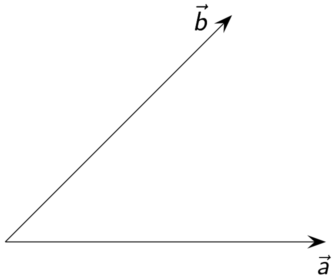
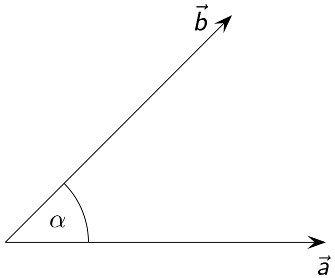


Mit dem Skalarprodukt $\vec{a} \cdot \vec{b}$ kann der Winkel berechnet werden, den zwei Vektoren miteinander einschließen.



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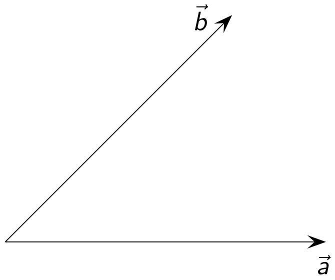
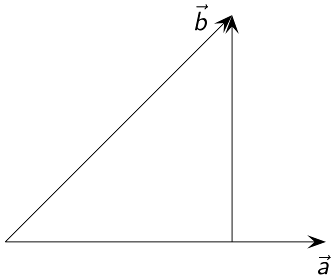
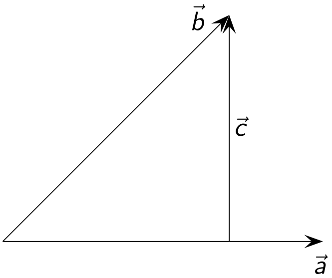
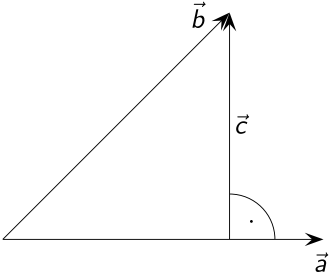
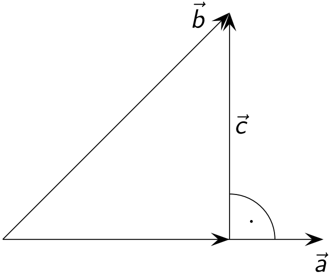
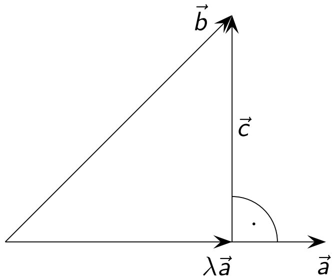

$\vec{b}$
$\vec{a}$

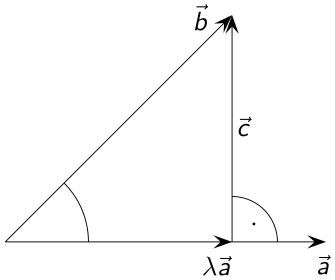

$\vec{b}$
$\vec{a}$


$\vec{b}$
$\vec{c}$
$\vec{a}$


$\vec{b}$
$\vec{c}$
$\vec{a}$


$\vec{b}$
$\vec{c}$
$\vec{a}$


$\vec{b}$
$\vec{c}$
$\lambda\vec{a}$
$\vec{a}$


$\vec{b}$
$\vec{c}$
$\lambda\vec{a}$
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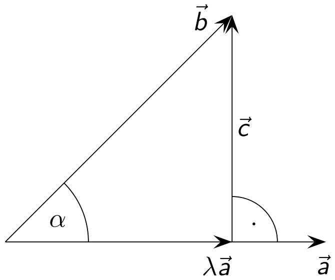
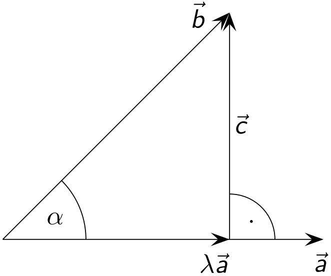
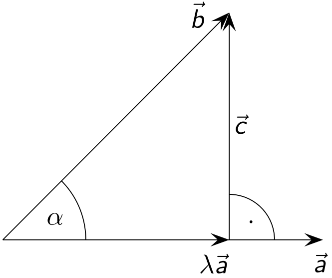
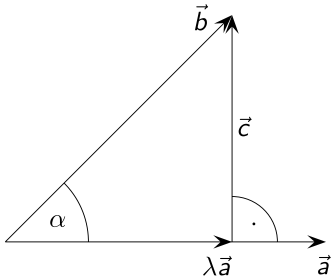

