Aufgabe 1

(a) $x^2 + y^2 + z^2 - 4x + 2y - 10z + 26 = 0$

$(x-2)^2 + (y+1)^2 + (z-5)^2 = -26 + 4 + 1 + 25 = 4$

$M(2, -1, 5)$; $r = 2$

(b) $x^2 + y^2 + z^2 + 12x - 6z + 9 = 0$

$(x+6)^2 + y^2 + (z-3)^2 = -9 + 36 + 9 = 36$

$M(-6, 0, 3)$, $r = 6$

(c) $x^2 + y^2 + z^2 - 14x + 4y + 53 = 0$

$(x-7)^2 + (y+2)^2 + z^2 = -53 + 49 + 4 = 0$

$M(7, -2, 0)$, $r = 0$

(d) $2x^2 + 2y^2 + 2z^2 - 2x + 6y - 4z - 11 = 0$

$x^2 + y^2 + z^2 - x + 3y - 2z = \frac{11}{2}$

$\left(x - \frac{1}{2}\right)^2 + \left(y + \frac{3}{2}\right)^2 + \left(z - 1\right)^2 = \frac{1}{4} + \frac{9}{4} + 1 + \frac{22}{4} = 9$

$M\left(\frac{1}{2}, -\frac{3}{2}, 1\right)$, $r = 3$

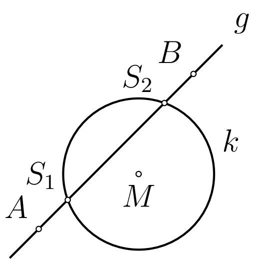
(e) $36x^2 + 36y^2 + 36z^2 + 48x - 108y + 60z - 103 = 0$

$x^2 + y^2 + z^2 + \frac{4}{3}x - 3y + \frac{5}{3}z = \frac{103}{36}$

$\left(x + \frac{2}{3}\right)^2 + \left(y - \frac{3}{2}\right)^2 + \left(z + \frac{5}{6}\right)^2 = \frac{103}{36} + \frac{4}{9} + \frac{9}{4} + \frac{25}{36} = \frac{25}{4}$

$M\left(-\frac{2}{3}, \frac{3}{2}, -\frac{5}{6}\right)$, $r = \frac{5}{2}$

Aufgabe 2



(a) $g\colon \begin{pmatrix} x \\ y \\ z \end{pmatrix} = \begin{pmatrix} 5 \\ 2 \\ 1 \end{pmatrix} + t \begin{pmatrix} 1 \\ -3 \\ 1 \end{pmatrix} \quad \Rightarrow \quad \begin{aligned} x &= t+5 \\ y &= -3t+2 \\ z &= t+1 \end{aligned}$

$g \cap k$:

$$\begin{aligned} x^2 + y^2 + z^2 &= 41 \\ (t+5)^2 + (-3t+2)^2 + (t+1)^2 &= 41 \\ 11t^2 + 30 &= 41 \\ 11t^2 &= 11 \\ t^2 &= 1 \\ t_1 &= 1 \quad \Rightarrow \quad S_1(6, -1, 2) \\ t_2 &= -1 \quad \Rightarrow \quad S_2(4, 5, 0) \end{aligned}$$

(b) $g\colon \begin{pmatrix} x \\ y \\ z \end{pmatrix} = \begin{pmatrix} 5 \\ 2 \\ 0 \end{pmatrix} + t \begin{pmatrix} 1 \\ 3 \\ -1 \end{pmatrix} \quad \Rightarrow \quad \begin{aligned} x &= t+5 \\ y &= 3t+2 \\ z &= -t \end{aligned}$

$g \cap k$:

$$\begin{aligned} x^2 + y^2 + z^2 &= 29 \\ (t+5)^2 + (3t+2)^2 + (-t)^2 &= 29 \\ 11t^2 + 22t + 29 &= 29 \\ 11t^2 + 22t &= 0 \\ 11t(t+2) &= 0 \\ t_1 &= 0 \quad \Rightarrow \quad S_1(5, 2, 0) \\ t_2 &= -2 \quad \Rightarrow \quad S_2(3, -4, 2) \end{aligned}$$

(c) $g\colon \begin{pmatrix} x \\ y \\ z \end{pmatrix} = \begin{pmatrix} 9 \\ 5 \\ 16 \end{pmatrix} + t \begin{pmatrix} 5 \\ 2 \\ 5 \end{pmatrix} \quad \Rightarrow \quad \begin{aligned} x &= 5t+9 \\ y &= 2t+5 \\ z &= 5t+16 \end{aligned}$

