

Precalculus

Solve triangle from side and two angles

Todor Milev

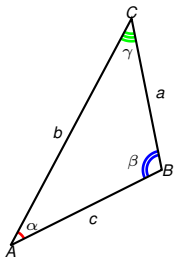
2019

Law of sines

Let $\triangle ABC$ have sides lengths a, b, c angles α, β, γ , as indicated: α is opposite to a , β is opposite to b , γ is opposite to c .

Proposition (Law of Sines)

$$\frac{a}{\sin \alpha} = \frac{b}{\sin \beta} = \frac{c}{\sin \gamma}.$$

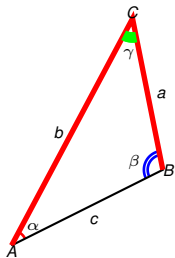


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Proof.

$$\text{Area}(\triangle ABC) = \frac{ab \sin \gamma}{2} = \frac{bc \sin \alpha}{2}$$

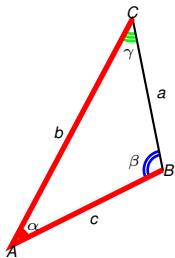


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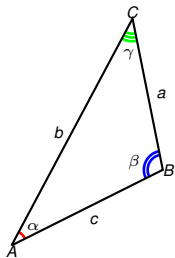


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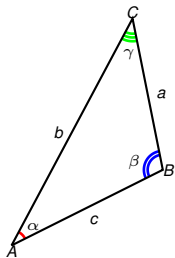


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Proof.

$$\text{Area}(\triangle ABC) = \frac{ab \sin \gamma}{2} = \frac{bc \sin \alpha}{2} \quad \left| \text{Div. by } \frac{b}{2} \right.$$

$$a \sin \gamma = c \sin \alpha$$

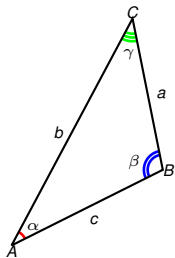


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Proof.

$$\begin{aligned} \text{Area}(\triangle ABC) &= \frac{ab \sin \gamma}{2} = \frac{bc \sin \alpha}{2} & \Bigg| \text{ Div. by } \frac{b}{2} \\ & \frac{a \sin \gamma}{a} = \frac{c \sin \alpha}{c} \\ & \sin \gamma = \sin \alpha. \end{aligned}$$

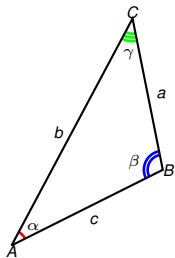


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$$\begin{aligned} \text{Area}(\triangle ABC) &= \frac{ab \sin \gamma}{2} = \frac{bc \sin \alpha}{2} & \left| \text{Div. by } \frac{b}{2} \right. \\ a \sin \gamma &= c \sin \alpha \\ \frac{a}{\sin \alpha} &= \frac{c}{\sin \gamma}. \end{aligned}$$

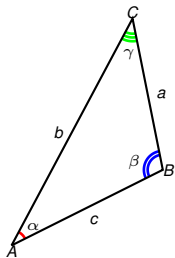


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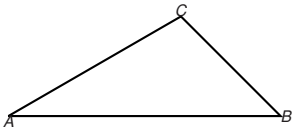


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The remaining cases are similar. □

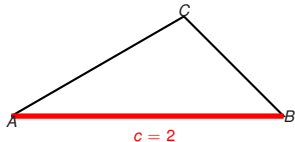
Example



A triangle has a side of length 2cm ; the two angles adjacent to it are 30° and 45° .

- Find the other two sides of the triangle.
- Find the area of the triangle.

Example

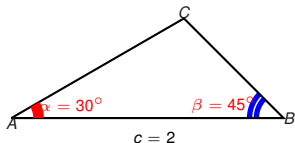


A triangle has a **side of length 2cm** ; the two angles adjacent to it are 30° and 45° .

