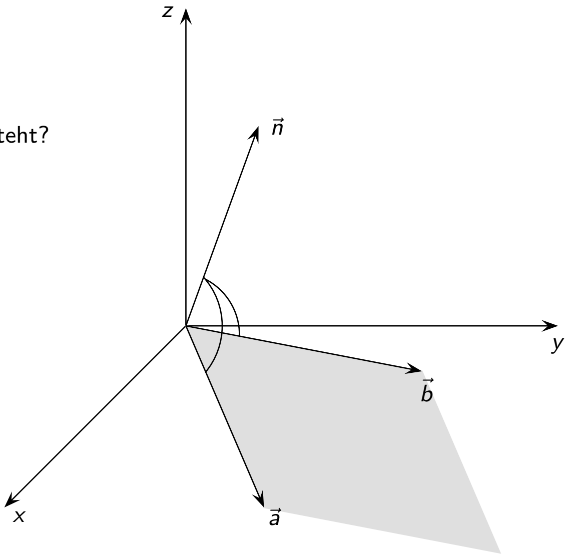
Wie finden wir einen Vektor $\vec{n}$, der auf den Vektoren

$$\vec{a} = \begin{pmatrix} 1 \\ -8 \\ 2 \end{pmatrix} \quad \text{und} \quad \vec{b} = \begin{pmatrix} 2 \\ -7 \\ 1 \end{pmatrix} \quad \text{senkrecht steht?}$$



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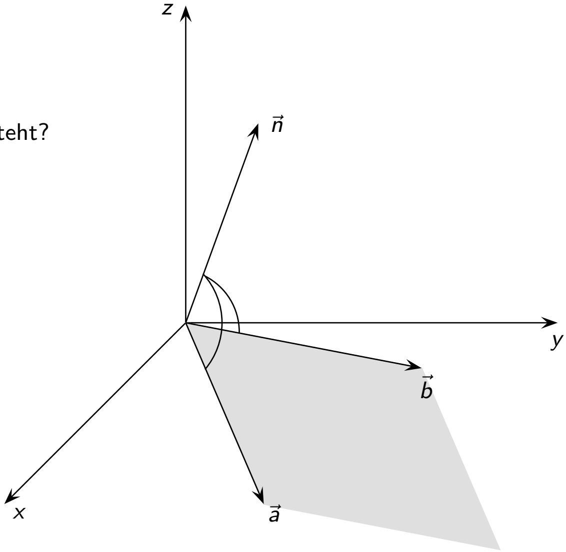

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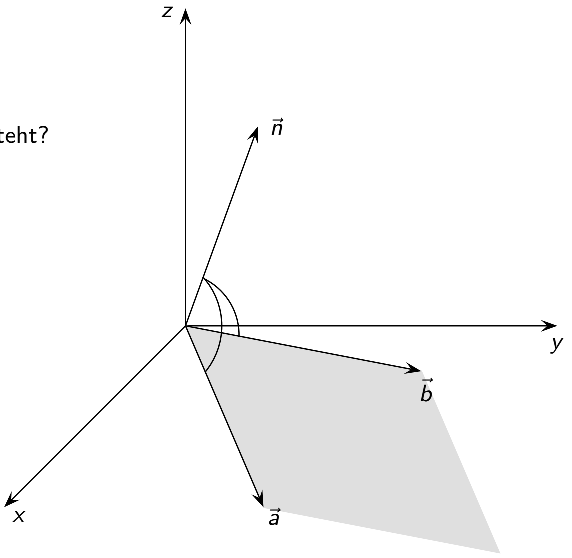
und $\quad II. \quad \vec{b} \cdot \vec{n} = 0$ gelten



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Es muss $\quad I. \quad \vec{a} \cdot \vec{n} = 0$

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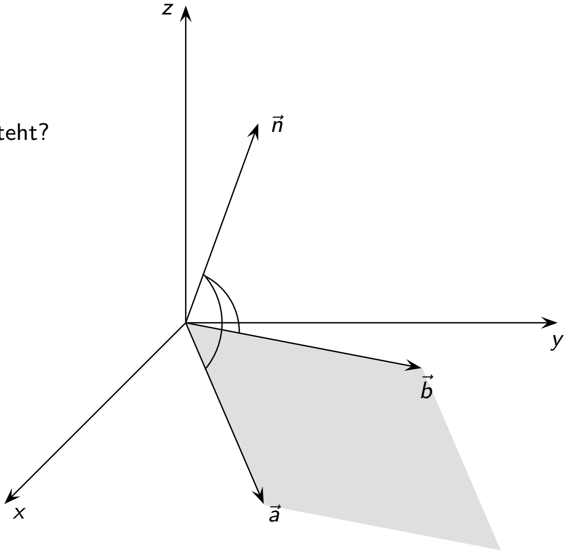
mit $\vec{n} = \begin{pmatrix} n_1 \\ n_2 \\ n_3 \end{pmatrix}$ also:



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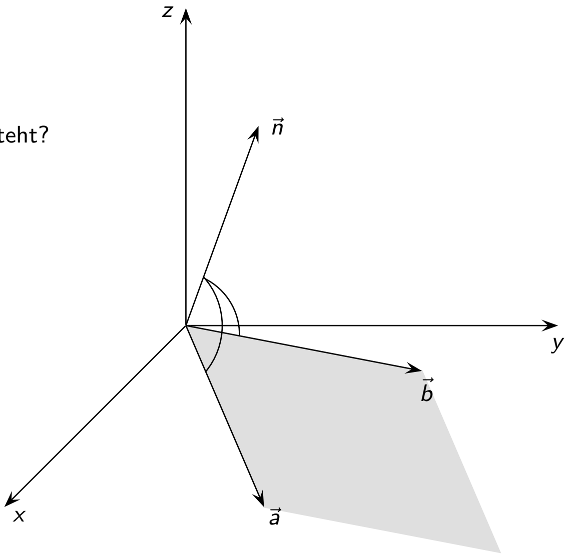
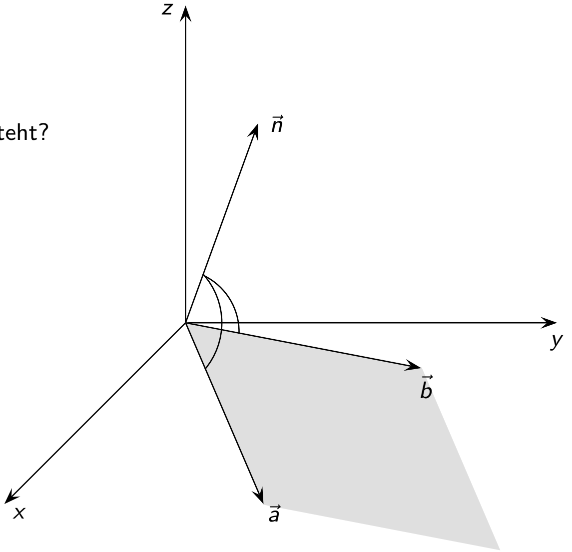
mit $\vec{n} = \begin{pmatrix} n_1 \\ n_2 \\ n_3 \end{pmatrix}$ also:

$$I. \qquad n_1 - 8n_2 + 2n_3 = 0$$



Wie finden wir einen Vektor $\vec{n}$, der auf den Vektoren

$$\vec{a} = \begin{pmatrix} 1 \\ -8 \\ 2 \end{pmatrix} \quad \text{und} \quad \vec{b} = \begin{pmatrix} 2 \\ -7 \\ 1 \end{pmatrix} \quad \text{senkrecht steht?}$$



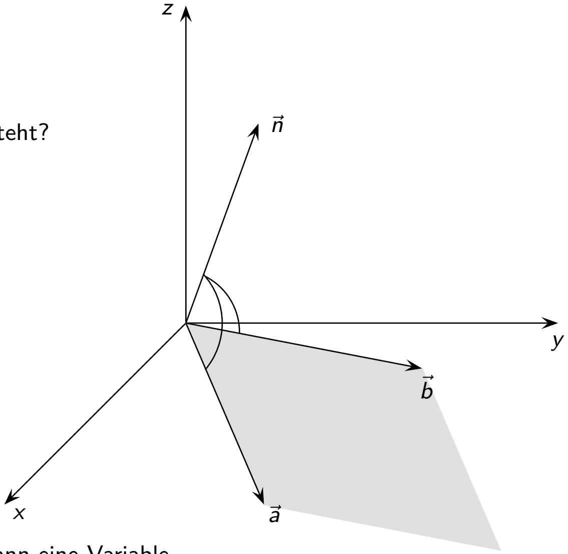
$$\begin{array}{lll} \text{Es muss} & I. & \vec{a} \cdot \vec{n} \;=\; 0 \\ \text{und} & II. & \vec{b} \cdot \vec{n} \;=\; 0 \;\; \text{gelten} \end{array}$$

mit $\vec{n} = \begin{pmatrix} n_1 \\ n_2 \\ n_3 \end{pmatrix}$ also:

$$\begin{array}{lrcrcrcl} I. & n_1 & - & 8n_2 & + & 2n_3 & = & 0 \\ II. & 2n_1 & - & 7n_2 & + & n_3 & = & 0 \\ \hline \end{array}$$