$g \cap k$:

$$
\begin{aligned}
(x-2)^2+(y+5)^2+z^2&=81\\
(5t+7)^2+(2t+10)^2+(5t+16)^2&=81\\
54t^2+270t+324&=0\\
t^2+5t+6&=0\\
(t+2)(t+3)&=0\\
t_1&=-2 \quad\Rightarrow\quad S_1(-1,1,6)\\
t_2&=-3 \quad\Rightarrow\quad S_2(-6,-1,1)
\end{aligned}
$$

(d) $g\colon \begin{pmatrix}x\\y\\z\end{pmatrix}=\begin{pmatrix}6\\0\\0\end{pmatrix}+t\begin{pmatrix}2\\-1\\0\end{pmatrix} \quad\Rightarrow\quad \begin{aligned}x&=2t+6\\y&=-t\\z&=0\end{aligned}$

$g\cap k$:

$$
\begin{aligned}
(x+1)^2+(y+4)^2+(z-2)^2&=49\\
(2t+7)^2+(-t+4)^2+(-2)^2&=49\\
5t^2+20t+20&=0\\
t^2+4t+4&=0\\
(t+2)^2&=0\\
t_{1,2}&=0 \quad\Rightarrow\quad S_{1,2}(2,2,0)
\end{aligned}
$$

Aufgabe 3

(a) $M(3,-1,2)$

$r=\frac{1}{2}\left|\vec{r}_B-\vec{r}_A\right|=\frac{1}{2}\sqrt{16+16+16}=\sqrt{12}$

$k\colon (x-3)^2+(y+1)^2+(z-2)^2=12$

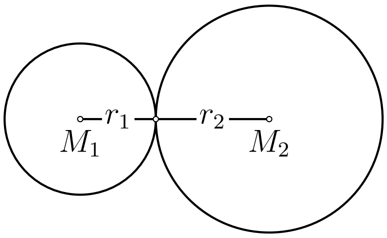
(b) $M(2,3,1)$

$r=\frac{1}{2}\left|\vec{r}_B-\vec{r}_A\right|=\frac{1}{2}\sqrt{4+36+36}=\sqrt{19}$

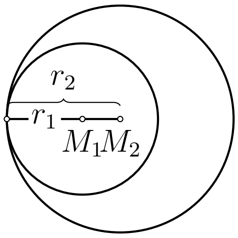
$k\colon (x-2)^2+(y-3)^2+(z-1)^2=19$

Aufgabe 4

Berührung aussen: $|M_1M_2| = r_1 + r_2$



Berührung innen: $|M_1M_2| = \max\{r_1, r_2\} - \min\{r_1, r_2\}$

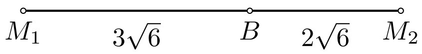


$k_1\colon (x-1)^2 + (y+3)^2 + z^2 = 54$

$k_2\colon (x-11)^2 + (y-2)^2 + (z+5)^2 = -126 + 121 + 4 + 25 = 24$

$M_1(1, -3, 0)$, $r_1 = \sqrt{54} = 3\sqrt{6}$
$M_2(11, 2, -5)$, $r_2 = \sqrt{24} = 2\sqrt{6}$

$$\overrightarrow{M_1M_2} = \begin{pmatrix} 10 \\ 5 \\ -5 \end{pmatrix} \quad \Rightarrow \quad |M_1M_2| = \sqrt{150} = \sqrt{6 \cdot 25} = 5\sqrt{6}$$

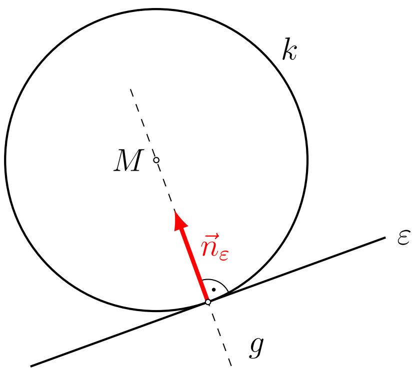


(a) $|M_1M_2| = 5\sqrt{6} = 3\sqrt{6} + 2\sqrt{6} = r_1 + r_2$ (stimmt)