- Find the other two sides of the triangle.
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- Let the known side be $c = 2\text{cm}$.

Example

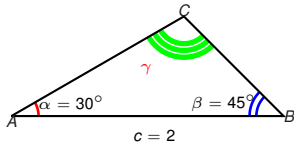


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- Find the other two sides of the triangle.
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- Let the known angles 30° , 45° be arranged as in the figure

Example

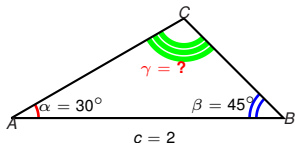


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- Find the other two sides of the triangle.
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- Let the known side be $c = 2\text{cm}$.
- Let the known angles 30° , 45° be arranged as in the figure, and let the **third angle be γ**

Example

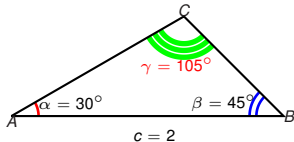


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Example

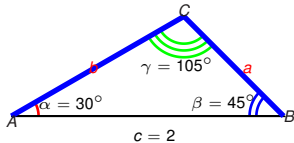


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Example

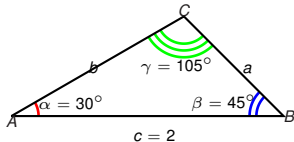


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- Label the unknown sides a, b as indicated.

Example



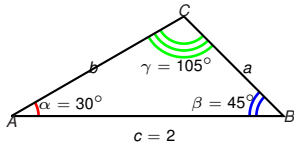
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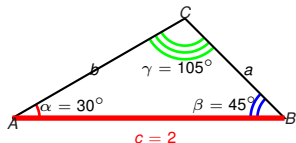
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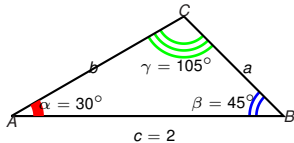
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$$a = \frac{c \sin \alpha}{\sin \gamma} = \frac{2 \sin 30^\circ}{\sin 105^\circ}$$

Example



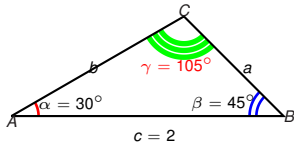
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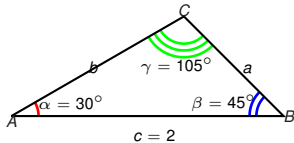
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$\sin 105^\circ$

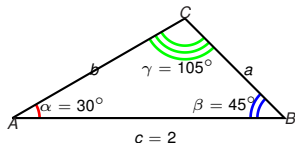
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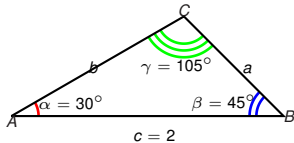
- Find the other two sides of the triangle.
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$$\sin 105^\circ = \sin(60^\circ + 45^\circ)$$

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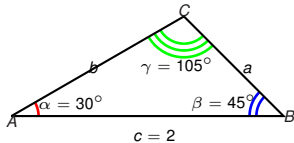
- Find the other two sides of the triangle.
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$$\sin 105^\circ = \sin(60^\circ + 45^\circ) = ?$$

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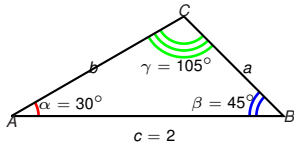
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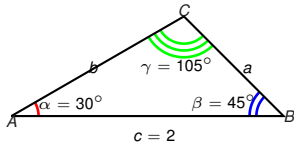
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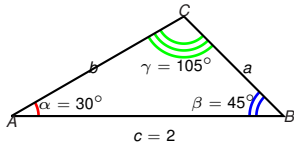
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$$= \frac{\sqrt{3}}{2} ? + ? ?$$