Wie finden wir einen Vektor $\vec{n}$, der auf den Vektoren

$$\vec{a} = \begin{pmatrix} 1 \\ -8 \\ 2 \end{pmatrix} \quad \text{und} \quad \vec{b} = \begin{pmatrix} 2 \\ -7 \\ 1 \end{pmatrix} \quad \text{senkrecht steht?}$$



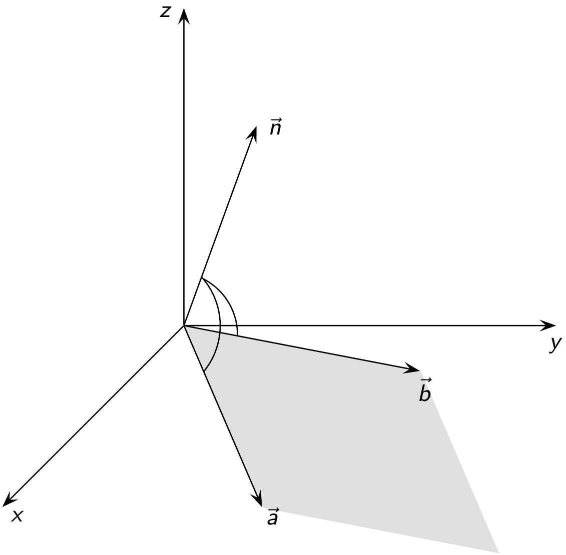
$$\begin{array}{lll} \text{Es muss} & I. & \vec{a}\cdot\vec{n} = 0 \\ \text{und} & II. & \vec{b}\cdot\vec{n} = 0 \ \text{gelten} \end{array}$$

mit $\vec{n} = \begin{pmatrix} n_1 \\ n_2 \\ n_3 \end{pmatrix}$ also:

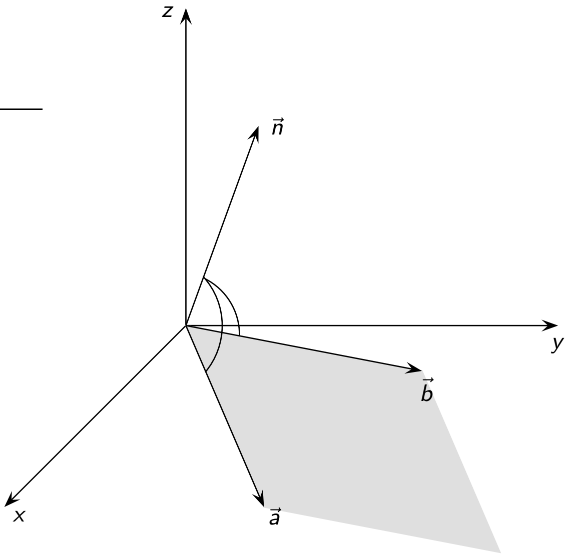
$$\begin{array}{lrcrcrcl} I. & n_1 & - & 8n_2 & + & 2n_3 & = & 0 \\ II. & 2n_1 & - & 7n_2 & + & n_3 & = & 0 \\ \hline \end{array}$$

Da zwei Gleichungen mit drei Variablen vorliegen, kann eine Variable frei gewählt werden, z. B. $n_1 = 2$

$$I. \qquad -\ 8n_2 + 2n_3 = -2$$

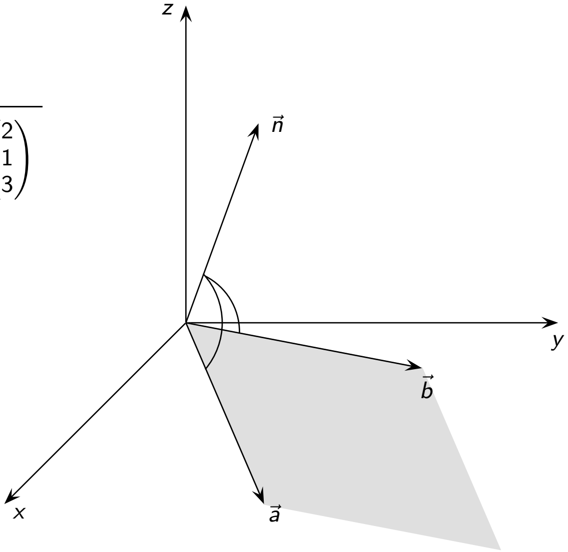


$$\begin{array}{lrcrcr} I. & -\ 8n_2 & + & 2n_3 & = & -2 \\ II. & -\ 7n_2 & + & n_3 & = & -4 \end{array}$$

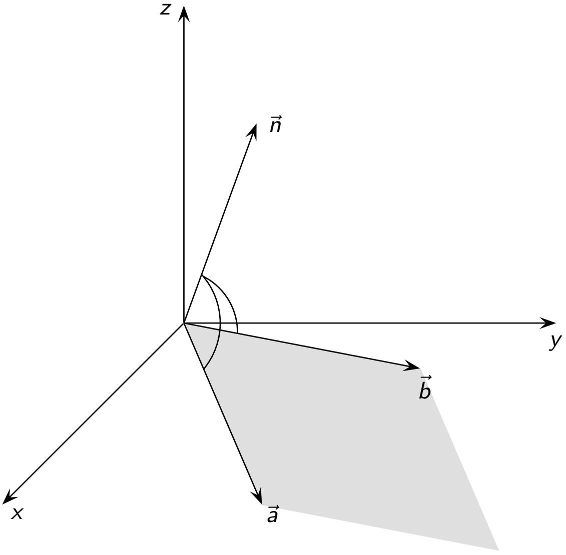


$$\begin{array}{lrcrcr} I. & -\ 8n_2 & + & 2n_3 & = & -2 \\ II. & -\ 7n_2 & + & n_3 & = & -4 \\ \hline \end{array}$$

$$\vdots \quad n_2 = 1, \quad n_3 = 3, \qquad \vec{n} = \begin{pmatrix} 2 \\ 1 \\ 3 \end{pmatrix}$$

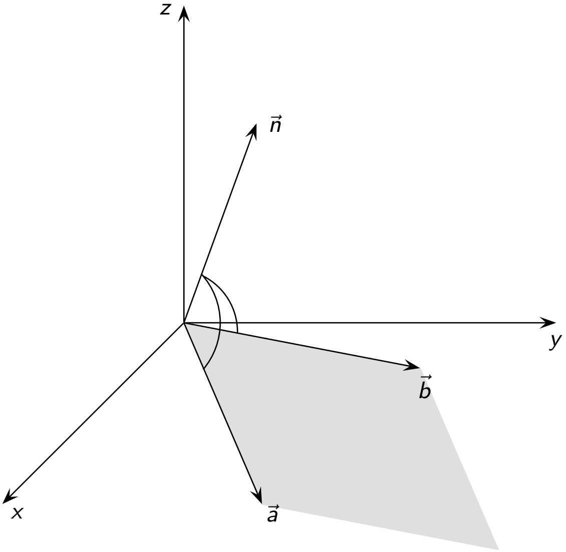


und nun allgemein



und nun allgemein

Seien also $\vec{a} = \begin{pmatrix} a_1 \\ a_2 \\ a_3 \end{pmatrix}$ und $\vec{b} = \begin{pmatrix} b_1 \\ b_2 \\ b_3 \end{pmatrix}$ gegeben,



