

A bearing is the angle between the north line and the direction of a movement from the centre of the compass, measured in a clockwise direction. Bearings always have three figures.

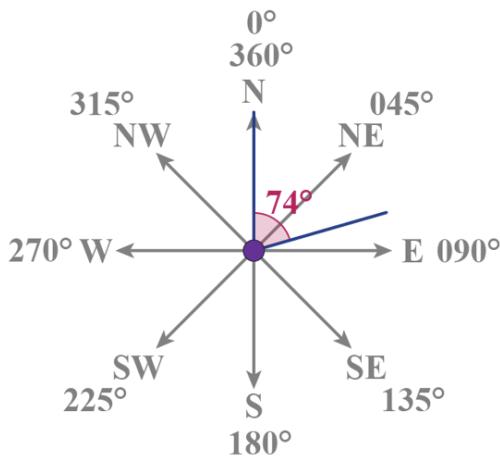
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On the compass shown below you can see a bearing of  $074^\circ$ .

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More information

The image is a compass rose diagram displaying cardinal directions along with intercardinal directions and corresponding degrees. At the top of the compass is North marked as both  $0^\circ$  and  $360^\circ$ , and directly opposite is South marked as  $180^\circ$ . East is on the right side marked as  $090^\circ$ , and West is on the left marked as  $270^\circ$ .

Intercardinal directions include:

- Northeast (NE) at  $045^\circ$
- Southeast (SE) at  $135^\circ$
- Southwest (SW) at  $225^\circ$
- Northwest (NW) at  $315^\circ$

In the center of the compass is a circle that serves as the origin point for all direction vectors. A highlighted bearing line extends from the center illustrating a bearing of  $074^\circ$ , which falls between North and East, slightly closer to East. This bearing is shown as a distinct line on the compass rose along with a marked arc to indicate the angle from the north direction.

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## Example 1

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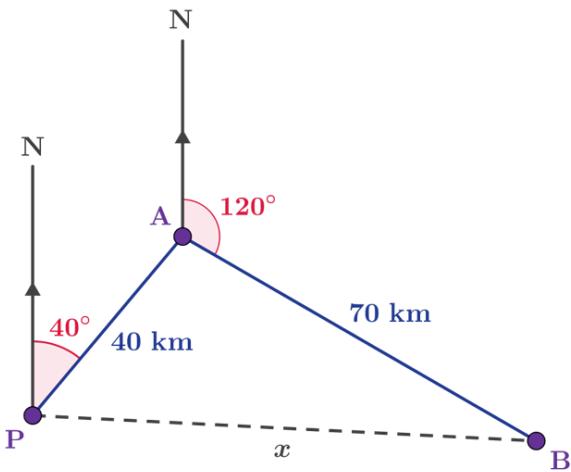


A ship leaves a port and travels 40 km on a bearing of  $040^\circ$ .

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After changing direction, it continues to travel another 70 km on a bearing of  $120^\circ$ .

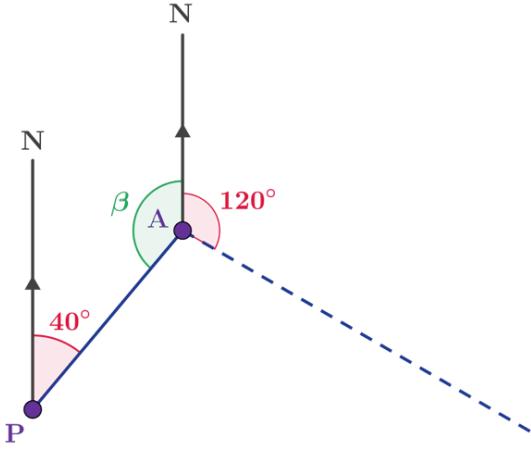
How far is the ship from the port?

Step	Explanation
	<p>First, sketch the information.</p> <p>In triangle PAB the lengths of two sides and the included angle are known. We need to find the length of the third side. Using the cosine rule we can find the size of angle PAB, you can use the cosine rule to calculate the distance from the port.</p>



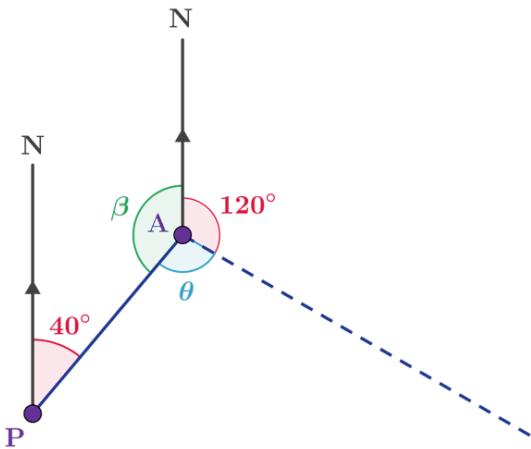
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Step	Explanation
	Angles $P$ and $\beta$ are interior angles of a straight line, so they add up to $180^\circ$ .

$$40 + \beta = 180$$

$$\beta = 140^\circ$$

	Angles at a point add up to $360^\circ$ .
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Step	Explanation
$\theta + 140 + 120 = 360$ $\theta = 100^\circ$	<p>Now you can use the cosine rule in triangle PAB.</p>

## Example 2



A ship sailing around an island, travels 30 km on a bearing of  $100^\circ$  to reach point B, as shown in the diagram below.