$\vec{b}$
$\vec{c}$
α
$\lambda\vec{a}$
$\vec{a}$



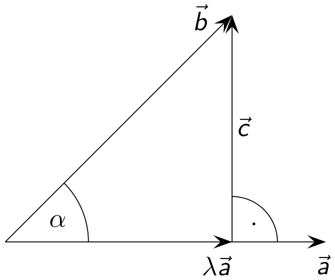
$$\cos\alpha \;=$$



$$\cos\alpha = \frac{\lambda\,|\,\vec{a}\,|}{|\,\vec{b}\,|}$$

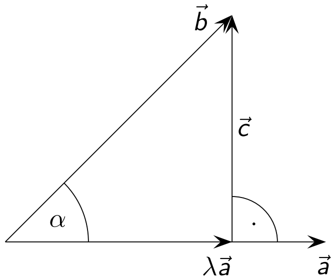


$$\cos\alpha = \frac{\lambda\,|\,\vec{a}\,|}{|\,\vec{b}\,|} \qquad \text{für positives } \lambda$$



$$\cos\alpha = \frac{\lambda\,|\,\vec{a}\,|}{|\,\vec{b}\,|}$$ für positives λ

$$\vec{a}\cdot\vec{b} =$$



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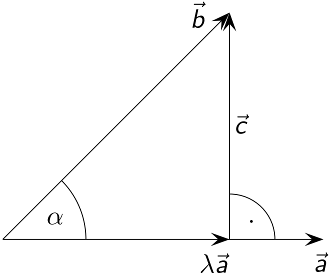
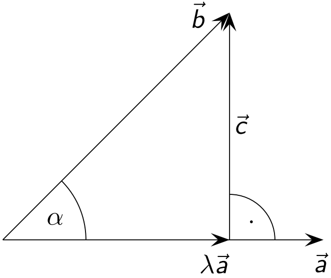
$$\vec{a}\cdot\vec{b} = \vec{a}\,\cdot$$



$$\cos\alpha = \frac{\lambda\,|\,\vec{a}\,|}{|\,\vec{b}\,|}$$ für positives λ

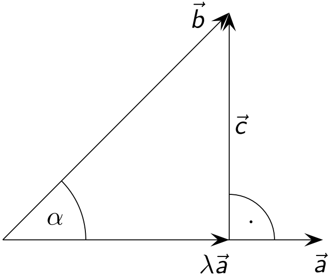
$$\vec{a}\cdot\vec{b} = \vec{a}\cdot(\lambda\vec{a}+\vec{c}\,)$$



$$\cos\alpha = \frac{\lambda\,|\,\vec{a}\,|}{|\,\vec{b}\,|} \qquad \text{für positives } \lambda$$

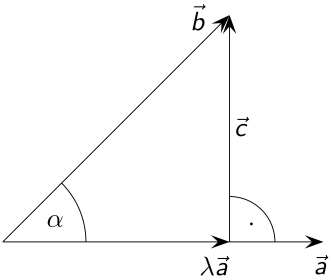
$$\vec{a}\cdot\vec{b} = \vec{a}\cdot(\lambda\vec{a}+\vec{c}\,)$$

$$=$$



$$\cos\alpha = \frac{\lambda\,|\,\vec{a}\,|}{|\,\vec{b}\,|} \qquad \text{für positives } \lambda$$

$$\begin{aligned} \vec{a}\cdot\vec{b} &= \vec{a}\cdot(\lambda\vec{a}+\vec{c}\,) \\ &= \lambda\vec{a}^2 \end{aligned}$$



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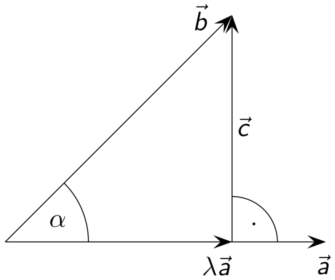
$$\begin{aligned} \vec{a}\cdot\vec{b} &= \vec{a}\cdot(\lambda\vec{a}+\vec{c}\,) \\ &= \lambda\vec{a}^2 \qquad \vec{a}\cdot\vec{c}=0 \end{aligned}$$



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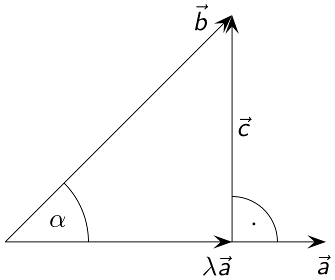

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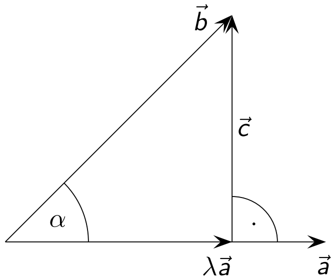