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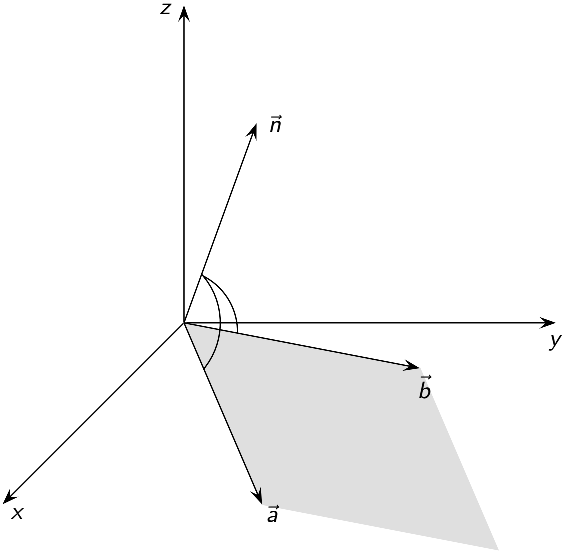
Seien also $\vec{a} = \begin{pmatrix} a_1 \\ a_2 \\ a_3 \end{pmatrix}$ und $\vec{b} = \begin{pmatrix} b_1 \\ b_2 \\ b_3 \end{pmatrix}$ gegeben,

gesucht ist $\vec{n} = \begin{pmatrix} n_1 \\ n_2 \\ n_3 \end{pmatrix}$



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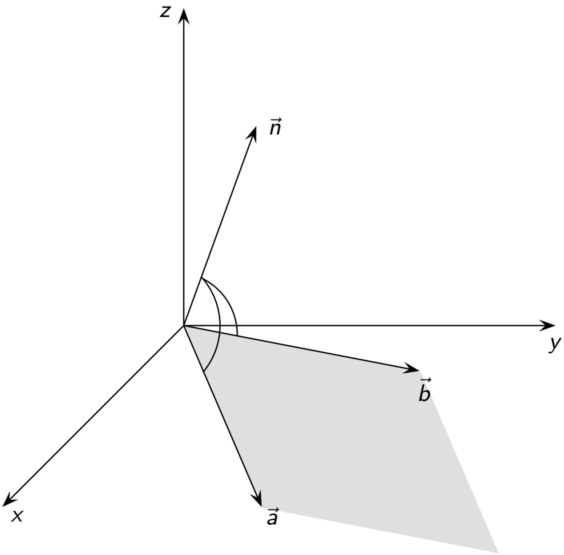

und nun allgemein

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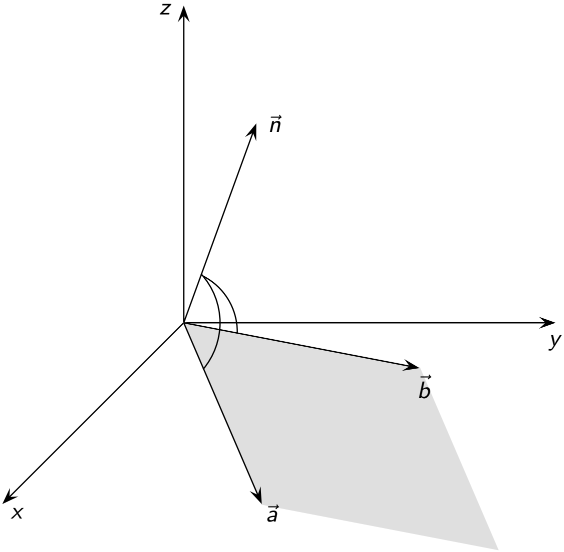
d.h. $\vec{n} \cdot \vec{a} = 0$ und $\vec{n} \cdot \vec{b} = 0$.



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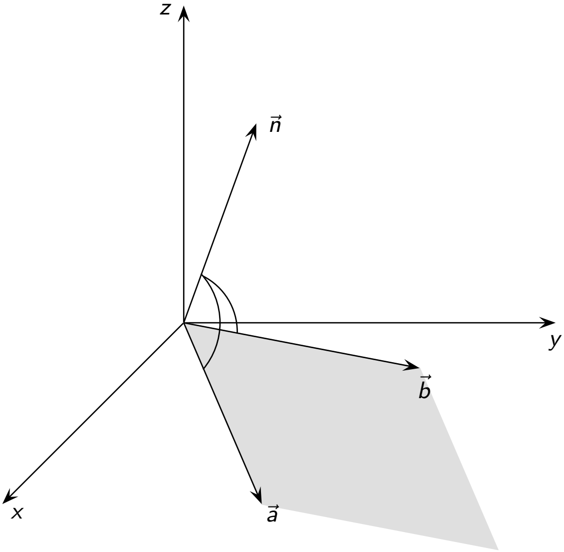
d.h. $\vec{n} \cdot \vec{a} = 0$ und $\vec{n} \cdot \vec{b} = 0$.

$$I. \quad a_1 n_1 + a_2 n_2 + a_3 n_3 = 0$$



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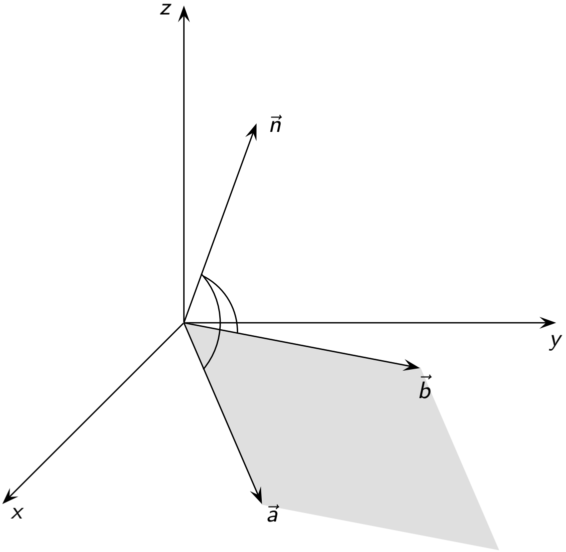
$$\begin{array}{lrcrcrcl} I. & a_1 n_1 & + & a_2 n_2 & + & a_3 n_3 & = & 0 \\ II. & b_1 n_1 & + & b_2 n_2 & + & b_3 n_3 & = & 0 \end{array}$$



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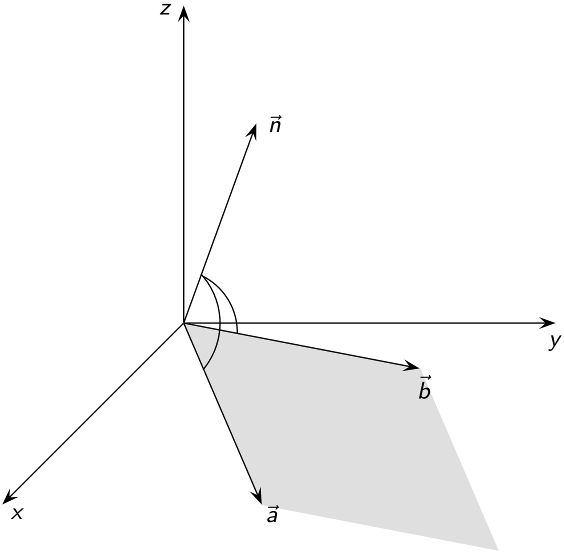
$$\begin{array}{llllll} I. & a_2 n_2 & + & a_3 n_3 & = & -a_1 n_1 \end{array}$$



und nun allgemein

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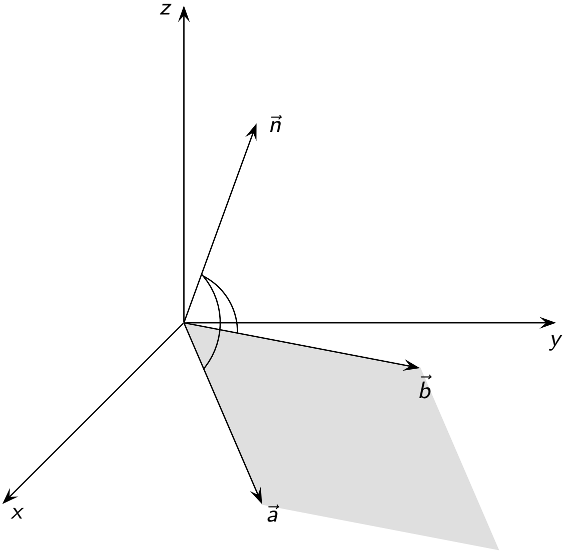
$$\begin{array}{lccccccc} I. & a_1 n_1 & + & a_2 n_2 & + & a_3 n_3 & = & 0 \\ II. & b_1 n_1 & + & b_2 n_2 & + & b_3 n_3 & = & 0 \end{array}$$

$$\begin{array}{lccccc} I. & a_2 n_2 & + & a_3 n_3 & = & -a_1 n_1 \\ II. & b_2 n_2 & + & b_3 n_3 & = & -b_1 n_1 \end{array}$$