From B, the ship changes direction and travels 23 km to point C.

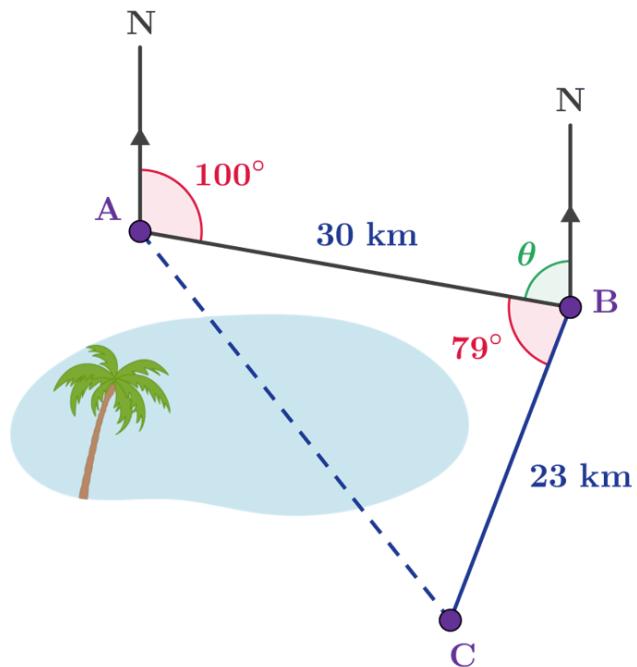
- a) If angle ABC =  $79^\circ$ , find the bearing of C from B.

Student view



b) Find the distance  $AC$ .

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More information

The image is a diagram illustrating a triangle labeled with points A, B, and C. Point A is connected to B with a distance of 30 km and an angle of  $100^\circ$  measured counterclockwise from North. Point B to C is 23 km, forming an angle of  $79^\circ$  with the line AB. There is an angle  $\theta$  labeled between the line AB and vertical at point B. The triangle is positioned with some geographical elements like a palm tree and a body of water depicted below the triangle, suggesting a real-world context for the distances.

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a) Angles  $A$  and  $\theta$  are co-interior angles; therefore  $\theta = 180^\circ - 100^\circ = 80^\circ$ .



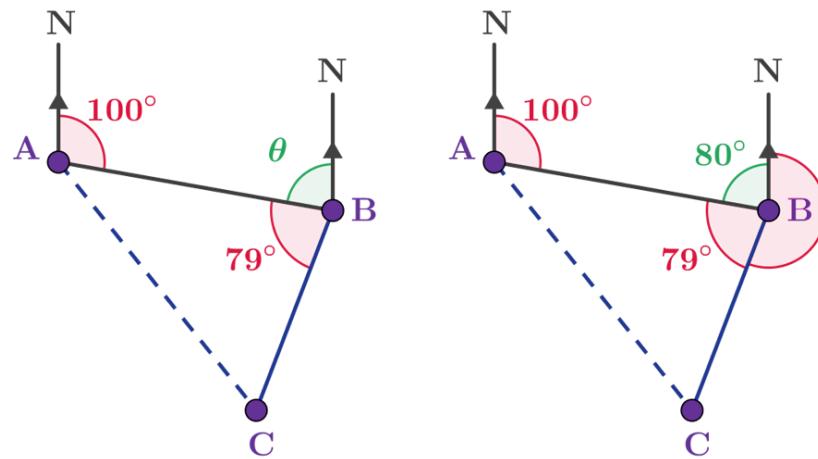
Student  
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Angles around point B add up to  $360^\circ$ .

Therefore, the bearing of C from B is  $360^\circ - 80^\circ - 79^\circ = 201^\circ$ .

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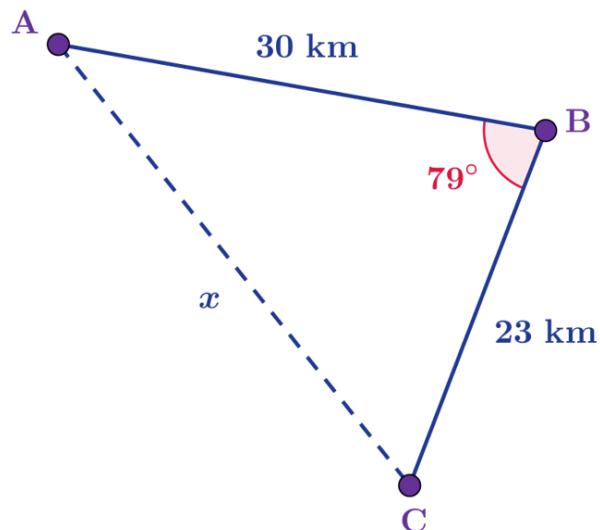
Angles  $\theta$  and  $A$  are co-interior angles    Angles around point B add up to  $360^\circ$

b) In triangle ABC, two sides and the included angle are given and you are asked to find the third side. So you can use the cosine rule to find the length of AC.