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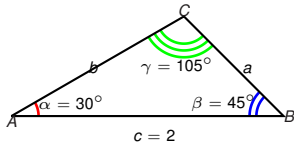
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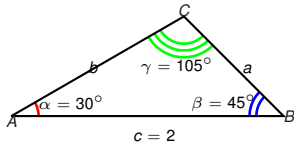
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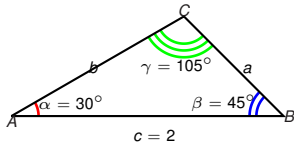
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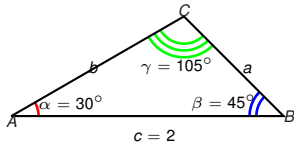
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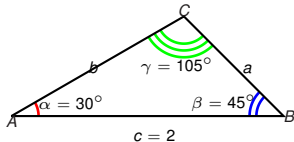
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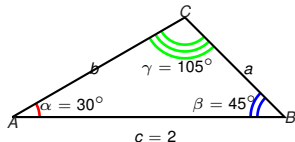
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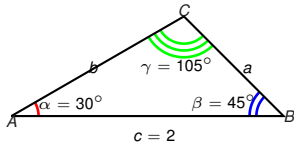
$$\sin 105^\circ = \sin(60^\circ + 45^\circ) = \sin 60^\circ \cos 45^\circ + \cos 60^\circ \sin 45^\circ$$

$$= \frac{\sqrt{3}}{2} \frac{\sqrt{2}}{2} + \frac{1}{2} \frac{\sqrt{2}}{2} = \frac{\sqrt{6} + \sqrt{2}}{4}$$

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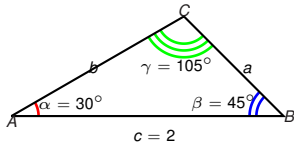
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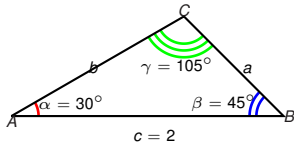


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 &= \frac{\sqrt{3}}{2} \frac{\sqrt{2}}{2} + \frac{1}{2} \frac{\sqrt{2}}{2} = \frac{\sqrt{6} + \sqrt{2}}{4} \\
 \frac{a}{\sin \alpha} &= \frac{c}{\sin \gamma} && \text{Law of sines} \\
 a &= \frac{c \sin \alpha}{\sin \gamma} = \frac{2 \sin 30^\circ}{\sin 105^\circ} = \frac{2 \cdot ?}{\frac{\sqrt{6} + \sqrt{2}}{4}}
 \end{aligned}$$

Example



A triangle has a side of length 2cm ; the two angles adjacent to it are 30° and 45° .

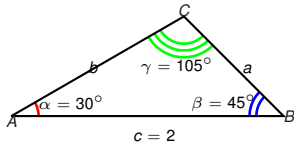
- Find the other two sides of the triangle.
- Find the area of the triangle.

$$\begin{aligned}\sin 105^\circ &= \sin(60^\circ + 45^\circ) = \sin 60^\circ \cos 45^\circ + \cos 60^\circ \sin 45^\circ \\ &= \frac{\sqrt{3}}{2} \frac{\sqrt{2}}{2} + \frac{1}{2} \frac{\sqrt{2}}{2} = \frac{\sqrt{6} + \sqrt{2}}{4}\end{aligned}$$

$$\frac{a}{\sin \alpha} = \frac{c}{\sin \gamma} \quad \text{| Law of sines}$$

$$a = \frac{c \sin \alpha}{\sin \gamma} = \frac{2 \sin 30^\circ}{\sin 105^\circ} = \frac{2 \cdot ?}{\frac{\sqrt{6} + \sqrt{2}}{4}}$$

Example



A triangle has a side of length 2cm ; the two angles adjacent to it are 30° and 45° .

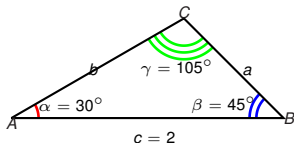
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Example



A triangle has a side of length 2cm ; the two angles adjacent to it are 30° and 45° .

