

1. Magnetfeld eines Koaxialkabels

For $r \leq R_1$:

$$I_{in} = I \frac{r^2}{R_1^2}$$

$$I_{in}\mu_0 = \oint \vec{B}(\vec{r}) \, d\vec{s} = B(r) \oint ds = B(r)2r\pi$$

$$B(r) = \frac{I\mu_0}{2\pi R_1^2} r$$

For $R_1 \leq r \leq R_2$:

$$I_{in} = I$$

$$I_{in}\mu_0 = \oint \vec{B}(\vec{r}) \, d\vec{s} = B(r) \oint ds = B(r)2r\pi$$

$$B(r) = \frac{I\mu_0}{2\pi} \frac{1}{r}$$

For $R_2 \leq r \leq R_3$:

$$I_{in} = I \left(1 - \frac{r^2 - R_2^2}{R_3^2 - R_2^2} \right)$$

$$I_{in}\mu_0 = \oint \vec{B}(\vec{r}) \, d\vec{s} = B(r) \oint ds = B(r)2r\pi$$

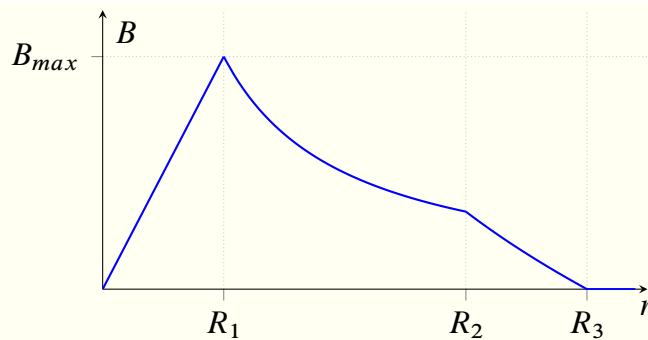
$$B(r) = \frac{I\mu_0}{2\pi} \left(\frac{1}{r} - \frac{r^2 - R_2^2}{r(R_3^2 - R_2^2)} \right)$$

For $R_3 \leq r$:

$$I_{in} = 0$$

$$B(r) = 0$$

$$B(r) = \begin{cases} \frac{I\mu_0}{2\pi R_1^2} r & \text{for } 0 < r \leq R_1, \\ \frac{I\mu_0}{2\pi} \frac{1}{r} & \text{for } R_1 \leq r \leq R_2, \\ \frac{I\mu_0}{2\pi} \left(\frac{1}{r} - \frac{r^2 - R_2^2}{r(R_3^2 - R_2^2)} \right) & \text{for } R_2 \leq r \leq R_3, \\ 0 & \text{for } R_3 \leq r. \end{cases}$$



2. Anwendung des Gesetzes von Biot-Savart – „Haarnadel“

$$R = \sqrt{x^2 + y^2}; \quad r = \sqrt{x^2 + y^2 + z^2} = \sqrt{R^2 + z^2}$$

$$dB_1 = \frac{\mu_0 I}{4\pi} \frac{|\vec{dl} \times \vec{r}|}{r^3} = \frac{\mu_0 I}{4\pi} \frac{dl}{r^2} = \frac{\mu_0 I}{4\pi} \frac{d\varphi R}{r^2}$$

$$B_1 = \frac{\mu_0 I}{4\pi} \frac{R}{r^2} \int_0^\pi 1 d\varphi = \frac{\mu_0 I}{4} \frac{R}{r^2}$$

$$B_{x,1} = B_1 \sin(\theta) = \frac{\mu_0 I}{4} \frac{R}{r^2} \sin(\theta) = \frac{\mu_0 I}{4} \frac{R^2}{r^3}$$

$$B_{z,1} = B_1 \cos(\theta) = \frac{\mu_0 I}{4} \frac{R}{r^2} \cos(\theta) = \frac{\mu_0 I}{4} \frac{Rz}{r^3}$$