(b) $$\vec{r}_B = \vec{r}_{M_1} + \frac{3}{5}\overrightarrow{M_1M_2} = \begin{pmatrix} 1 \\ -3 \\ 0 \end{pmatrix} + \frac{3}{5}\begin{pmatrix} 10 \\ 5 \\ -5 \end{pmatrix} = \begin{pmatrix} 7 \\ 0 \\ -3 \end{pmatrix}$$

$\Rightarrow \quad B(7, 0, -3)$

Aufgabe 5



(a) $M(6,5,-3)$; $\varepsilon\colon x-2y+2z+4=0$

Die etwas aufwändigere Lösung:

$$g\colon \begin{pmatrix} x\\ y\\ z \end{pmatrix} = \begin{pmatrix} 6\\ 5\\ -3 \end{pmatrix} + t\begin{pmatrix} 1\\ -2\\ 2 \end{pmatrix} \Rightarrow \begin{aligned} x &= t+6\\ y &= -2t+5\\ z &= 2t-3 \end{aligned}$$

$g \cap \varepsilon$:

$$\begin{aligned} x-2y+2z+4 &= 0\\ (t+6)-2(-2t+5)+2(2t-3)+4 &= 0\\ 9t-6 &= 0\\ t &= \tfrac{2}{3} \end{aligned}$$

$$\overline{MB} = \frac{2}{3}\left|\begin{pmatrix} 1\\ -2\\ 2 \end{pmatrix}\right| = \frac{2}{3}\cdot 3 = 2$$

$$\Rightarrow \quad (x-6)^2+(y-5)^2+(z+3)^2 = 4$$

(b) $M(-4,30,-5)$, $\varepsilon\colon 5x-14y+2z=0$

Schnellere Lösung mit der Punkt-Ebene-Abstandsformel:

$$d(M,\varepsilon) = \frac{|5\cdot(-4)-14\cdot 30+2\cdot(5)+0|}{\sqrt{5^2+(-14)^2+2^2}} = \frac{450}{15} = 30$$

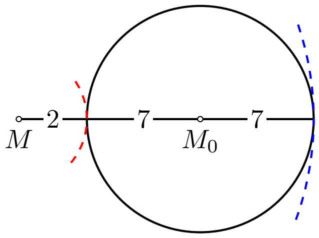
$$\Rightarrow \quad (x+4)^2+(y-30)^2+(z+5)^2 = 900$$

Aufgabe 6

(a) $k_0\colon (x-2)^2+(y+3)^2+(z-1)^2=49;\ M_0(2,-3,1),\ r_0=7$

$M(9,1,5) \qquad \overrightarrow{M_0M}=\begin{pmatrix}9\\1\\5\end{pmatrix}-\begin{pmatrix}2\\-3\\1\end{pmatrix}=\begin{pmatrix}7\\4\\4\end{pmatrix}$

$|M_0M|=\sqrt{49+16+16}=\sqrt{81}=9$



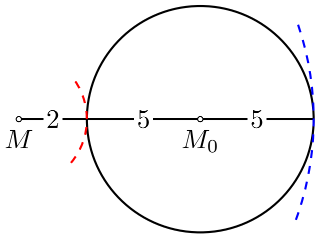
$k_1\colon (x-9)^2+(y-1)^2+(z-5)^2=4$

$k_2\colon (x-9)^2+(y-1)^2+(z-5)^2=256$

(b) $k_0\colon (x+1)^2+(y-2)^2+(z-3)^2=25;\ M_0(-1,2,3),\ r_0=5$

$M(5,4,6) \qquad \overrightarrow{M_0M}=\begin{pmatrix}5\\4\\6\end{pmatrix}-\begin{pmatrix}-1\\2\\3\end{pmatrix}=\begin{pmatrix}6\\2\\3\end{pmatrix}$

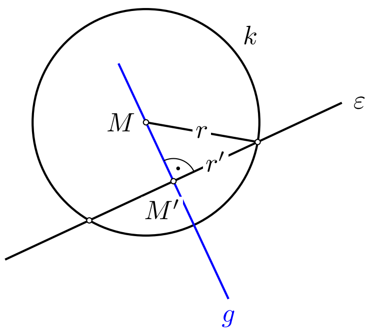
$|M_0M|=\sqrt{36+4+9}=\sqrt{49}=7$



$k_1\colon (x-5)^2+(y-4)^2+(z-6)^2=4$

$k_2\colon (x-5)^2+(y-4)^2+(z-6)^2=144$

Aufgabe 7



$x^2 + y^2 + z^2 - 2y - 22z - 103 = 0$

$x^2 + (y-1)^2 + (z-11)^2 = 103 + 1 + 121 = 225$

$\Rightarrow M(0,1,11),\ r = 15$

$$g\colon \begin{pmatrix} x \\ y \\ z \end{pmatrix} = \begin{pmatrix} 0 \\ 1 \\ 11 \end{pmatrix} + t \begin{pmatrix} 2 \\ 2 \\ -1 \end{pmatrix}$$