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$$x^2 = 30^2 + 23^2 - 2 \times 30 \times 23 \times \cos 79^\circ = 1165.68\dots$$

$$x = 34.142\dots = 34.1 \text{ km (3 significant figures)}$$

## 2 section questions ^

### Question 1



★★★

A ship leaves port  $A$  and sails  $120 \text{ km}$  on a bearing of  $070^\circ$  to reach port  $C$ .

Another ship leaves port  $B$  and sails  $140 \text{ km}$  on a bearing of  $145^\circ$  and reaches port  $C$ .

Find the distance between port  $A$  and port  $B$  correct to 3 significant figures.

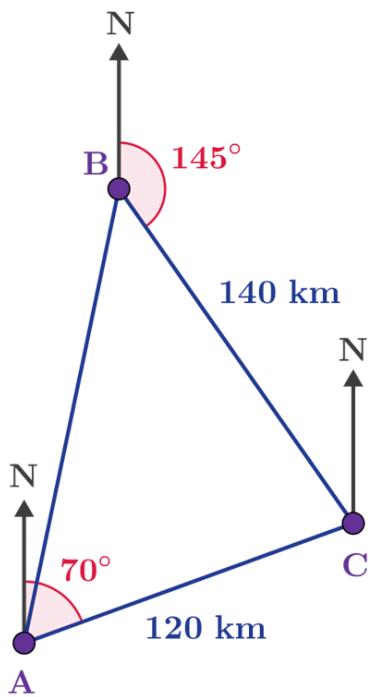


You do not need to give the units with your answer.



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More information

159

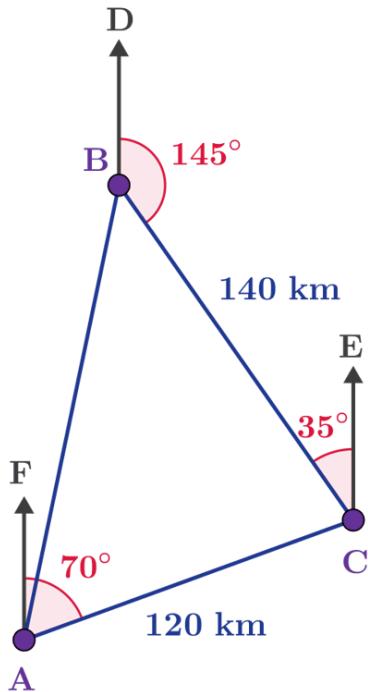


### Accepted answers

159, 159 km, 159km

### Explanation

angle ECB =  $180 - 145 = 35^\circ$



More information



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view



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$$\text{angle ECA} = 180 - 70 = 110^\circ$$

Let angle ACB =  $x$

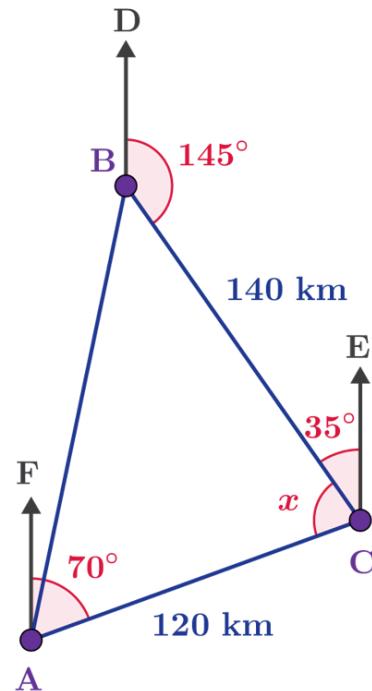
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More information

Now that you know two sides and the included angle, you can use the cosine rule to find the length of AB in triangle ABC

$$AB^2 = 120^2 + 140^2 - 2 \times 120 \times 140 \times \cos 75^\circ$$

$$AB = 159.07\dots = 159 \text{ km (3 significant figures)}$$

## Question 2

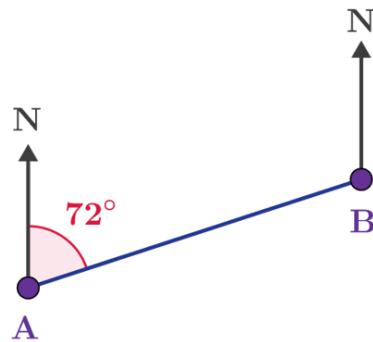


If the bearing from A to B is  $072^\circ$ , find the bearing from B to A.