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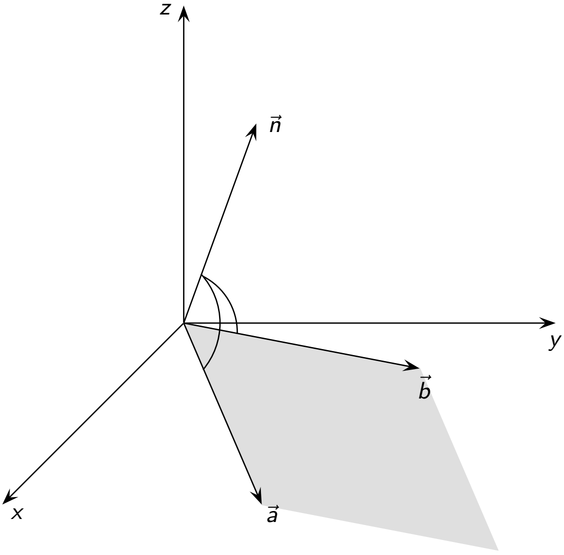
$$\begin{array}{llllllll} I. & a_1 n_1 & + & a_2 n_2 & + & a_3 n_3 & = & 0 \\ II. & b_1 n_1 & + & b_2 n_2 & + & b_3 n_3 & = & 0 \end{array}$$

$$\begin{array}{llllllll} I. & a_2 n_2 & + & a_3 n_3 & = & -a_1 n_1 & | & \cdot (-b_2) \\ II. & b_2 n_2 & + & b_3 n_3 & = & -b_1 n_1 & & \end{array}$$



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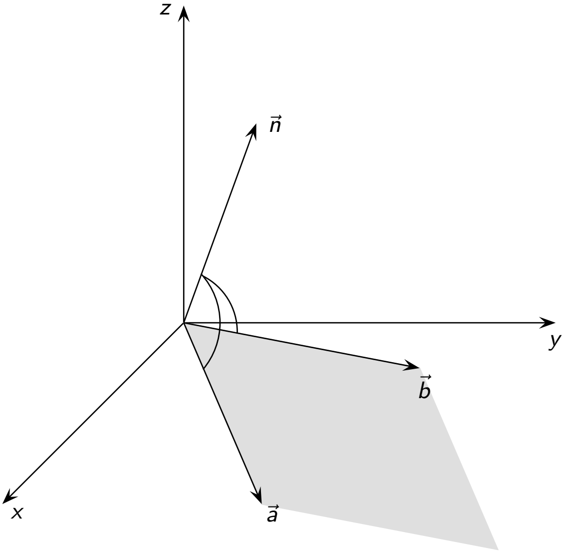
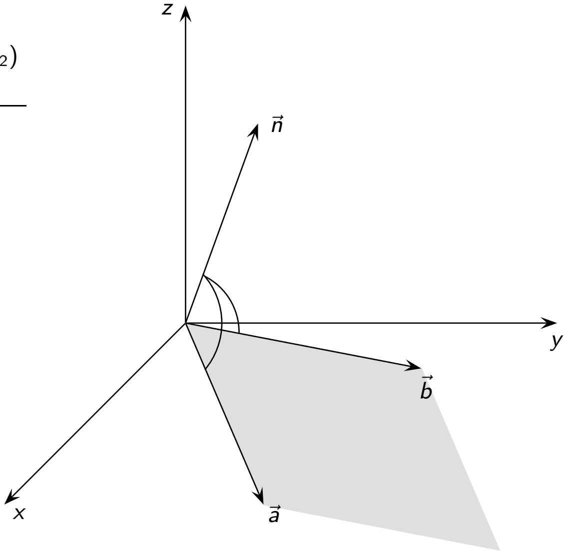
$$\begin{array}{lccccccc} I. & a_1 n_1 & + & a_2 n_2 & + & a_3 n_3 & = & 0 \\ II. & b_1 n_1 & + & b_2 n_2 & + & b_3 n_3 & = & 0 \end{array}$$

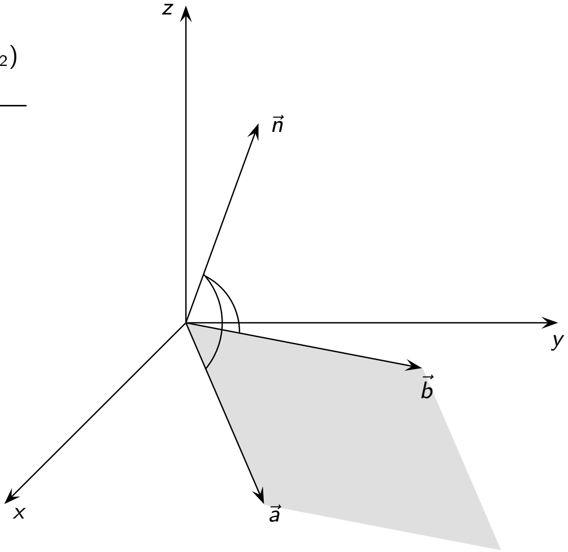
$$\begin{array}{lccccc|l} I. & a_2 n_2 & + & a_3 n_3 & = & -a_1 n_1 & \cdot (-b_2) \\ II. & b_2 n_2 & + & b_3 n_3 & = & -b_1 n_1 & \cdot a_2 \\ \hline \end{array}$$



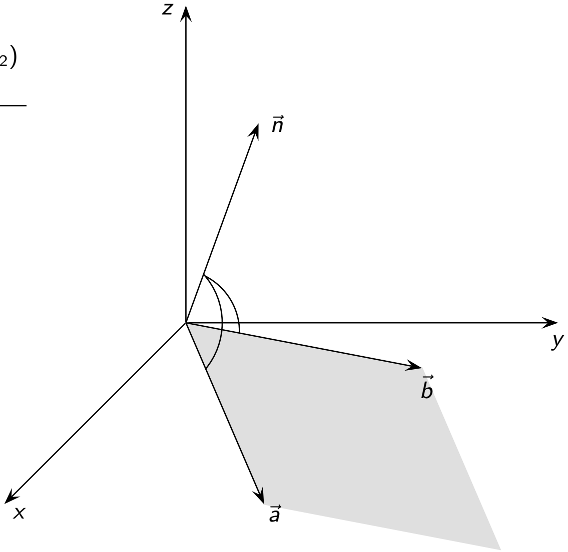
$$\begin{array}{llcllcll}
I. & a_2 n_2 & + & a_3 n_3 & = & -a_1 n_1 & \mid & \cdot(-b_2) \\
II. & b_2 n_2 & + & b_3 n_3 & = & -b_1 n_1 & \mid & \cdot a_2 \\
\hline
\end{array}$$



$$\begin{array}{llcllcl}
I. & a_2 n_2 & + & a_3 n_3 & = & -a_1 n_1 & \mid \cdot (-b_2) \\
II. & b_2 n_2 & + & b_3 n_3 & = & -b_1 n_1 & \mid \cdot a_2 \\
\hline
I. & -a_2 b_2 n_2 & - & a_3 b_2 n_3 & = & a_1 b_2 n_1 &
\end{array}$$

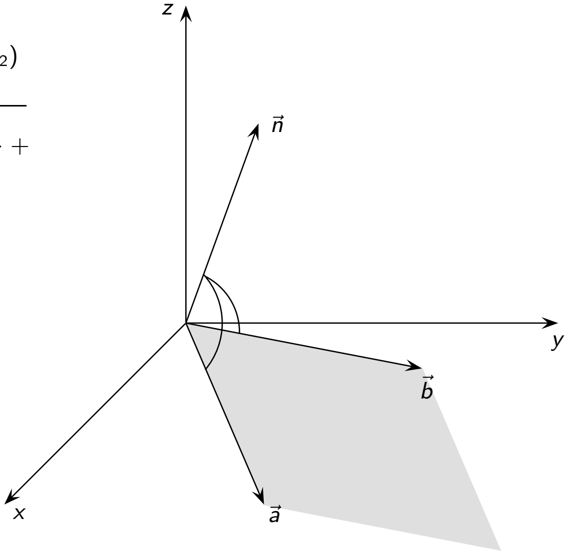


$$\begin{array}{lrcrcrl} I. & a_2 n_2 & + & a_3 n_3 & = & -a_1 n_1 & \mid \cdot(-b_2) \\ II. & b_2 n_2 & + & b_3 n_3 & = & -b_1 n_1 & \mid \cdot a_2 \\ \hline I. & -a_2 b_2 n_2 & - & a_3 b_2 n_3 & = & a_1 b_2 n_1 & \\ II. & a_2 b_2 n_2 & + & a_2 b_3 n_3 & = & -a_2 b_1 n_1 & \\ \hline \end{array}$$



$$
\begin{array}{lrcrcrl}
I. & a_2n_2 & + & a_3n_3 & = & -a_1n_1 & \mid \cdot(-b_2) \\
II. & b_2n_2 & + & b_3n_3 & = & -b_1n_1 & \mid \cdot a_2 \\
\hline
\end{array}
$$