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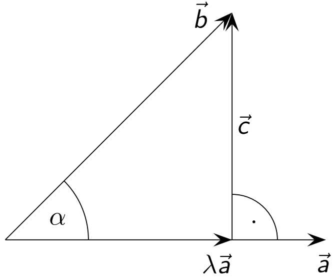

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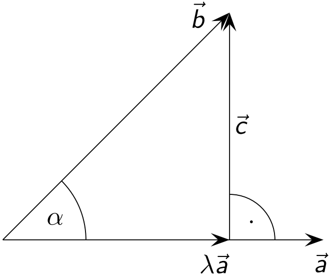
$$\begin{aligned} \vec{a}\cdot\vec{b} &= \vec{a}\cdot(\lambda\vec{a}+\vec{c}) \\ &= \lambda\vec{a}^2 && \vec{a}\cdot\vec{c}=0 \\ \lambda &= \frac{\vec{a}\cdot\vec{b}}{|\,\vec{a}\,|^2} && |\,\vec{a}\,| = \sqrt{\vec{a}^2} \end{aligned}$$



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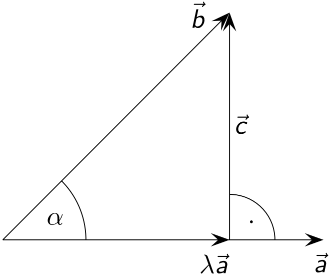

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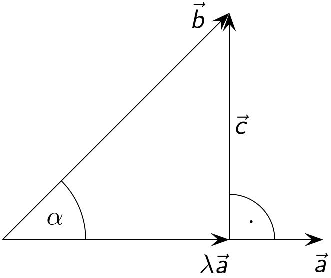

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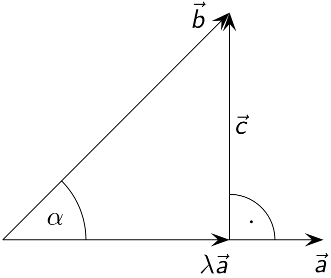

$$\cos\alpha = \frac{\lambda\,|\,\vec{a}\,|}{|\,\vec{b}\,|} \qquad \text{für positives } \lambda$$

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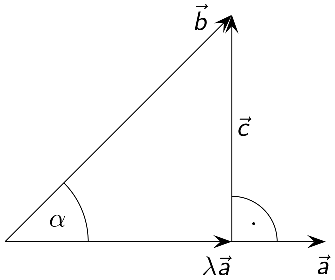
$$\lambda = \frac{\vec{a}\cdot\vec{b}}{|\,\vec{a}\,|^2} \qquad |\,\vec{a}\,| = \sqrt{\vec{a}^2} \implies |\,\vec{a}\,|^2 = \vec{a}^2$$

$$\cos\alpha =$$



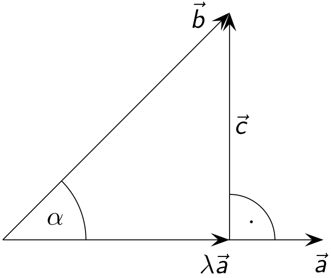
$$\cos\alpha = \frac{\lambda\,|\,\vec{a}\,|}{|\,\vec{b}\,|}$$ für positives λ

$$\vec{a}\cdot\vec{b} = \vec{a}\cdot(\lambda\vec{a}+\vec{c})$$

$$= \lambda\vec{a}^2$$ $\vec{a}\cdot\vec{c} = 0$

$$\lambda = \frac{\vec{a}\cdot\vec{b}}{|\,\vec{a}\,|^2}$$ $|\,\vec{a}\,| = \sqrt{\vec{a}^2} \Longrightarrow |\,\vec{a}\,|^2 = \vec{a}^2$

$$\cos\alpha = \frac{\vec{a}\cdot\vec{b}}{|\,\vec{a}\,||\,\vec{b}\,|}$$



$$\cos\alpha = \frac{\lambda\,|\,\vec{a}\,|}{|\,\vec{b}\,|} \qquad \text{für positives } \lambda$$

$$\vec{a}\cdot\vec{b} = \vec{a}\cdot(\lambda\vec{a}+\vec{c})$$

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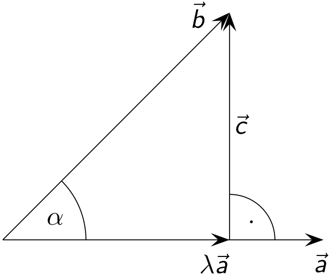
$$\lambda = \frac{\vec{a}\cdot\vec{b}}{|\,\vec{a}\,|^2} \qquad |\,\vec{a}\,| = \sqrt{\vec{a}^2} \implies |\,\vec{a}\,|^2 = \vec{a}^2$$

$$\cos\alpha = \frac{\vec{a}\cdot\vec{b}}{|\,\vec{a}\,||\,\vec{b}\,|} \qquad \text{oder}$$