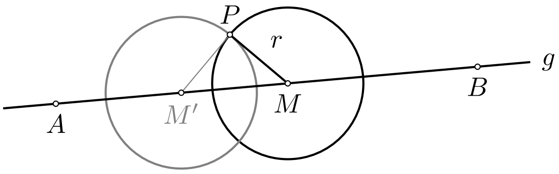
$g \cap \varepsilon$:

$$\begin{aligned} 2(2t) + 2(2t+1) - (-t+11) - 18 &= 0 \\ 9t - 27 &= 0 \\ t &= 3 \quad \Rightarrow \quad M'(6,7,8) \end{aligned}$$

$$|MM'| = \left| \begin{pmatrix} 6 \\ 7 \\ 8 \end{pmatrix} - \begin{pmatrix} 0 \\ 1 \\ 11 \end{pmatrix} \right| = \left| \begin{pmatrix} 6 \\ 6 \\ -3 \end{pmatrix} \right| = \sqrt{36 + 36 + 9} = 9$$

$r' = \sqrt{r^2 - |MM'|^2} = \sqrt{15^2 - 9^2} = 12$

Aufgabe 8



$$g\colon \begin{pmatrix} x \\ y \\ z \end{pmatrix} = \begin{pmatrix} 0 \\ 7 \\ -2 \end{pmatrix} + t \begin{pmatrix} -1 \\ 2 \\ 1 \end{pmatrix} \quad \Rightarrow \quad \begin{aligned} x &= -t \\ y &= 2t + 7 \\ z &= t - 2 \end{aligned}$$

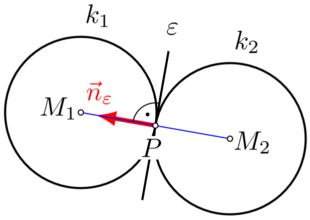
$M(-t, 2t+7, t-2) \in g$

$$\begin{aligned} |\overrightarrow{PM}| &= 3 \\ (-t-3)^2 + (2t+t)^2 + (t)^2 &= 9 \\ 6t^2 + 30t + 36 &= 0 \\ t^2 + 5t + 6 &= 0 \\ (t+2)(t+3) &= 0 \\ t_1 &= -2 \quad \Rightarrow \quad M_1(2, 3, -4) \\ t_2 &= -3 \quad \Rightarrow \quad M_1(3, 1, -5) \end{aligned}$$

$k_1\colon (x-2)^2 + (y-3)^2 + (z+4)^2 = 9$

$k_2\colon (x-3)^2 + (y-1)^2 + (z+5)^2 = 9$

Aufgabe 9



(a) $r = 18,\ A(0,-2,4),\ B(-1,2,-2),\ C(-10,6,0),\ P(3,-2,z)$

$$\overrightarrow{AB} = \begin{pmatrix}-1\\4\\-6\end{pmatrix},\ \overrightarrow{AC} = \begin{pmatrix}-10\\8\\-4\end{pmatrix} \Rightarrow \overrightarrow{AB}\times\overrightarrow{AC} = \begin{pmatrix}32\\56\\32\end{pmatrix} = 8\begin{pmatrix}4\\7\\4\end{pmatrix}$$

$\varepsilon\colon 4x + 7y + 4z - 2 = 0$

$$P \in \varepsilon\colon 4\cdot 3 + 7\cdot(-2) + 4z - 2 = 0$$
$$4z - 4 = 0$$
$$z = 1 \quad\Rightarrow\quad P(2,-2,1)$$

$$\vec{r}_P + \frac{r}{|\vec{n}|}\vec{n} = \begin{pmatrix}2\\-2\\1\end{pmatrix} + \frac{18}{9}\begin{pmatrix}4\\7\\4\end{pmatrix} = \begin{pmatrix}11\\12\\9\end{pmatrix} \Rightarrow M_1(11,12,9)$$