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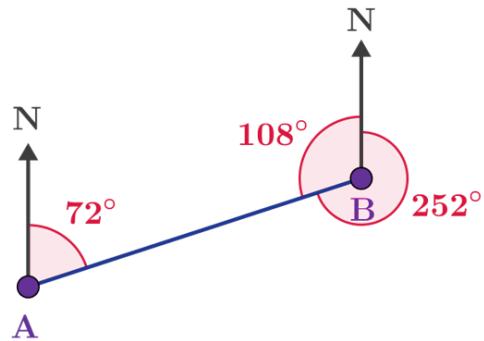
1  $252^\circ$

2  $072^\circ$

3  $108^\circ$

4  $288^\circ$

### Explanation



More information

3. Geometry and trigonometry / 3.3 Applications of trigonometry

## Angles of elevation and depression



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# Defining the heights

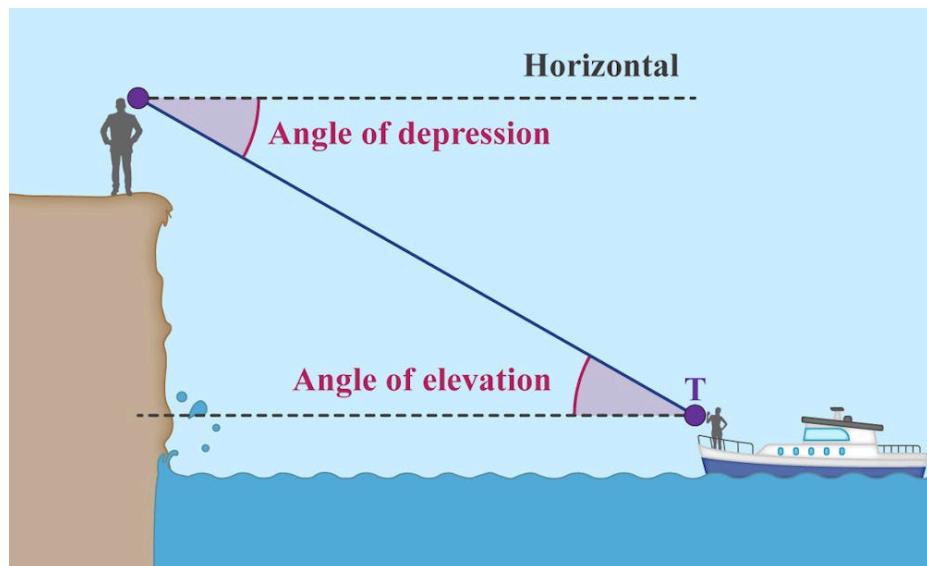
- If you are standing on a tower or a high object and looking downwards, your perspective will be different from that of a person who is standing at a distance and looking upward to where you are standing.

## ☆ Definition

The upward angle from a horizontal line of sight from an observer to a landmark on a high location is called **the angle of elevation**.

The downward angle from a horizontal line of sight from an observer to a landmark on a lower location is called **the angle of depression**.

The diagram shows an angle of elevation and an angle of depression. These two angles are used to calculate the distances and heights in navigation and surveying.



More information

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The image is a diagram illustrating the angles of elevation and depression used in navigation and surveying. A person is standing on a cliff edge observing a boat on the water level. A horizontal line intersects at the observer's eye level, extending towards the boat. The angle of depression is marked from the horizontal line downwards to the boat. Conversely, the angle of elevation is measured upwards from the water level position of the boat to the same horizontal line. The observer's line of sight towards the boat is depicted as a solid line, creating a triangular shape with the horizontal. The boat is labeled 'T'.

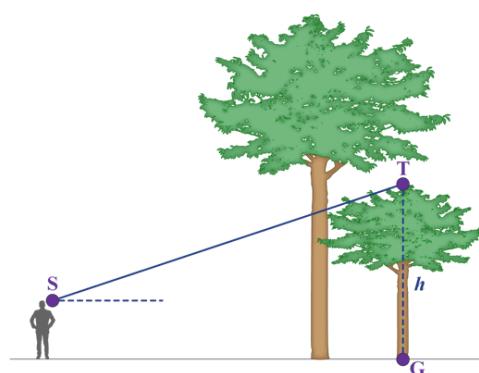
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## Example 1



The world's second tallest tree is a centurion, in Arve Valley Tasmania, Australia. It towers above the trees around it as it is 99.82 m tall. A forest surveyor is measuring the heights of other trees around the region. He measures the angle of elevation from his eye level to be  $81^\circ$  and the distance to the foot of the tree to be 8 m.

If his eye level is 1.58 m above the ground, find the height of the tree to the nearest centimetre.



More information



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The diagram shows a comparison between two trees in terms of height. The larger tree is positioned in the background, and the smaller tree is in the foreground. A person is standing to the left of the smaller tree, marked by the letter 'S'. From 'S', a diagonal line is drawn towards the top of the smaller tree marked 'T'. From 'T', a vertical line labeled 'h' extends down to the base point 'G' of the smaller tree. This represents the tree's height. The larger tree does not have any specific labels or measurements shown. The diagram illustrates a method of measuring tree height using proportional relationships, with visual lines showing horizontal and vertical alignments.