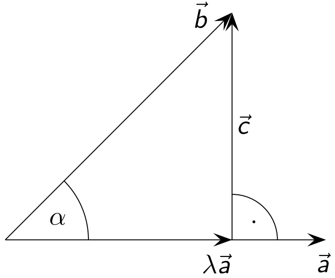
$$\cos\alpha = \frac{\lambda\,|\,\vec{a}\,|}{|\,\vec{b}\,|} \qquad \text{für positives } \lambda$$

$$\vec{a}\cdot\vec{b} = \vec{a}\cdot(\lambda\vec{a}+\vec{c})$$

$$= \lambda\vec{a}^2 \qquad \vec{a}\cdot\vec{c} = 0$$

$$\lambda = \frac{\vec{a}\cdot\vec{b}}{|\,\vec{a}\,|^2} \qquad |\,\vec{a}\,| = \sqrt{\vec{a}^2} \implies |\,\vec{a}\,|^2 = \vec{a}^2$$

$$\cos\alpha = \frac{\vec{a}\cdot\vec{b}}{|\,\vec{a}\,||\,\vec{b}\,|} \qquad \text{oder} \qquad \cos\alpha = \vec{a}^\circ\cdot\vec{b}^\circ$$



$$\cos\alpha = \frac{\lambda\,|\,\vec{a}\,|}{|\,\vec{b}\,|}$$ für positives λ

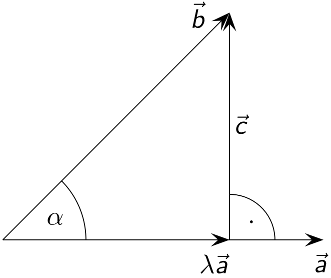
$$\vec{a}\cdot\vec{b} = \vec{a}\cdot(\lambda\vec{a}+\vec{c})$$

$$= \lambda\vec{a}^2$$ $\vec{a}\cdot\vec{c}=0$

$$\lambda = \frac{\vec{a}\cdot\vec{b}}{|\,\vec{a}\,|^2}$$ $|\,\vec{a}\,| = \sqrt{\vec{a}^2} \implies |\,\vec{a}\,|^2 = \vec{a}^2$

$$\cos\alpha = \frac{\vec{a}\cdot\vec{b}}{|\,\vec{a}\,||\,\vec{b}\,|}$$ oder $\cos\alpha = \vec{a}^\circ\cdot\vec{b}^\circ$

$$\vec{a}\cdot\vec{b} =$$



$$\cos\alpha = \frac{\lambda\,|\,\vec{a}\,|}{|\,\vec{b}\,|} \qquad \text{für positives } \lambda$$

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$$\lambda = \frac{\vec{a}\cdot\vec{b}}{|\,\vec{a}\,|^2} \qquad |\,\vec{a}\,| = \sqrt{\vec{a}^2} \implies |\,\vec{a}\,|^2 = \vec{a}^2$$

$$\cos\alpha = \frac{\vec{a}\cdot\vec{b}}{|\,\vec{a}\,||\,\vec{b}\,|} \qquad \text{oder} \qquad \cos\alpha = \vec{a}^\circ\cdot\vec{b}^\circ$$

$$\vec{a}\cdot\vec{b} = |\,\vec{a}\,|\cdot|\,\vec{b}\,|\cdot\cos\alpha$$

$$\vec{a} = \begin{pmatrix} 1 \\ 3 \\ 2 \end{pmatrix}, \quad \vec{b} = \begin{pmatrix} -2 \\ 1 \\ 4 \end{pmatrix}$$

Winkel, den die Ortsvektoren einschließen?

$$\vec{a} = \begin{pmatrix} 1 \\ 3 \\ 2 \end{pmatrix}, \quad \vec{b} = \begin{pmatrix} -2 \\ 1 \\ 4 \end{pmatrix}$$

Winkel, den die Ortsvektoren einschließen?

$$\cos\alpha = \vec{a}^\circ \cdot \vec{b}^\circ$$

$$\vec{a} = \begin{pmatrix} 1 \\ 3 \\ 2 \end{pmatrix}, \quad \vec{b} = \begin{pmatrix} -2 \\ 1 \\ 4 \end{pmatrix}$$

Winkel, den die Ortsvektoren einschließen?

$$\begin{aligned} \cos\alpha &= \vec{a}^\circ \cdot \vec{b}^\circ \\ \alpha &= \end{aligned}$$

$$\vec{a} = \begin{pmatrix} 1 \\ 3 \\ 2 \end{pmatrix}, \quad \vec{b} = \begin{pmatrix} -2 \\ 1 \\ 4 \end{pmatrix}$$