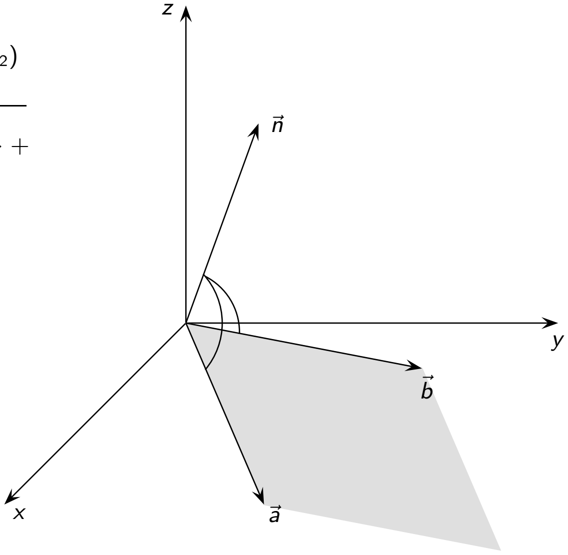
$$
\left.
\begin{array}{lrcrcr}
I. & -a_2b_2n_2 & - & a_3b_2n_3 & = & a_1b_2n_1 \\
II. & a_2b_2n_2 & + & a_2b_3n_3 & = & -a_2b_1n_1 \\
\hline
\end{array}
\right\} +
$$



$$\begin{array}{lrcrcrl}
I. & a_2 n_2 & + & a_3 n_3 & = & -a_1 n_1 & \mid \cdot (-b_2) \\
II. & b_2 n_2 & + & b_3 n_3 & = & -b_1 n_1 & \mid \cdot a_2 \\
\hline
\end{array}$$

$$\left.\begin{array}{lrcrcr}
I. & -a_2 b_2 n_2 & - & a_3 b_2 n_3 & = & a_1 b_2 n_1 \\
II. & a_2 b_2 n_2 & + & a_2 b_3 n_3 & = & -a_2 b_1 n_1 \\
\hline
\end{array}\right\} +$$

$$n_3(a_2 b_3 - a_3 b_2) \; = \; (a_1 b_2 - a_2 b_1) n_1$$

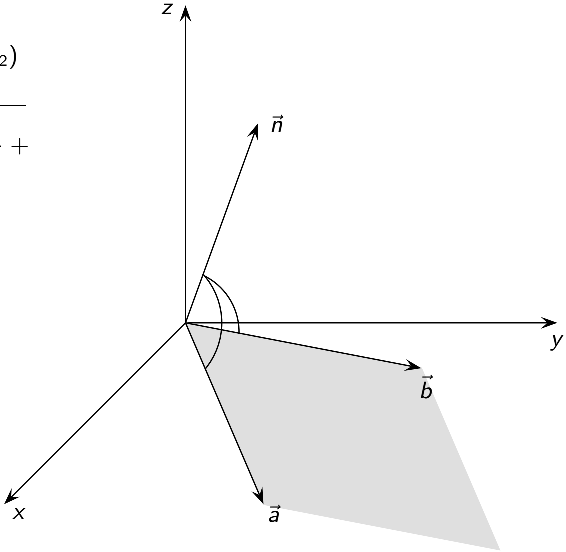


$$
\begin{array}{lrcrcrl}
I. & a_2 n_2 & + & a_3 n_3 & = & -a_1 n_1 & \mid \cdot (-b_2) \\
II. & b_2 n_2 & + & b_3 n_3 & = & -b_1 n_1 & \mid \cdot a_2 \\
\hline
\end{array}
$$

$$
\left.\begin{array}{lrcrcr}
I. & -a_2 b_2 n_2 & - & a_3 b_2 n_3 & = & a_1 b_2 n_1 \\
II. & a_2 b_2 n_2 & + & a_2 b_3 n_3 & = & -a_2 b_1 n_1 \\
\hline
\end{array}\right\} +
$$

$$
n_3(a_2 b_3 - a_3 b_2) = (a_1 b_2 - a_2 b_1) n_1
$$

$$
n_3 = \frac{(a_1 b_2 - a_2 b_1) n_1}{a_2 b_3 - a_3 b_2}
$$



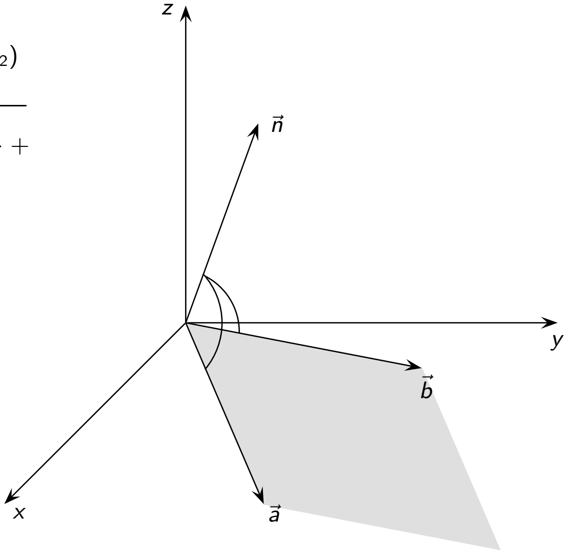
$$
\begin{array}{lrcrcrl}
I. & a_2 n_2 & + & a_3 n_3 & = & -a_1 n_1 & \mid \cdot (-b_2) \\
II. & b_2 n_2 & + & b_3 n_3 & = & -b_1 n_1 & \mid \cdot a_2 \\
\hline
\end{array}
$$

$$
\left.\begin{array}{lrcrcr}
I. & -a_2 b_2 n_2 & - & a_3 b_2 n_3 & = & a_1 b_2 n_1 \\
II. & a_2 b_2 n_2 & + & a_2 b_3 n_3 & = & -a_2 b_1 n_1 \\
\hline
\end{array}\right\} +
$$

$$
n_3(a_2 b_3 - a_3 b_2) = (a_1 b_2 - a_2 b_1) n_1
$$

$$
n_3 = \frac{(a_1 b_2 - a_2 b_1) n_1}{a_2 b_3 - a_3 b_2}
$$

$$
n_2 = \frac{(a_3 b_1 - a_1 b_3) n_1}{a_2 b_3 - a_3 b_2}
$$



$$
\begin{array}{llcllcl|l}
I. & a_2 n_2 & + & a_3 n_3 & = & -a_1 n_1 & \cdot(-b_2) \\
II. & b_2 n_2 & + & b_3 n_3 & = & -b_1 n_1 & \cdot a_2 \\
\hline
\end{array}
$$