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Centurion tree, Arve Valley Tasmania, Australia

Source: "[Centurion tree 99.82](#)

([https://commons.wikimedia.org/wiki/File:Centurion\\_tree\\_99.82.jpg](https://commons.wikimedia.org/wiki/File:Centurion_tree_99.82.jpg))" by Eucalyptus 99 is licensed under CC BY-SA 4.0 (<https://creativecommons.org/licenses/by-sa/4.0/>)



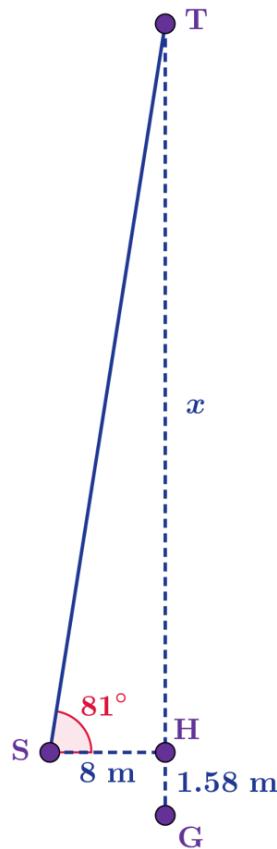
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## Step

## Explan



$$\tan 81^\circ = \frac{x}{8}$$

$$\begin{aligned}x &= 8 \tan 81^\circ \\&= 50.510\dots\end{aligned}$$

$$TG = 50.510\dots + 1.58 = 52.09\dots$$

So the height of the tree is 52.09 m (to the nearest cm).



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## Example 2

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An eagle sits at the top of a tree at the edge of the ocean watching a fishing boat.

The angle of depression is  $24^\circ$  and the tree is 47 m tall.



Bonelli's eagle

Credit: AndreAnita Getty Images

a) How far is the fishing boat from the eagle?

b) How far is the fishing boat from the base of the tree?

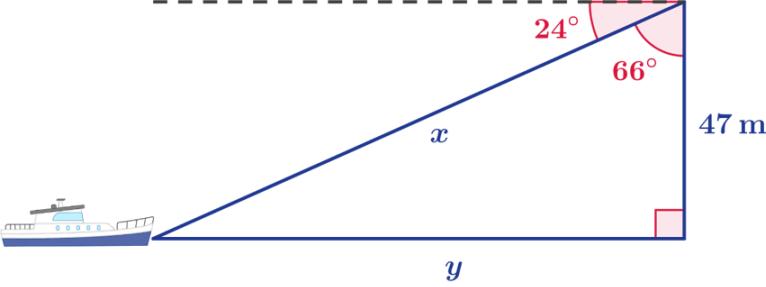
Give your answers to nearest metre.



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Step	Explanation
	<p>First, sketch a diagram.</p> <p>Notice that the angle of depression is measured horizontal, not from the</p>
$\odot$	
$\begin{aligned} \cos 66 &= \frac{\text{adj}}{\text{hyp}} \\ &= \frac{47}{x} \\ x \cos 66 &= 47 \\ x &= \frac{47}{\cos 66} = 115.55\dots \end{aligned}$ <p>So the distance of the fishing boat to the eagle is 116 m (to 3 significant figures).</p>	<p>To find the distance from the eagle to the boat, you need to find the length of the hypotenuse. You have the side adjacent to the angle <math>66^\circ</math>, so you can use the cosine ratio.</p>
$\begin{aligned} \tan 66 &= \frac{\text{opp}}{\text{adj}} \\ &= \frac{y}{47} \\ 47 \tan 66 &= y \\ y &= 105.56\dots \end{aligned}$ <p>So the distance of the fishing boat to the base of the tree is 106 m (to 3 significant figures).</p>	<p>To find the distance from the base of the tree to the boat, you need to find the length of the side opposite the angle of <math>66^\circ</math>. Since you have been given the adjacent side, you can use the tangent ratio.</p>



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## 🔗 Making connections



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Have you ever wondered how ships find their way in the ocean where there are no visible landmarks on the surface of earth? This section of the historic Piri Reis map (1513) shows South America and Antarctica in great detail even before they were claimed to have been discovered. How is this possible?

How does maths guide our ships at sea?

How does math guide our ships at sea? - George Christoph



## Example 3



The 3D diagram below shows the air traffic control tower (CD) and the starting point of two runways. The start of Runway 1 is at point A and the start of Runway 2 is at point B. Points A, B and C are on horizontal ground and the control tower is vertical.

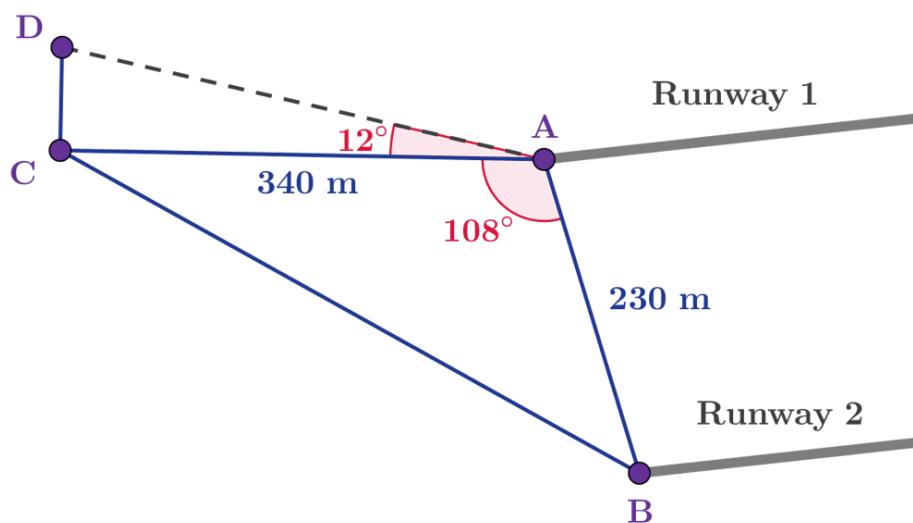
$AB = 230 \text{ m}$ ,  $AC = 340 \text{ m}$ , the angle of elevation of point D from point A is  $12^\circ$  and angle  $CAB = 108^\circ$ .