Winkel, den die Ortsvektoren einschließen?

$$\begin{aligned} \cos\alpha &= \vec{a}^\circ \cdot \vec{b}^\circ \\ \alpha &= \arccos(\vec{a}^\circ \cdot \vec{b}^\circ) \end{aligned}$$

$$\vec{a} = \begin{pmatrix} 1 \\ 3 \\ 2 \end{pmatrix}, \quad \vec{b} = \begin{pmatrix} -2 \\ 1 \\ 4 \end{pmatrix}$$

Winkel, den die Ortsvektoren einschließen?

$$\begin{aligned} \cos\alpha &= \vec{a}^\circ \cdot \vec{b}^\circ \\ \alpha &= \arccos(\vec{a}^\circ \cdot \vec{b}^\circ) \end{aligned}$$

$$\vec{a}^\circ =$$

$$\vec{a} = \begin{pmatrix} 1 \\ 3 \\ 2 \end{pmatrix}, \quad \vec{b} = \begin{pmatrix} -2 \\ 1 \\ 4 \end{pmatrix}$$

Winkel, den die Ortsvektoren einschließen?

$$\begin{aligned} \cos\alpha &= \vec{a}^\circ \cdot \vec{b}^\circ \\ \alpha &= \arccos(\vec{a}^\circ \cdot \vec{b}^\circ) \\ \vec{a}^\circ &= \frac{1}{14} \begin{pmatrix} 1 \\ 3 \\ 2 \end{pmatrix}, \end{aligned}$$

$$\vec{a} = \begin{pmatrix} 1 \\ 3 \\ 2 \end{pmatrix}, \quad \vec{b} = \begin{pmatrix} -2 \\ 1 \\ 4 \end{pmatrix}$$

Winkel, den die Ortsvektoren einschließen?

$$\begin{aligned} \cos\alpha &= \vec{a}^{\circ} \cdot \vec{b}^{\circ} \\ \alpha &= \arccos(\vec{a}^{\circ} \cdot \vec{b}^{\circ}) \\ \vec{a}^{\circ} &= \frac{1}{14} \begin{pmatrix} 1 \\ 3 \\ 2 \end{pmatrix}, \quad \vec{b}^{\circ} = \end{aligned}$$

$$\vec{a} = \begin{pmatrix} 1 \\ 3 \\ 2 \end{pmatrix}, \quad \vec{b} = \begin{pmatrix} -2 \\ 1 \\ 4 \end{pmatrix}$$

Winkel, den die Ortsvektoren einschließen?

$$\begin{aligned} \cos\alpha &= \vec{a}^{\circ} \cdot \vec{b}^{\circ} \\ \alpha &= \arccos(\vec{a}^{\circ} \cdot \vec{b}^{\circ}) \\ \vec{a}^{\circ} &= \frac{1}{14} \begin{pmatrix} 1 \\ 3 \\ 2 \end{pmatrix}, \quad \vec{b}^{\circ} = \frac{1}{21} \begin{pmatrix} -2 \\ 1 \\ 4 \end{pmatrix} \end{aligned}$$

$$\vec{a} = \begin{pmatrix} 1 \\ 3 \\ 2 \end{pmatrix}, \quad \vec{b} = \begin{pmatrix} -2 \\ 1 \\ 4 \end{pmatrix}$$

Winkel, den die Ortsvektoren einschließen?

$$\begin{aligned} \cos\alpha &= \vec{a}^{\circ} \cdot \vec{b}^{\circ} \\ \alpha &= \arccos(\vec{a}^{\circ} \cdot \vec{b}^{\circ}) \\ \vec{a}^{\circ} &= \frac{1}{14} \begin{pmatrix} 1 \\ 3 \\ 2 \end{pmatrix}, \quad \vec{b}^{\circ} = \frac{1}{21} \begin{pmatrix} -2 \\ 1 \\ 4 \end{pmatrix} \\ \alpha &= \end{aligned}$$

$$\vec{a} = \begin{pmatrix} 1 \\ 3 \\ 2 \end{pmatrix}, \quad \vec{b} = \begin{pmatrix} -2 \\ 1 \\ 4 \end{pmatrix}$$

Winkel, den die Ortsvektoren einschließen?

$$\begin{aligned} \cos\alpha &= \vec{a}^\circ \cdot \vec{b}^\circ \\ \alpha &= \arccos(\vec{a}^\circ \cdot \vec{b}^\circ) \\ \vec{a}^\circ &= \tfrac{1}{14} \begin{pmatrix} 1 \\ 3 \\ 2 \end{pmatrix}, \quad \vec{b}^\circ = \tfrac{1}{21} \begin{pmatrix} -2 \\ 1 \\ 4 \end{pmatrix} \\ \alpha &= \arccos(\tfrac{9}{14 \cdot 21}) \end{aligned}$$

$$\vec{a} = \begin{pmatrix} 1 \\ 3 \\ 2 \end{pmatrix}, \quad \vec{b} = \begin{pmatrix} -2 \\ 1 \\ 4 \end{pmatrix}$$

Winkel, den die Ortsvektoren einschließen?