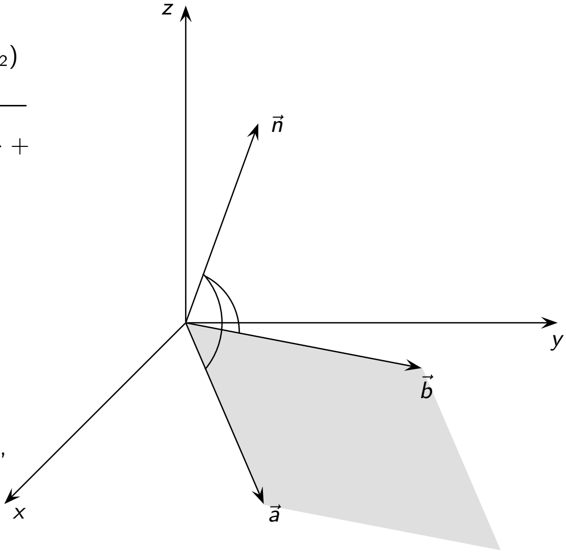
$$
\left.\begin{array}{llcllcl}
I. & -a_2 b_2 n_2 & - & a_3 b_2 n_3 & = & a_1 b_2 n_1 \\
II. & a_2 b_2 n_2 & + & a_2 b_3 n_3 & = & -a_2 b_1 n_1 \\
\hline
\end{array}\right\} +
$$

$$n_3(a_2 b_3 - a_3 b_2) = (a_1 b_2 - a_2 b_1) n_1$$

$$n_3 = \frac{(a_1 b_2 - a_2 b_1) n_1}{a_2 b_3 - a_3 b_2}$$

$$n_2 = \frac{(a_3 b_1 - a_1 b_3) n_1}{a_2 b_3 - a_3 b_2}$$

Um ein möglichst einfaches Ergebnis zu bekommen, wählen wir



$$\begin{array}{llcll}
I. & a_2 n_2 + a_3 n_3 & = & -a_1 n_1 & \mid \cdot(-b_2) \\
II. & b_2 n_2 + b_3 n_3 & = & -b_1 n_1 & \mid \cdot a_2
\end{array}$$

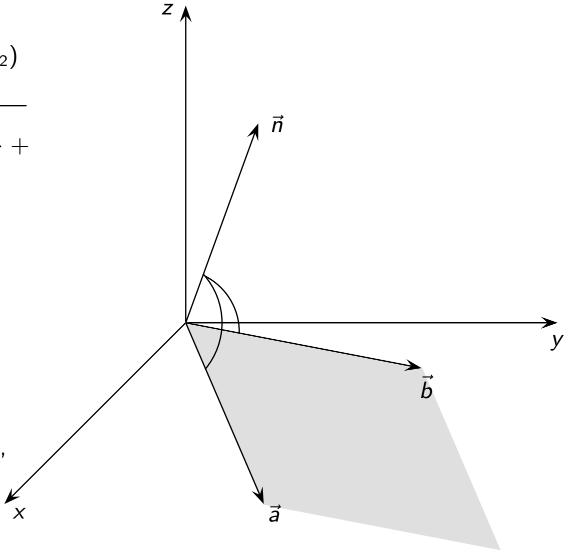
$$\left.\begin{array}{llcl}
I. & -a_2 b_2 n_2 - a_3 b_2 n_3 & = & a_1 b_2 n_1 \\
II. & a_2 b_2 n_2 + a_2 b_3 n_3 & = & -a_2 b_1 n_1
\end{array}\right\} +$$

$$n_3(a_2 b_3 - a_3 b_2) = (a_1 b_2 - a_2 b_1) n_1$$

$$n_3 = \frac{(a_1 b_2 - a_2 b_1) n_1}{a_2 b_3 - a_3 b_2}$$

$$n_2 = \frac{(a_3 b_1 - a_1 b_3) n_1}{a_2 b_3 - a_3 b_2}$$

Um ein möglichst einfaches Ergebnis zu bekommen, wählen wir $n_1 = a_2 b_3 - a_3 b_2$ und erhalten



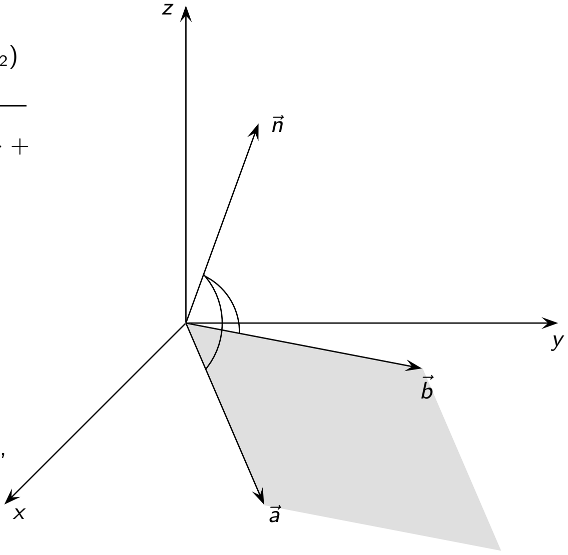
$$
\begin{array}{llcrcrl}
I. & a_2 n_2 & + & a_3 n_3 & = & -a_1 n_1 & \mid \cdot (-b_2) \\
II. & b_2 n_2 & + & b_3 n_3 & = & -b_1 n_1 & \mid \cdot a_2 \\
\hline
\end{array}
$$

$$
\left.
\begin{array}{llcrcr}
I. & -a_2 b_2 n_2 & - & a_3 b_2 n_3 & = & a_1 b_2 n_1 \\
II. & a_2 b_2 n_2 & + & a_2 b_3 n_3 & = & -a_2 b_1 n_1 \\
\hline
\end{array}
\right\} +
$$

$$
\begin{aligned}
n_3(a_2 b_3 - a_3 b_2) &= (a_1 b_2 - a_2 b_1) n_1 \\
n_3 &= \frac{(a_1 b_2 - a_2 b_1) n_1}{a_2 b_3 - a_3 b_2} \\
n_2 &= \frac{(a_3 b_1 - a_1 b_3) n_1}{a_2 b_3 - a_3 b_2}
\end{aligned}
$$

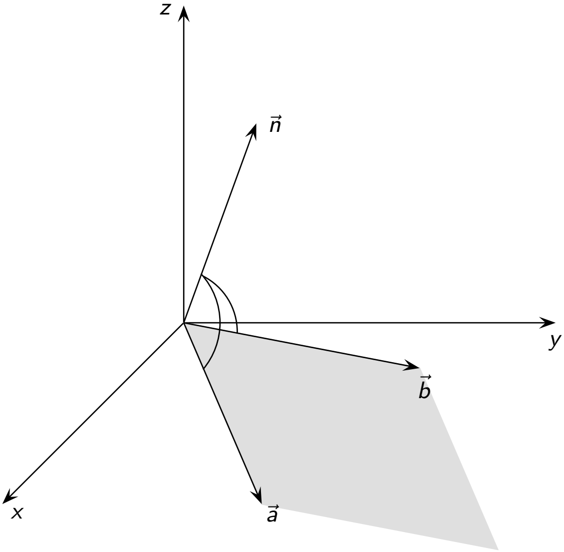
Um ein möglichst einfaches Ergebnis zu bekommen, wählen wir $n_1 = a_2 b_3 - a_3 b_2$ und erhalten

$$
\vec{n} = \begin{pmatrix} a_2 b_3 - a_3 b_2 \\ a_3 b_1 - a_1 b_3 \\ a_1 b_2 - a_2 b_1 \end{pmatrix}
$$



Definition des Vektorprodukts:

$$\begin{pmatrix} a_1 \\ a_2 \\ a_3 \end{pmatrix} \times \begin{pmatrix} b_1 \\ b_2 \\ b_3 \end{pmatrix} = \begin{pmatrix} a_2 b_3 - a_3 b_2 \\ a_3 b_1 - a_1 b_3 \\ a_1 b_2 - a_2 b_1 \end{pmatrix}$$

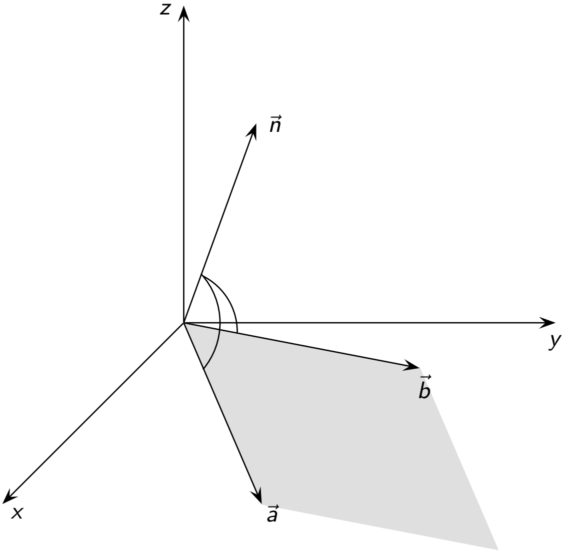


Definition des Vektorprodukts:

$$\begin{pmatrix} a_1 \\ a_2 \\ a_3 \end{pmatrix} \times \begin{pmatrix} b_1 \\ b_2 \\ b_3 \end{pmatrix} = \begin{pmatrix} a_2 b_3 - a_3 b_2 \\ a_3 b_1 - a_1 b_3 \\ a_1 b_2 - a_2 b_1 \end{pmatrix}$$