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More information

The image is a geometric diagram depicting a quadrilateral with labeled vertices A, B, C, and D. Points B and C are connected by a line segment labeled 230 m, while points C and A are connected by another segment labeled 340 m. The angle at vertex A between lines AB and AC is marked as 108 degrees. Above this angle, the angle of elevation from point A to point D is noted as 12 degrees. The diagram also includes lines representing runway paths labeled as "Runway 1" along AC and "Runway 2" along AB.

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## Calculate

- a) the distance BC
- b) the height of the control desk above the ground
- c) the angle of depression of the start of Runway 2 from the control desk.

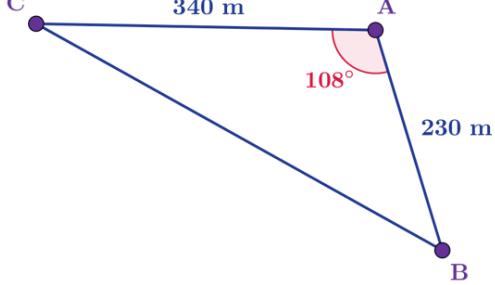
The airport management is planting more grass to make the airport feel more welcoming to passengers. The triangle ABC is to be seeded with grass. A bag of grass seed weighing 10 kg covers  $1156 \text{ m}^2$  and costs 320 Norwegian krone (NOK).

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d) How much will it cost to seed the triangular area ABC? Give your answer to the nearest 100 NOK.

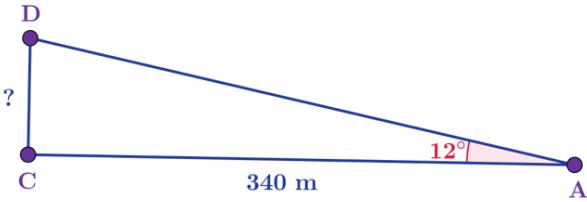
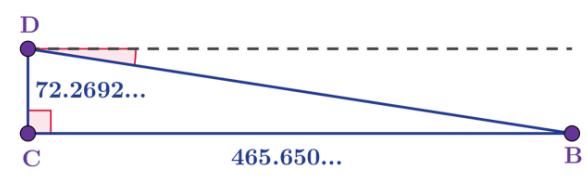
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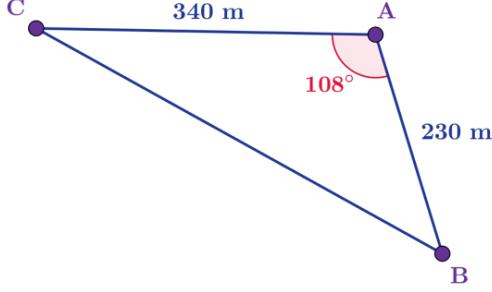
	Step	Explanation
a)	 <p>First, sketch the triangle ABC and list the information you are given.</p>	
	$BC^2 = 340^2 + 230^2 - 2(340)(230) \cos 108^\circ$ $BC^2 = 216830.257\dots$ $BC = 465.65036\dots$ <p>So <math>BC = 466</math> m (to 3 significant figures).</p>	<p>You have two sides and the enclosed angle. Therefore, you can use the cosine rule</p> $c^2 = a^2 + b^2 - 2ab \cos C$ <p>This is a question given in context. You need to include units in your answer to score full marks.</p>



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	Step	Explanation
<span data-bbox="112 92 152 125">Home</span> Overview (/study/app/math-aa-hl/sid-134-cid-761926/o)	<b>b)</b> 	<p>You can use the right-angled triangle DCA to work out the height of the control desk above the ground. This is the length CD on the diagram.</p> <p>Since you have the sides opposite and adjacent to the angle of <math>12^\circ</math>, you can use the tangent ratio.</p>
	$\tan 12 = \frac{CD}{340}$ $CD = 340 \tan 12 = 72.2692\dots$	Rearrange and solve for CD.
	Therefore, the height of the control desk above the ground is 72.3 m (to 3 significant figures).	
<span data-bbox="112 2023 152 2057">X</span> Student view	<b>c)</b> 	<p>To find the angle of depression, we need to look down from point D to point B. The angle you want to measure is the angle measured downwards from the horizontal, as shown in the diagram.</p> <p>Using alternate angles, the angle of depression is equal to angle B.</p>
	$\tan B = \frac{72.2692}{465.650}$	Again, you have opposite and adjacent sides in a right-angled triangle. You can use the tangent ratio.