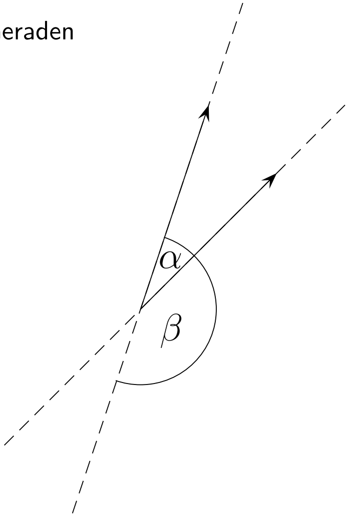
$$\begin{aligned}
\cos\alpha &= \vec{a}^\circ \cdot \vec{b}^\circ \\
\alpha &= \arccos(\vec{a}^\circ \cdot \vec{b}^\circ) \\
\vec{a}^\circ &= \frac{1}{14}\begin{pmatrix} 1 \\ 3 \\ 2 \end{pmatrix}, \quad \vec{b}^\circ = \frac{1}{21}\begin{pmatrix} -2 \\ 1 \\ 4 \end{pmatrix} \\
\alpha &= \arccos(\frac{9}{14 \cdot 21}) \\
\alpha &=
\end{aligned}$$

$$\vec{a} = \begin{pmatrix} 1 \\ 3 \\ 2 \end{pmatrix}, \quad \vec{b} = \begin{pmatrix} -2 \\ 1 \\ 4 \end{pmatrix}$$

Winkel, den die Ortsvektoren einschließen?

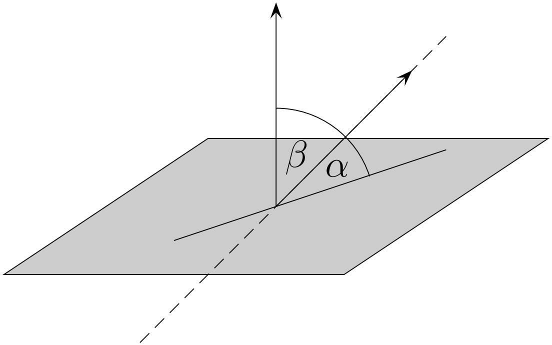
$$\begin{aligned}
\cos\alpha &= \vec{a}^\circ \cdot \vec{b}^\circ \\
\alpha &= \arccos(\vec{a}^\circ \cdot \vec{b}^\circ) \\
\vec{a}^\circ &= \tfrac{1}{14} \begin{pmatrix} 1 \\ 3 \\ 2 \end{pmatrix}, \quad \vec{b}^\circ = \tfrac{1}{21} \begin{pmatrix} -2 \\ 1 \\ 4 \end{pmatrix} \\
\alpha &= \arccos(\tfrac{9}{14 \cdot 21}) \\
\alpha &= 58{,}3^\circ
\end{aligned}$$

Der Schnittwinkel zweier sich schneidender Geraden ist der kleinere der beiden Winkel α und β.



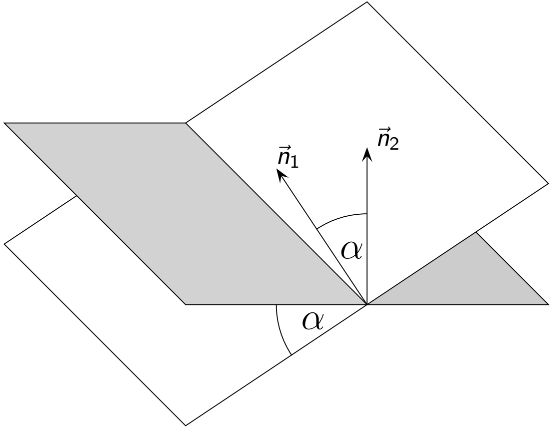
$\cos\alpha = |\vec{a}^{\circ} \cdot \vec{b}^{\circ}|$ führt stets zum (korrekten) spitzen Winkel.

Der Schnittwinkel α von Gerade und Ebene ist der Winkel zwischen der Geraden und ihrer senkrechten Projektion.