$k_1\colon (x-11)^2 + (y-12)^2 + (z-9)^2 = 324$

$$\vec{r}_P - \frac{r}{|\vec{n}|}\vec{n} = \begin{pmatrix}2\\-2\\1\end{pmatrix} - \frac{18}{9}\begin{pmatrix}4\\7\\4\end{pmatrix} = \begin{pmatrix}-5\\-16\\-7\end{pmatrix} \Rightarrow M_2(-5,-16,-7)$$

$k_2\colon (x+5)^2 + (y+16)^2 + (z+7)^2 = 324$

(b) $r = 42;\ A(6,1,0),\ B(0,-3,7),\ C(-3,-3,1);\ P(10,y,8)$

$$\overrightarrow{AB} = \begin{pmatrix}-6\\-4\\7\end{pmatrix},\ \overrightarrow{AC} = \begin{pmatrix}-9\\-4\\1\end{pmatrix} \Rightarrow \overrightarrow{AC}\times\overrightarrow{AC} = \begin{pmatrix}24\\-57\\-12\end{pmatrix} = 3\begin{pmatrix}8\\-19\\-4\end{pmatrix}$$

$d = -\vec{n}\cdot\vec{r}_A = -29 \quad\Rightarrow\quad \varepsilon\colon 8x - 19y - 4z - 29 = 0$

$$P \in \varepsilon\colon 8\cdot 10 - 19\cdot y - 4\cdot 8 - 29 = 0$$
$$19y - 19 = 0$$
$$z = 1 \quad\Rightarrow\quad P(10,1,8)$$

$$\vec{r}_P + \frac{r}{|\vec{n}|}\vec{n} = \begin{pmatrix}10\\1\\8\end{pmatrix} + \frac{42}{21}\begin{pmatrix}8\\-19\\-4\end{pmatrix} = \begin{pmatrix}26\\-37\\0\end{pmatrix} \Rightarrow M_1(26,-37,0)$$

$k_1\colon (x-26)^2 + (y-37)^2 + z^2 = 1764$

$$\vec{r}_P - \frac{r}{|\vec{n}|}\vec{n} = \begin{pmatrix}10\\1\\8\end{pmatrix} - \frac{42}{21}\begin{pmatrix}8\\-19\\-4\end{pmatrix} = \begin{pmatrix}-6\\39\\16\end{pmatrix} \Rightarrow M_2(-6,39,16)$$

$k_2\colon (x+6)^2 + (y-39)^2 + (z-16)^2 = 1764$

Aufgabe 10

(a) $M(1,-3,0),\ r=5,\ P(1,1,-3)$

$$\overrightarrow{MP}=\begin{pmatrix}1\\1\\-3\end{pmatrix}-\begin{pmatrix}1\\-3\\0\end{pmatrix}=\begin{pmatrix}0\\4\\3\end{pmatrix}$$

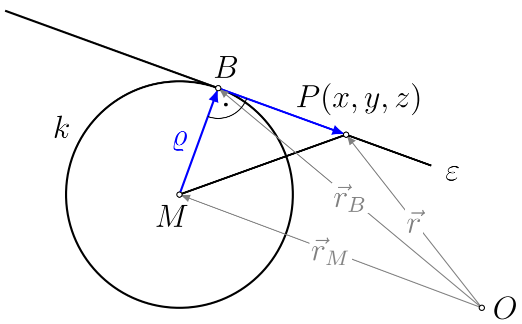
$$\begin{aligned}4y-3z+d&=0 \qquad P(1,1,-3)\in\tau\\ 4\cdot 1-3\cdot(-3)+d&=0 \quad\Rightarrow\quad d=-13\\ \tau\colon 4y-3z-13&=0\end{aligned}$$

(b) $M(3,0,1),\ r=5,\ P(3,-4,-2)$

$$\overrightarrow{MP}=\begin{pmatrix}3\\-4\\-2\end{pmatrix}-\begin{pmatrix}3\\0\\1\end{pmatrix}=\begin{pmatrix}0\\-4\\-3\end{pmatrix}=-\begin{pmatrix}0\\4\\3\end{pmatrix}$$

$$\begin{aligned}4y+3z+d&=0 \qquad P(3,-4,-2)\in\tau\\ 4\cdot(-4)+3\cdot(-2)+d&=0 \quad\Rightarrow\quad d=22\\ \tau\colon 4y+3z+22&=0\end{aligned}$$