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	Step	Explanation
	$\tan^{-1} \left( \frac{72.2692}{465.650} \right) = 8.82196\ldots^\circ$ <p>The angle of depression of B from D is <math>8.82^\circ</math> (to 3 significant figures).</p>	<p>To find the angle, you need to use inverse tangent.</p> <p>Remember: on the calculator either type <math>\tan^{-1} \left( \frac{72.2692}{465.650} \right)</math> or type <math>\tan^{-1}(72.2692 / 465.650)</math> and then enter <math>\tan^{-1}(ANS)</math> rather than rounding the decimal.</p>
d)		<p>To find the amount of grass needed to know the area of the triangle ABC. The easiest approach is to use the formula</p> $\text{area} = \frac{1}{2}ab \sin C$ <p>because you are given two sides and the included angle and the triangle does not have a right angle.</p>
	<p>Number of bags of grass seed = <math>37186.3\ldots \div 1156 = 32.1680\ldots</math> so 33 bags are needed.</p>	<p>To find out how many bags are required, you need to divide <math>37186.3\ldots \text{ m}^2</math> by <math>1156 \text{ m}^2</math>.</p> <p>You don't need to use the full answer as each bag weighs 10 kg.</p> <p>You need more than 32 bags as you cannot buy exactly 32.168 bags, so you will need to buy 33 bags.</p>



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	Step	Explanation
	<p>This costs</p> $33 \times 320 = 10\,560 \text{ NOK}$ <p>To the nearest 100 NOK, the answer is 10 600 NOK.</p>	<p>Each bag costs 320 NOK.</p> <p>Round your final answer to the nearest 100 NOK.</p>

## ① Exam tip

It is essential to include the line of work that demonstrates correct substitution into the correct formula. When the IB exam papers say ‘you are advised to show all working’ they definitely mean to include this particular line of working.

Examiners consistently advise students to show their unrounded answers in their work, before attempting to round correctly. Do not round until you give your final answer.

## 2 section questions ^

### Question 1



★★★

From the top of a lighthouse, the angles below the horizontal to two ships P and Q are  $30^\circ$  and  $40^\circ$  respectively. The ships and the lighthouse are on a straight line.

The distance between the ships is 100 m.

Find the height of the lighthouse to the nearest metre.

You do not need to give the units with your answer.



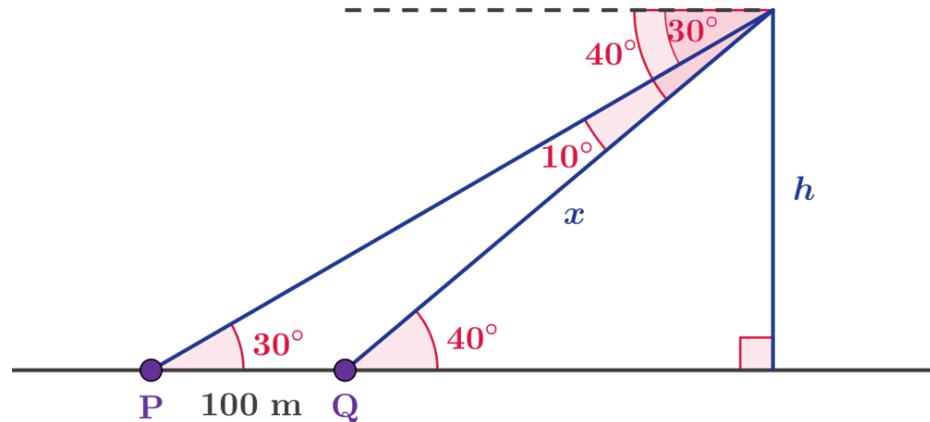
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**Accepted answers**

185, 185m, 185 m

**Explanation**

Make a sketch using the information given.


 ⓘ More information

$$\begin{aligned}\frac{x}{\sin 30} &= \frac{100}{\sin 10} \\ x &= \frac{100 \sin 30}{\sin 10} \\ \frac{h}{\sin 40} &= \frac{x}{\sin 90} \\ \text{so } h &= 100 \times \sin 30 \times \sin 40 / \sin 10 \\ &= 185.08\dots\end{aligned}$$

So the height of the lighthouse is 185 m (to the nearest metre).

**Question 2**

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More information

In the diagram above, what is the angle of elevation of the point C from the point A?

Assume that the line segment joining B and C is vertical.

1     $BAC$

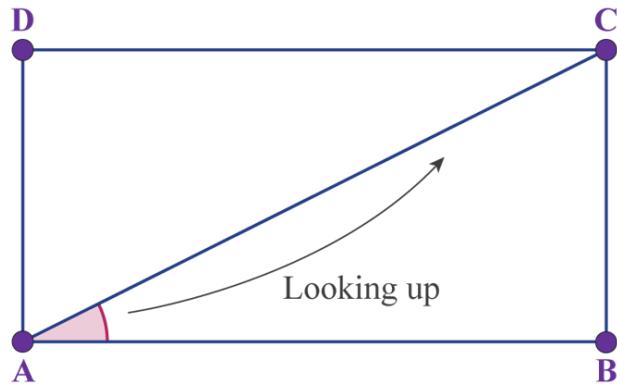


2     $ABC$

3     $ACB$

4     $DAC$

### Explanation



More information

The angle of elevation of C from A is the angle between the horizontal line AB and the line segment AC.



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Therefore the angle of elevation is  $BAC$  (or  $CAB$ ).