$$dB_2 = \frac{\mu_0 I}{4\pi} \frac{|\vec{dl} \times \vec{r}|}{r^3} = \frac{\mu_0 I}{4\pi} \frac{dl \sin(\theta)}{r^2} = \frac{\mu_0 I}{4\pi} \frac{dl \sqrt{y^2 + z^2}}{r^3}$$

$$B_2 = \frac{\mu_0 I}{2\pi} \int_{-\infty}^0 \frac{\sqrt{y^2 + z^2}}{r^3} dx = \frac{\mu_0 I}{2\pi} \frac{1}{\sqrt{y^2 + z^2}}$$

$$B_{z,2} = B_2 \cos(\theta) = \frac{\mu_0 I}{2\pi} \frac{1}{\sqrt{y^2 + z^2}} \cos(\theta) = \frac{\mu_0 I}{2\pi} \frac{z}{\sqrt{y^2 + z^2} \sqrt{x^2 + y^2 + z^2}}$$

$$\vec{B}(z) = \frac{\mu_0 I}{4} \left(\begin{array}{c} R^2 / (R^2 + z^2)^{3/2} \\ 0 \\ \frac{Rz}{(R^2 + z^2)^{3/2}} + \frac{2z}{\pi \sqrt{y^2 + z^2} \sqrt{R^2 + z^2}} \end{array} \right)$$

3. Drehmoment auf rechteckige Leiterschleife

a) $\varphi = \arctan\left(\frac{d}{2x}\right); \quad r = \sqrt{\frac{4x^2 + d^2}{4}}$

$$\vec{B}(r) = \frac{\mu_0 I_1}{2r\pi} \begin{pmatrix} -\sin(\varphi) \\ \cos(\varphi) \\ 0 \end{pmatrix}$$

$$\vec{F}_1 = I_2 \vec{h} \times \vec{B} = \frac{\mu_0 I_1 I_2 h}{2\pi} \begin{pmatrix} -\cos(\varphi) \\ -\sin(\varphi) \\ 0 \end{pmatrix}$$

$$\vec{F}_2 = I_2 \vec{h} \times \vec{B} = \frac{\mu_0 I_1 I_2 h}{2r\pi} \begin{pmatrix} \cos(\varphi) \\ \sin(\varphi) \\ 0 \end{pmatrix}$$

$$\vec{M}_1 = \vec{r}_1 \times \vec{F}_1 = \begin{pmatrix} 0 \\ d/2 \\ 0 \end{pmatrix} \times \frac{\mu_0 I_1 I_2 h}{2r\pi} \begin{pmatrix} -\cos(\varphi) \\ -\sin(\varphi) \\ 0 \end{pmatrix} = \frac{\mu_0 I_1 I_2 h d}{4r\pi} \begin{pmatrix} 0 \\ 0 \\ \cos(\varphi) \end{pmatrix}$$

$$\vec{M}_2 = \vec{r}_2 \times \vec{F}_2 = \begin{pmatrix} 0 \\ -d/2 \\ 0 \end{pmatrix} \times \frac{\mu_0 I_1 I_2 h}{2r\pi} \begin{pmatrix} \cos(\varphi) \\ \sin(\varphi) \\ 0 \end{pmatrix} = \frac{\mu_0 I_1 I_2 h d}{4r\pi} \begin{pmatrix} 0 \\ 0 \\ \cos(\varphi) \end{pmatrix}$$

$$\vec{M} = \vec{M}_1 + \vec{M}_2 = \frac{\mu_0 I_1 I_2 h d}{2r\pi} \begin{pmatrix} 0 \\ 0 \\ \cos(\varphi) \end{pmatrix}$$

b) $\mu_0 = 4\pi * 10^{-7} \text{ H/m}; \quad I_1 = 16 \text{ A}; \quad I_2 = 1 \text{ A}; \quad d = h = x = 0.1 \text{ m}$

$$\vec{M} = \frac{\mu_0 I_1 I_2 h d}{2r\pi} \cos(\varphi) \hat{z} = \underline{\underline{2.56 * 10^{-7} \text{ Nm}}}$$

Bolts on Bike : 5 – 30 Nm

Basic Electromotor : 0.3 – 0.5 Nm

Car wheels : 110 – 120 Nm