Beispiele:

$$\begin{pmatrix} 2 \\ 3 \\ 1 \end{pmatrix} \times \begin{pmatrix} 4 \\ 2 \\ 3 \end{pmatrix} =$$

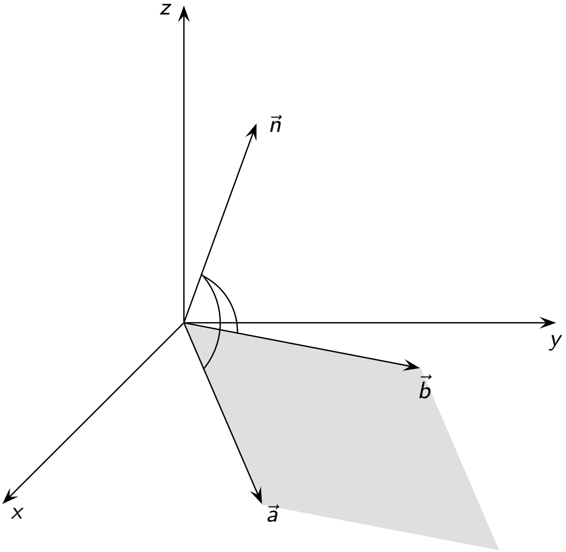


Definition des Vektorprodukts:

$$\begin{pmatrix} a_1 \\ a_2 \\ a_3 \end{pmatrix} \times \begin{pmatrix} b_1 \\ b_2 \\ b_3 \end{pmatrix} = \begin{pmatrix} a_2 b_3 - a_3 b_2 \\ a_3 b_1 - a_1 b_3 \\ a_1 b_2 - a_2 b_1 \end{pmatrix}$$

Beispiele:

$$\begin{pmatrix} 2 \\ 3 \\ 1 \end{pmatrix} \times \begin{pmatrix} 4 \\ 2 \\ 3 \end{pmatrix} = \begin{pmatrix} 7 \\ -2 \\ -8 \end{pmatrix}$$



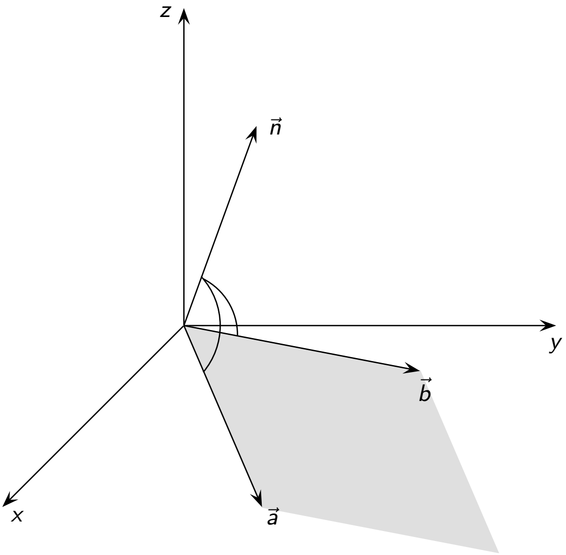
Definition des Vektorprodukts:

$$\begin{pmatrix} a_1 \\ a_2 \\ a_3 \end{pmatrix} \times \begin{pmatrix} b_1 \\ b_2 \\ b_3 \end{pmatrix} = \begin{pmatrix} a_2 b_3 - a_3 b_2 \\ a_3 b_1 - a_1 b_3 \\ a_1 b_2 - a_2 b_1 \end{pmatrix}$$

Beispiele:

$$\begin{pmatrix} 2 \\ 3 \\ 1 \end{pmatrix} \times \begin{pmatrix} 4 \\ 2 \\ 3 \end{pmatrix} = \begin{pmatrix} 7 \\ -2 \\ -8 \end{pmatrix}$$

$$\begin{pmatrix} -3 \\ 1 \\ -2 \end{pmatrix} \times \begin{pmatrix} 1 \\ 0 \\ -2 \end{pmatrix} =$$



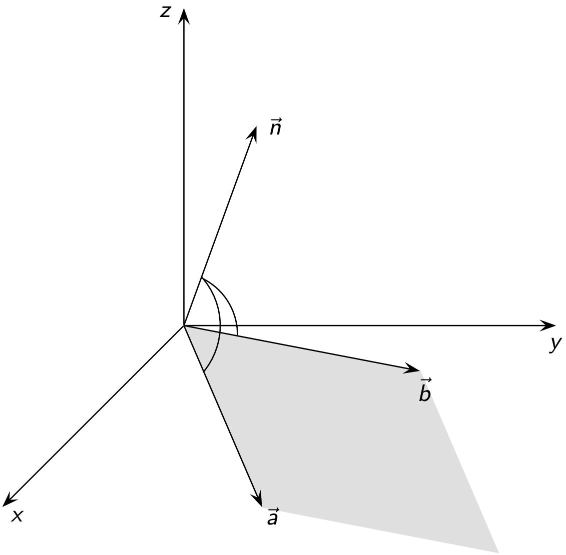
Definition des Vektorprodukts:

$$\begin{pmatrix} a_1 \\ a_2 \\ a_3 \end{pmatrix} \times \begin{pmatrix} b_1 \\ b_2 \\ b_3 \end{pmatrix} = \begin{pmatrix} a_2 b_3 - a_3 b_2 \\ a_3 b_1 - a_1 b_3 \\ a_1 b_2 - a_2 b_1 \end{pmatrix}$$

Beispiele:

$$\begin{pmatrix} 2 \\ 3 \\ 1 \end{pmatrix} \times \begin{pmatrix} 4 \\ 2 \\ 3 \end{pmatrix} = \begin{pmatrix} 7 \\ -2 \\ -8 \end{pmatrix}$$

$$\begin{pmatrix} -3 \\ 1 \\ -2 \end{pmatrix} \times \begin{pmatrix} 1 \\ 0 \\ -2 \end{pmatrix} = \begin{pmatrix} -2 \\ -8 \\ -1 \end{pmatrix}$$



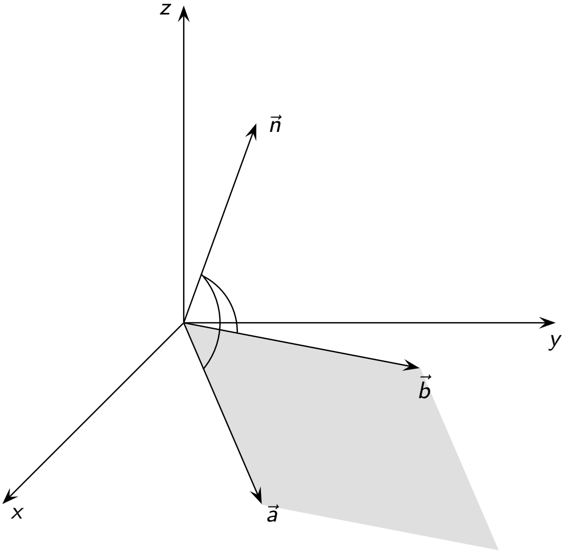
Definition des Vektorprodukts:

$$\begin{pmatrix} a_1 \\ a_2 \\ a_3 \end{pmatrix} \times \begin{pmatrix} b_1 \\ b_2 \\ b_3 \end{pmatrix} = \begin{pmatrix} a_2 b_3 - a_3 b_2 \\ a_3 b_1 - a_1 b_3 \\ a_1 b_2 - a_2 b_1 \end{pmatrix}$$

Beispiele:

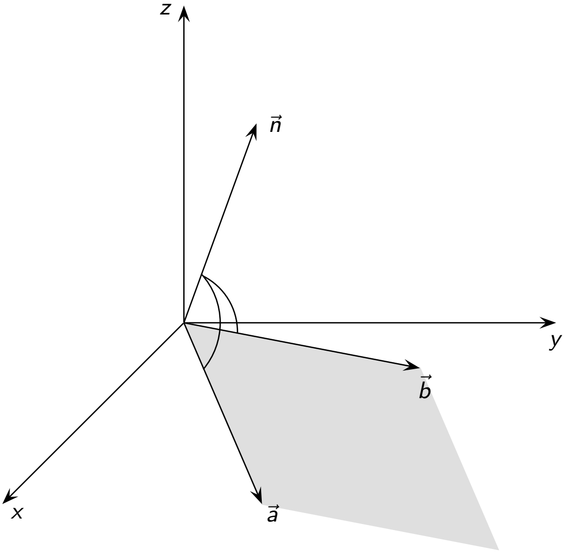
$$\begin{pmatrix} 2 \\ 3 \\ 1 \end{pmatrix} \times \begin{pmatrix} 4 \\ 2 \\ 3 \end{pmatrix} = \begin{pmatrix} 7 \\ -2 \\ -8 \end{pmatrix}$$

$$\begin{pmatrix} -3 \\ 1 \\ -2 \end{pmatrix} \times \begin{pmatrix} 1 \\ 0 \\ -2 \end{pmatrix} = \begin{pmatrix} -2 \\ -8 \\ -1 \end{pmatrix}$$