Die Polare (Ebene durch $B\perp$ zu $\overrightarrow{MB}$)



$$0=\overrightarrow{MB}\cdot\overrightarrow{BP}$$
$$0=\left(\vec r_B-\vec r_M\right)\cdot\left(\vec r-\vec r_B\right)$$
$$0=\left(\vec r_B-\vec r_M\right)\cdot\left(\vec r-\vec r_M+\vec r_M-\vec r_B\right)$$
$$0=\left(\vec r_B-\vec r_M\right)\cdot\left((\vec r-\vec r_M)-(\vec r_B-\vec r_M)\right)$$
$$0=\left(\vec r_B-\vec r_M\right)\cdot\left(\vec r-\vec r_M\right)-\left(\vec r_B-\vec r_M\right)\cdot\left(\vec r_B-\vec r_M\right)$$
$$0=\left(\vec r_B-\vec r_M\right)\cdot\left(\vec r-\vec r_M\right)-\varrho^2 \quad \text{Polare von } k \text{ durch } B$$

Aufgabe 10 (Lösung mit der Polaren)

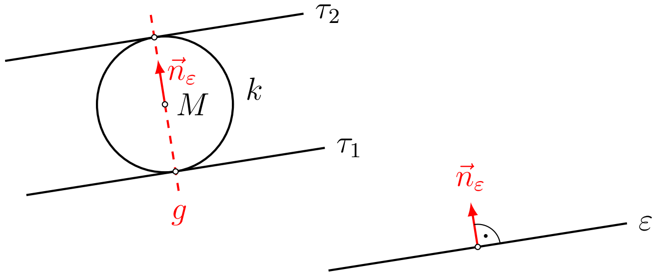
(a) $M(1, -3, 0)$, $r = 5$, $P(1, 1, -3)$

$$\begin{aligned}
(\vec{r}_P - \vec{r}_M) \cdot (\vec{r} - \vec{r}_M) &= 0 \\
\begin{pmatrix} 0 \\ 4 \\ -3 \end{pmatrix} \cdot \left(\begin{pmatrix} x \\ y \\ z \end{pmatrix} - \begin{pmatrix} 1 \\ -3 \\ 0 \end{pmatrix} \right) - 25 &= 0 \\
4y - 3z + 12 - 25 &= 0 \\
4y - 3z - 13 &= 0
\end{aligned}$$

(b) $M(3, 0, 1)$, $r = 5$, $P(3, -4, -2)$

$$\begin{aligned}
(\vec{r}_P - \vec{r}_M) \cdot (\vec{r} - \vec{r}_M) &= 0 \\
\begin{pmatrix} 0 \\ -4 \\ -3 \end{pmatrix} \cdot \left(\begin{pmatrix} x \\ y \\ z \end{pmatrix} - \begin{pmatrix} 3 \\ 0 \\ 1 \end{pmatrix} \right) - 25 &= 0 \\
-4y - 3z + 3 - 25 &= 0 \\
4y + 3z + 22 &= 0
\end{aligned}$$

Aufgabe 11



(a) $k\colon (x-3)^2 + (y-1)^2 + (z+2)^2 = 49, \;\; \varepsilon\colon 3x + 2y - 6z = 0$

$M(3, 1, -2)$; $r = 7$

$$g\colon \begin{pmatrix} x \\ y \\ z \end{pmatrix} = \begin{pmatrix} 3 \\ 1 \\ -2 \end{pmatrix} + t \begin{pmatrix} 3 \\ 2 \\ -6 \end{pmatrix}$$

$$\begin{aligned} g \cap k\colon 49 &= (x-3)^2 + (y-1)^2 + (z+2)^2 \\ 49 &= (3t)^2 + (2t)^2 + (-6t)^2 \\ 49 &= 49t^2 \\ t_1 &= 1 \quad \Rightarrow \quad B_1(6, 3, -8) \\ t_2 &= -1 \quad \Rightarrow \quad B_2(0, -1, 4) \end{aligned}$$

$\tau_1\colon 3x + 2y - 6z - 72 = 0$
$\tau_2\colon 3x + 2y - 6z + 26 = 0$

(b) $k\colon (x-4)^2 + y^2 + (z+1)^2 = 81, \;\; \varepsilon\colon 2x - 2y + z - 7 = 0$