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# Checklist

**Section**

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Feedback



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**Assign**

## What you should know

By the end of this subtopic you should be able to:

- sketch diagrams in order to solve problems involving angles and lengths
- select and use the correct formula to solve a problem from the information given in the question
- use triangulation to find distances and areas
- find a bearing and use it to calculate distances
- identify and calculate angles of elevation and depression.

3. Geometry and trigonometry / 3.3 Applications of trigonometry

# Investigation

**Section**

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Feedback



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**Assign**

# Parallax

Have you wondered how astronomers measure the distance to stars without actually having to travel there? Or why some objects seem to be moving faster than others when you are in a moving car and watching the view outside. Or why, when you



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hold your thumb up in front of your eye and close only your left eye looking at an object in the distance, and then close only your right eye looking at the same object without moving your thumb, the object moves? All this illusion is created by parallax, an apparent displacement of an object because of the change in the observer's point of view.

Stellar parallax is used to determine the distance of nearby stars but it is not reliable because of the errors involved in measurements. See the video below if you would like to learn more about the use of parallax in astronomy.

Light seconds, light years, light centuries: How to measure extreme d...



In this investigation, you will be using the idea of parallax to measure the distance to a distant object.

Materials needed:

- A protractor or a compass
- A tape measure or a trundle wheel

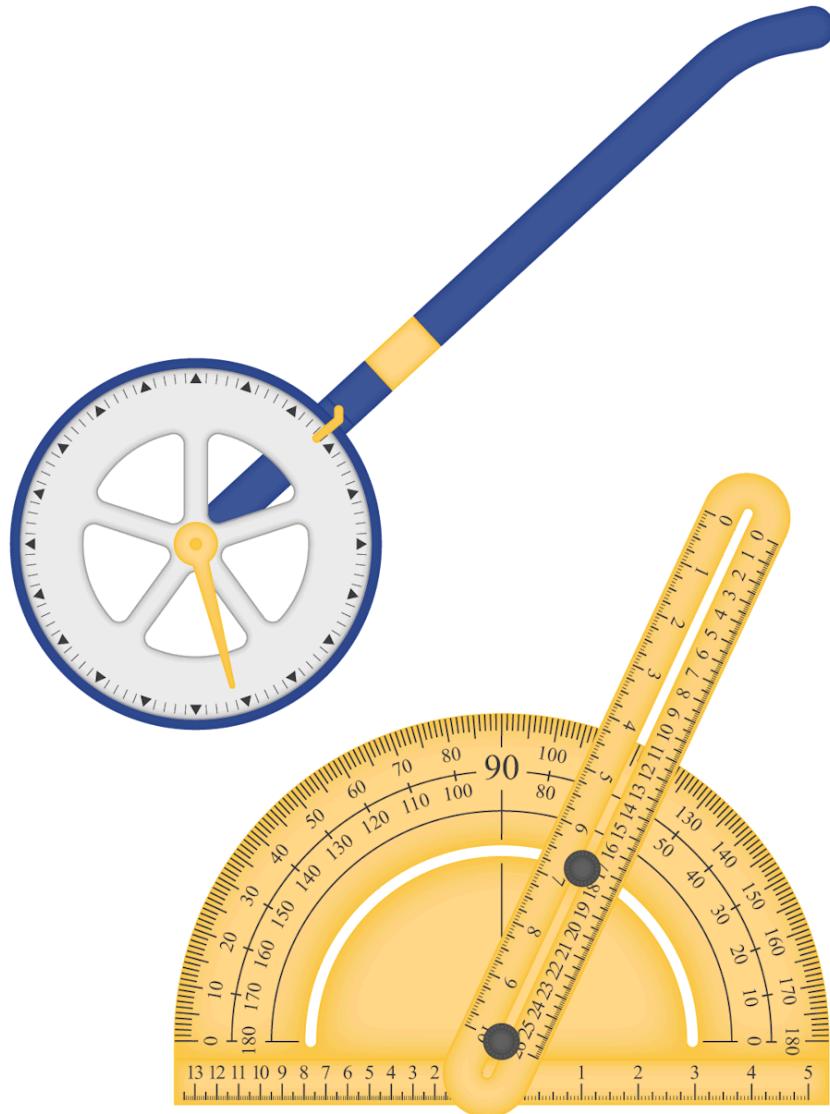


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## Before you go out and start measuring

Parallax:

- Why do you think there is a difference in the observed and measured distance to distant objects?
- Does the distance to the distant object have effect on parallax measurements? Explain.

Measurements:

- What are the measurements that you can take to calculate to distance? Sketch a diagram of measurements that you will need to take.
- What do you need to be careful about when measuring?



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- Which materials will you need?

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## Outside

- Identify a distant object and measure the distance and angles. (Remember you are not going to measure the actual distance.)
- Label your initial sketch with the measurements you take.

## Calculations and reflection

- Calculate the distance to the object.
- Consider whether the solutions make sense in real life.
- Consider the accuracy of your solutions – justify the accuracy and explain any reasons why inaccuracy exists.
- Write your report showing how you solved the problem.
- Write a conclusion.

### Rate subtopic 3.3 Applications of trigonometry

Help us improve the content and user experience.



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