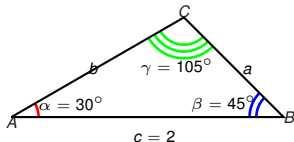
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Example



A triangle has a side of length 2cm ; the two angles adjacent to it are 30° and 45° .

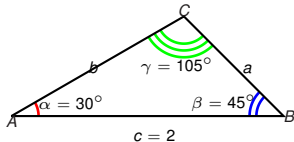
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Example



A triangle has a side of length 2cm ; the two angles adjacent to it are 30° and 45° .

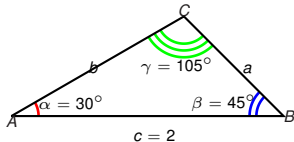
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$$a = \frac{c \sin \alpha}{\sin \gamma} = \frac{2 \sin 30^\circ}{\sin 105^\circ} = \frac{2 \cdot \frac{1}{2}}{\frac{\sqrt{6} + \sqrt{2}}{4}} = \frac{4(\sqrt{6} - \sqrt{2})}{(\sqrt{6} + \sqrt{2})(\sqrt{6} - \sqrt{2})}$$

Example



A triangle has a side of length 2cm ; the two angles adjacent to it are 30° and 45° .

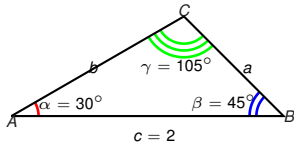
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Example



A triangle has a side of length 2cm ; the two angles adjacent to it are 30° and 45° .

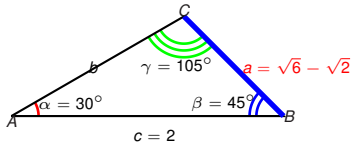
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Example



A triangle has a side of length 2cm ; the two angles adjacent to it are 30° and 45° .

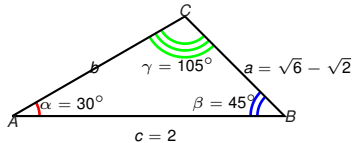
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Example



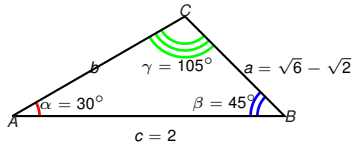
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| Law of sines

$$\frac{b}{\sin \beta} = \frac{c}{\sin \gamma}$$

Example



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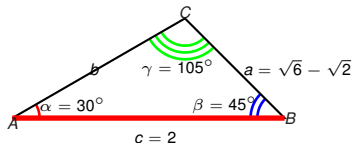
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$$b = \frac{c \sin \beta}{\sin \gamma}$$

Example



A triangle has a side of length 2cm ; the two angles adjacent to it are 30° and 45° .

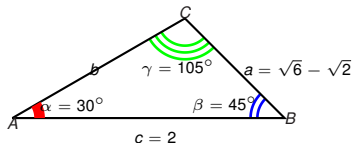
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$$b = \frac{c \sin \beta}{\sin \gamma} = \frac{2 \sin 45^\circ}{\sin 105^\circ}$$

Example



A triangle has a side of length 2cm ; the two angles adjacent to it are 30° and 45° .

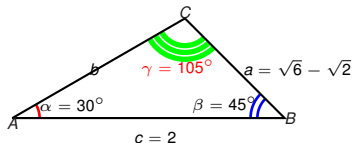
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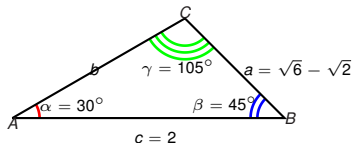
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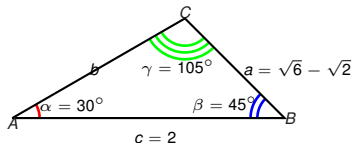
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Example