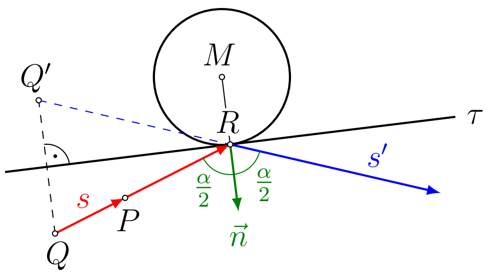
$M(4, 0, -1)$; $r = 9$

$$g\colon \begin{pmatrix} x \\ y \\ z \end{pmatrix} = \begin{pmatrix} 4 \\ 0 \\ -1 \end{pmatrix} + t \begin{pmatrix} 2 \\ -2 \\ 1 \end{pmatrix}$$

$$\begin{aligned} g \cap k\colon 81 &= (x-4)^2 + y^2 + (z+1)^2 \\ 81 &= (2t)^2 + (-2t)^2 + (t)^2 \\ 81 &= 9t^2 \\ t_1 &= 3 \quad \Rightarrow \quad B_1(10, -6, 2) \\ t_2 &= -3 \quad \Rightarrow \quad B_2(-2, 6, -4) \end{aligned}$$

$\tau_1\colon 2x - 2y + z - 34 = 0$
$\tau_2\colon 2x - 2y + z + 20 = 0$

Aufgabe 12



(a) $s\colon \begin{pmatrix} x \\ y \\ z \end{pmatrix} = \begin{pmatrix} 5 \\ 38 \\ -7 \end{pmatrix} + t \begin{pmatrix} -2 \\ -16 \\ 1 \end{pmatrix} \quad \Rightarrow \quad \begin{aligned} x &= -2t+5 \\ y &= -16t+38 \\ z &= t-7 \end{aligned}$

$s \cap k$:

$$\begin{aligned} 225 &= (-2t+5-3)^2 + (-16t+38+8)^2 + (t-7)^2 \\ 225 &= (-2t+2)^2 + (-16t+46)^2 + (t-7)^2 \\ 0 &= 261t^2 - 1494t + 1944 \\ t_1 &= \tfrac{108}{29} \approx 3.72 \quad \text{zu weit weg} \\ t_2 &= 2 \quad \Rightarrow \quad R(1, 6, -5) \end{aligned}$$

(b) $M(3, -8, 0)$, $r = 15$

$$\overrightarrow{MR} = \begin{pmatrix} 1 \\ 6 \\ -5 \end{pmatrix} - \begin{pmatrix} 3 \\ -8 \\ 0 \end{pmatrix} = \begin{pmatrix} -2 \\ 14 \\ -5 \end{pmatrix} = (-1) \cdot \begin{pmatrix} 2 \\ -14 \\ 5 \end{pmatrix}$$

$d = -\vec{n} \cdot \vec{r}_R = 107 \quad \Rightarrow \quad \tau\colon 2x - 14y + 5z + 107 = 0$

$g\colon \begin{pmatrix} x \\ y \\ z \end{pmatrix} = \begin{pmatrix} 5 \\ 38 \\ -7 \end{pmatrix} + t \begin{pmatrix} -2 \\ 14 \\ 15 \end{pmatrix} \quad \Rightarrow \quad \begin{aligned} x &= -2t+5 \\ y &= 14t+38 \\ z &= -5t-7 \end{aligned}$

$$\begin{aligned} g \cap \tau\colon 0 &= 2(-2t+5) - 14(14t+38) + 5(-5t-7) + 107 \\ 0 &= -225t - 450 \\ t &= -2 \quad \Rightarrow \quad t' = -4 \quad \Rightarrow \quad Q'(13, -18, 13) \end{aligned}$$

$$\overrightarrow{QR} = \begin{pmatrix} 1 \\ 6 \\ -5 \end{pmatrix} - \begin{pmatrix} 13 \\ -18 \\ 13 \end{pmatrix} = \begin{pmatrix} -12 \\ 24 \\ -18 \end{pmatrix} = 6 \cdot \begin{pmatrix} -2 \\ 4 \\ -3 \end{pmatrix}$$

$$s'\colon \begin{pmatrix} x \\ y \\ z \end{pmatrix} = \begin{pmatrix} 1 \\ 6 \\ -5 \end{pmatrix} + t \begin{pmatrix} -2 \\ 4 \\ -3 \end{pmatrix}$$

(c) $\alpha = 2 \arccos \dfrac{\vec{n} \cdot \vec{v}}{|\vec{n}| \cdot |\vec{v}|} = 2 \arccos \dfrac{75}{15 \cdot \sqrt{29}} = 43.60°$