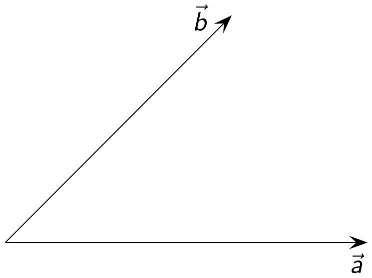


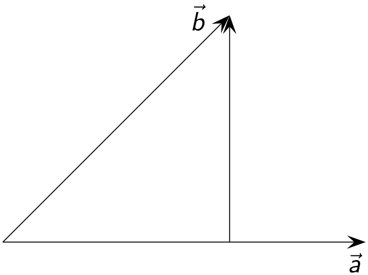
$$\sin\alpha = |\vec{a}^\circ \cdot \vec{b}^\circ|$$

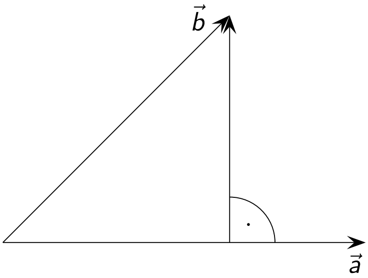
Der Schnittwinkel α von zwei Ebenen wird durch die Normalenvektoren bestimmt.

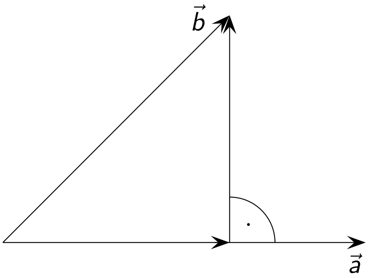


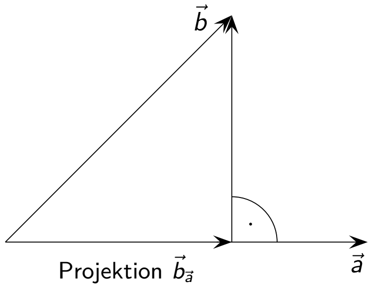
$\cos\alpha = |\vec{n}_1^\circ \cdot \vec{n}_2^\circ|$

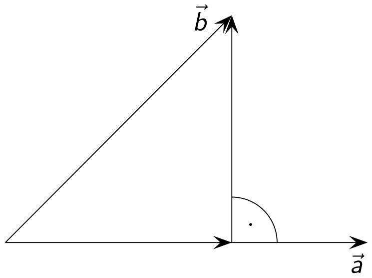

$\vec{b}$
$\vec{a}$


$\vec{b}$
$\vec{a}$


$\vec{b}$
$\vec{a}$

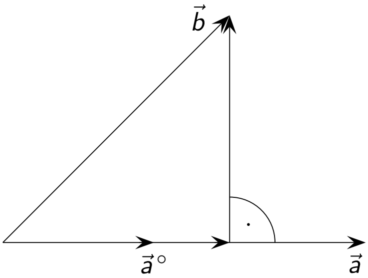

$\vec{b}$
$\vec{a}$

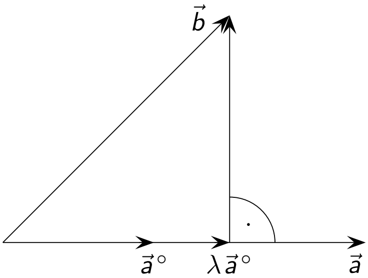

$\vec{b}$
Projektion $\vec{b}_{\vec{a}}$
$\vec{a}$

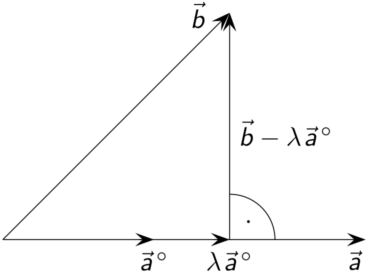


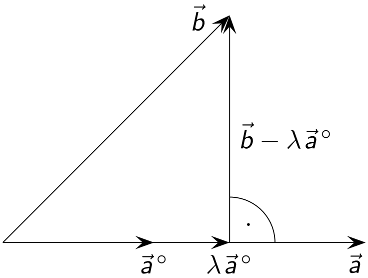
$\vec{b}$
$\vec{a}$

Projektion

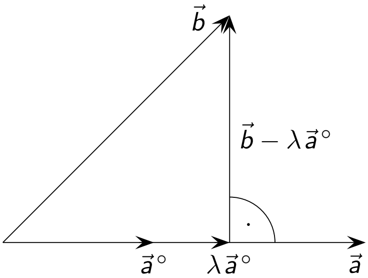



$\vec{b}$
$\vec{a}^\circ$
$\lambda\vec{a}^\circ$
$\vec{a}$


$\vec{b}$
$\vec{b} - \lambda\vec{a}^\circ$
$\vec{a}^\circ$
$\lambda\vec{a}^\circ$
$\vec{a}$