Definition des Vektorprodukts:

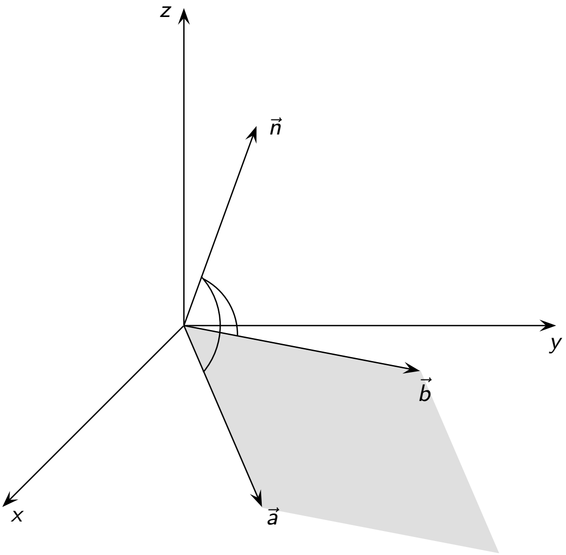
$$\begin{pmatrix} a_1 \\ a_2 \\ a_3 \end{pmatrix} \times \begin{pmatrix} b_1 \\ b_2 \\ b_3 \end{pmatrix} = \begin{pmatrix} a_2 b_3 - a_3 b_2 \\ a_3 b_1 - a_1 b_3 \\ a_1 b_2 - a_2 b_1 \end{pmatrix}$$



Definition des Vektorprodukts:

$$\begin{pmatrix} a_1 \\ a_2 \\ a_3 \end{pmatrix} \times \begin{pmatrix} b_1 \\ b_2 \\ b_3 \end{pmatrix} = \begin{pmatrix} a_2 b_3 - a_3 b_2 \\ a_3 b_1 - a_1 b_3 \\ a_1 b_2 - a_2 b_1 \end{pmatrix}$$

Merkregel:



$$\begin{pmatrix} a_1 \\ a_2 \\ a_3 \end{pmatrix} \times \begin{pmatrix} b_1 \\ b_2 \\ b_3 \end{pmatrix} = \begin{pmatrix} \\ \\ \\ \end{pmatrix}$$

$$\begin{pmatrix} \cancel{a_1} \\ a_2 \\ a_3 \end{pmatrix} \times \begin{pmatrix} \cancel{b_1} \\ b_2 \\ b_3 \end{pmatrix} = \begin{pmatrix} \\ \\ \\ \end{pmatrix}$$

$$\begin{pmatrix} a_1 \\ a_2 \\ a_3 \end{pmatrix} \times \begin{pmatrix} b_1 \\ b_2 \\ b_3 \end{pmatrix} = \begin{pmatrix} \\ \\ \\ \end{pmatrix}$$

$$\begin{pmatrix} a_1 \\ a_2 \\ a_3 \end{pmatrix} \times \begin{pmatrix} b_1 \\ b_2 \\ b_3 \end{pmatrix} = \begin{pmatrix} a_2 b_3 - \qquad \\ \\ \\ \end{pmatrix}$$

$$\begin{pmatrix} a_1 \\ a_2 \\ a_3 \end{pmatrix} \times \begin{pmatrix} b_1 \\ b_2 \\ b_3 \end{pmatrix} = \begin{pmatrix} a_2 b_3 - \\ \\ \\ \end{pmatrix}$$

$$\begin{pmatrix} a_1 \\ a_2 \\ a_3 \end{pmatrix} \times \begin{pmatrix} b_1 \\ b_2 \\ b_3 \end{pmatrix} = \begin{pmatrix} a_2 b_3 - a_3 b_2 \\ \\ \\ \end{pmatrix}$$

$$\begin{pmatrix} a_1 \\ a_2 \\ a_3 \end{pmatrix} \times \begin{pmatrix} b_1 \\ b_2 \\ b_3 \end{pmatrix} = \begin{pmatrix} a_2 b_3 - a_3 b_2 \\ \\ \end{pmatrix}$$

$$\begin{pmatrix} a_1 \\ \cancel{a_2} \\ a_3 \end{pmatrix} \times \begin{pmatrix} b_1 \\ \cancel{b_2} \\ b_3 \end{pmatrix} = \begin{pmatrix} a_2 b_3 - a_3 b_2 \\ \\ \\ \end{pmatrix}$$

$$\begin{pmatrix} a_1 \\ a_2 \\ a_3 \end{pmatrix} \times \begin{pmatrix} b_1 \\ b_2 \\ b_3 \end{pmatrix} = \begin{pmatrix} a_2 b_3 - a_3 b_2 \\ \\ \end{pmatrix}$$

$$\begin{pmatrix} a_1 \\ a_2 \\ a_3 \end{pmatrix} \times \begin{pmatrix} b_1 \\ b_2 \\ b_3 \end{pmatrix} = \begin{pmatrix} a_2 b_3 - a_3 b_2 \\ a_3 b_1 - \\ \end{pmatrix}$$

$$\begin{pmatrix} a_1 \\ a_2 \\ a_3 \end{pmatrix} \times \begin{pmatrix} b_1 \\ b_2 \\ b_3 \end{pmatrix} = \begin{pmatrix} a_2 b_3 - a_3 b_2 \\ a_3 b_1 - \\ \end{pmatrix}$$

$$\begin{pmatrix} a_1 \\ a_2 \\ a_3 \end{pmatrix} \times \begin{pmatrix} b_1 \\ b_2 \\ b_3 \end{pmatrix} = \begin{pmatrix} a_2 b_3 - a_3 b_2 \\ a_3 b_1 - a_1 b_3 \\ \end{pmatrix}$$

$$\begin{pmatrix} a_1 \\ a_2 \\ a_3 \end{pmatrix} \times \begin{pmatrix} b_1 \\ b_2 \\ b_3 \end{pmatrix} = \begin{pmatrix} a_2 b_3 - a_3 b_2 \\ a_3 b_1 - a_1 b_3 \\ \end{pmatrix}$$

$$\begin{pmatrix} a_1 \\ a_2 \\ a_3 \end{pmatrix} \times \begin{pmatrix} b_1 \\ b_2 \\ b_3 \end{pmatrix} = \begin{pmatrix} a_2 b_3 - a_3 b_2 \\ a_3 b_1 - a_1 b_3 \\ \end{pmatrix}$$

$$\begin{pmatrix} a_1 \\ a_2 \\ a_3 \end{pmatrix} \times \begin{pmatrix} b_1 \\ b_2 \\ b_3 \end{pmatrix} = \begin{pmatrix} a_2 b_3 - a_3 b_2 \\ a_3 b_1 - a_1 b_3 \\ \end{pmatrix}$$

$$\begin{pmatrix} a_1 \\ a_2 \\ a_3 \end{pmatrix} \times \begin{pmatrix} b_1 \\ b_2 \\ b_3 \end{pmatrix} = \begin{pmatrix} a_2 b_3 - a_3 b_2 \\ a_3 b_1 - a_1 b_3 \\ a_1 b_2 - \end{pmatrix}$$

$$\begin{pmatrix} a_1 \\ a_2 \\ a_3 \end{pmatrix} \times \begin{pmatrix} b_1 \\ b_2 \\ b_3 \end{pmatrix} = \begin{pmatrix} a_2 b_3 - a_3 b_2 \\ a_3 b_1 - a_1 b_3 \\ a_1 b_2 - \end{pmatrix}$$

$$\begin{pmatrix} a_1 \\ a_2 \\ a_3 \end{pmatrix} \times \begin{pmatrix} b_1 \\ b_2 \\ b_3 \end{pmatrix} = \begin{pmatrix} a_2 b_3 - a_3 b_2 \\ a_3 b_1 - a_1 b_3 \\ a_1 b_2 - a_2 b_1 \end{pmatrix}$$