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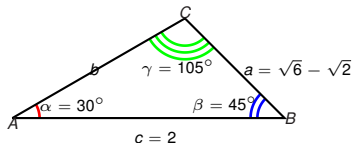
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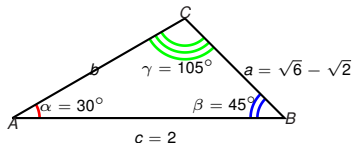
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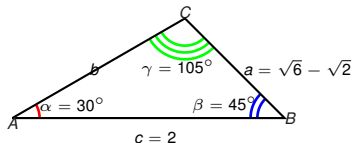
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Example



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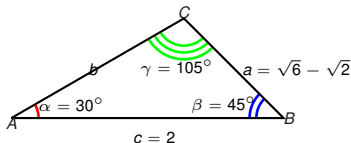
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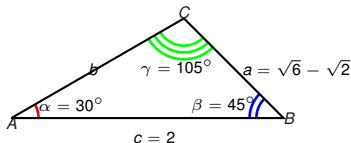
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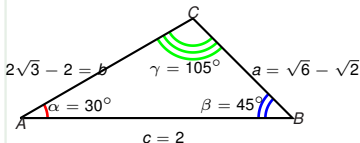
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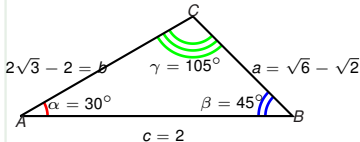
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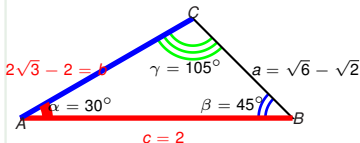
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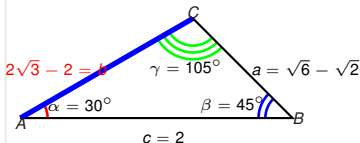
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$$\text{Area} = \frac{bc \sin \alpha}{2}$$

Example



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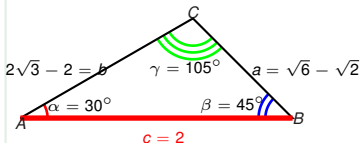
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$$= \frac{4\sqrt{2}(\sqrt{6} - \sqrt{2})}{4} = 2\sqrt{3} - 2$$

$$\text{Area} = \frac{bc \sin \alpha}{2} = \frac{(2\sqrt{3} - 2)2^{\frac{1}{2}}}{2}$$

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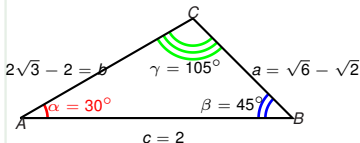
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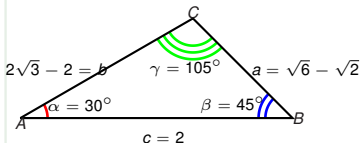
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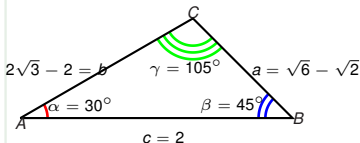
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| Law of sines

$$\frac{b}{\sin \beta} = \frac{c}{\sin \gamma}$$

$$b = \frac{c \sin \beta}{\sin \gamma} = \frac{2 \sin 45^\circ}{\sin 105^\circ} = \frac{\cancel{2} \frac{\sqrt{2}}{2}}{\frac{\sqrt{6} + \sqrt{2}}{4}} = \frac{4\sqrt{2}(\sqrt{6} - \sqrt{2})}{(\sqrt{6} + \sqrt{2})(\sqrt{6} - \sqrt{2})}$$

$$= \frac{\cancel{4}\sqrt{2}(\sqrt{6} - \sqrt{2})}{\cancel{4}} = 2\sqrt{3} - 2$$

$$\text{Area} = \frac{bc \sin \alpha}{2} = \frac{(\cancel{2}\sqrt{3} - \cancel{2})\cancel{2}^1}{\cancel{2}} = \sqrt{3} - 1 \quad \text{cm}^2$$