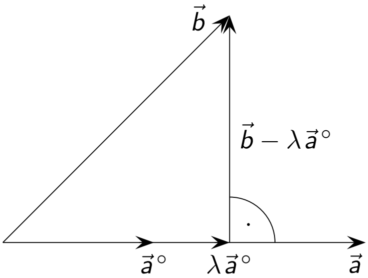


$$\vec{a}^\circ \perp (\vec{b} - \lambda \vec{a}^\circ)$$

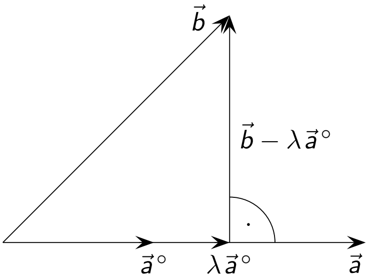


$$\vec{a}^\circ \perp (\vec{b} - \lambda\vec{a}^\circ)$$

$$0 = \vec{a}^\circ \cdot (\vec{b} - \lambda\vec{a}^\circ)$$



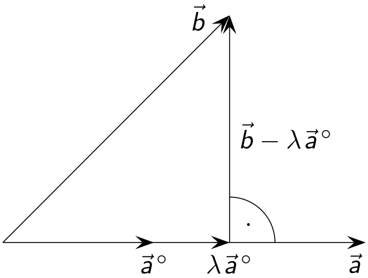
$$\vec{a}^\circ \perp (\vec{b} - \lambda \vec{a}^\circ)$$
$$0 = \vec{a}^\circ \cdot (\vec{b} - \lambda \vec{a}^\circ)$$
$$= \vec{a}^\circ \cdot \vec{b} - \lambda$$



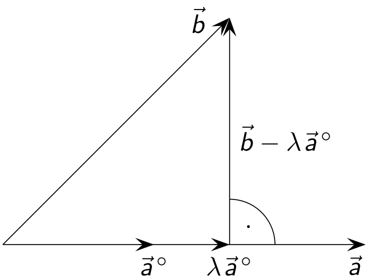
$$\vec{a}^\circ \perp (\vec{b} - \lambda\vec{a}^\circ)$$

$$\begin{aligned} 0 &= \vec{a}^\circ \cdot (\vec{b} - \lambda\vec{a}^\circ) \\ &= \vec{a}^\circ \cdot \vec{b} - \lambda \end{aligned}$$

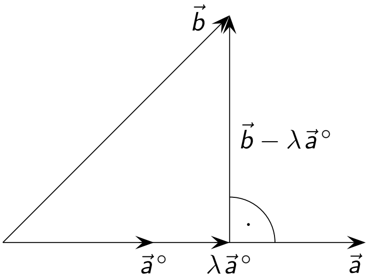
$$\vec{a}^\circ \cdot \vec{a}^\circ = 0$$



$$
\begin{aligned}
\vec{a}^\circ &\perp (\vec{b} - \lambda\vec{a}^\circ) \\
0 &= \vec{a}^\circ \cdot (\vec{b} - \lambda\vec{a}^\circ) \\
&= \vec{a}^\circ \cdot \vec{b} - \lambda \qquad \vec{a}^\circ \cdot \vec{a}^\circ = 0 \\
\lambda &= \vec{a}^\circ \cdot \vec{b}
\end{aligned}
$$



$$\begin{aligned} \vec{a}^\circ &\perp (\vec{b} - \lambda \vec{a}^\circ) \\ 0 &= \vec{a}^\circ \cdot (\vec{b} - \lambda \vec{a}^\circ) \\ &= \vec{a}^\circ \cdot \vec{b} - \lambda \qquad\qquad \vec{a}^\circ \cdot \vec{a}^\circ = 0 \\ \lambda &= \vec{a}^\circ \cdot \vec{b} \\ \vec{b}_{\vec{a}} &= \end{aligned}$$



$$\vec{a}^\circ \perp (\vec{b} - \lambda \vec{a}^\circ)$$

$$\begin{aligned} 0 &= \vec{a}^\circ \cdot (\vec{b} - \lambda \vec{a}^\circ) \\ &= \vec{a}^\circ \cdot \vec{b} - \lambda \qquad \vec{a}^\circ \cdot \vec{a}^\circ = 0 \\ \lambda &= \vec{a}^\circ \cdot \vec{b} \end{aligned}$$

$$\vec{b}_{\vec{a}} = (\vec{a}^\circ \cdot \vec{b})\, \vec{a}^\circ$$