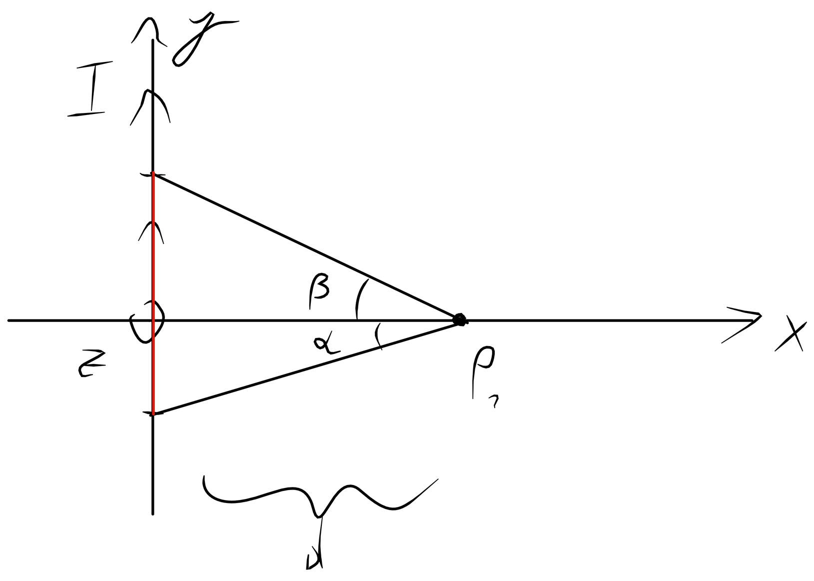


$d\bar{B} = \frac{\mu_0 I}{4\pi}\frac{d\bar{l}\times\bar{r}}{r^3}$ $\quad d\bar{l} = d\sec^2\varphi\,\hat{e}_y\,d\varphi = \begin{bmatrix}0\\ d\sec^2\varphi\\ 0\end{bmatrix}d\varphi \quad \bar{r} = \begin{bmatrix}d\\ -d\tan\varphi\\ 0\end{bmatrix}$

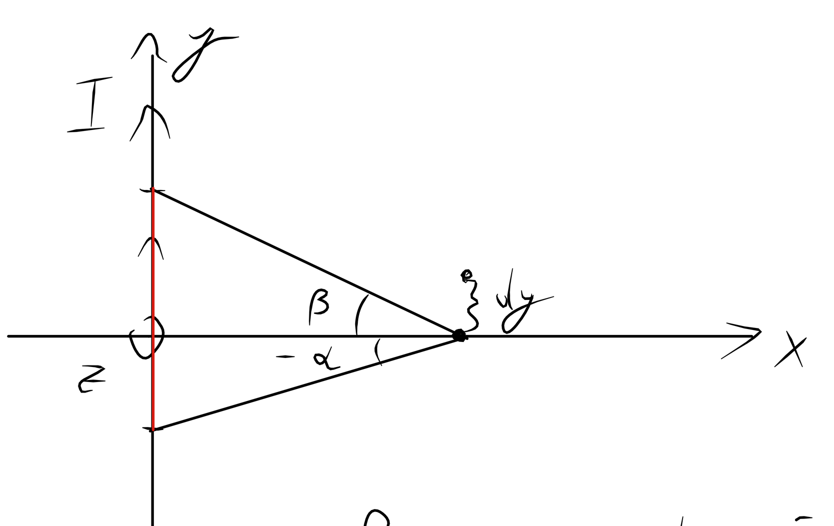
$\bar{l} = d\tan\varphi\,\hat{e}_y$

$$d\bar{l}\times\bar{r} = \begin{bmatrix}0\\ d\sec^2\varphi\,d\varphi\\ 0\end{bmatrix}\times\begin{bmatrix}d\\ -d\tan\varphi\\ 0\end{bmatrix} = d^2 d\varphi\begin{bmatrix}0\\ 0\\ \sec^2\varphi\end{bmatrix} = d^2 d\varphi\sec^2\varphi\,\hat{e}_z$$

$$\bar{B} = \frac{\mu_0 I}{4\pi}\int_{-\alpha}^{\beta}\frac{d^2\sec^2\varphi\,d\varphi}{\underbrace{\sqrt{d^2+\tan^2\varphi\, d^2}}_{d\sec\varphi}{}^3} = \frac{\mu_0 I}{4\pi d}\int_{-\alpha}^{\beta}\cos\varphi\,d\varphi = \frac{\mu_0 I}{4\pi d}\left(\sin\beta+\sin\alpha\right)\hat{e}_z =$$

$$= \frac{\mu_0 I}{4\pi d}\left(\frac{y_\beta}{\sqrt{d^2+y_\beta^2}} - \frac{y_\alpha}{\sqrt{d^2+y_\alpha^2}}\right) = \left\{\begin{matrix} y_\beta - y_\alpha = a \\ \underbrace{y_\alpha}_{y} + a = y_\beta\end{matrix}\right\} = \frac{\mu_0 I}{4\pi d}\left(\frac{y+a}{\sqrt{d^2+(y+a)^2}} - \frac{y}{\sqrt{d^2+y^2}}\right)\hat{e}_z = \bar{B}(y)\hat{e}_z$$

y to współrzędna dolna



Ruszam prętem, nie punktem.

$d\bar{F} = I\,d\bar{y}\times\bar{B} \qquad d\bar{F} = I\,dy\,B(y)\,\hat{e}_y\times e_z = I\,dy\,B(y)\,\hat{e}_x$

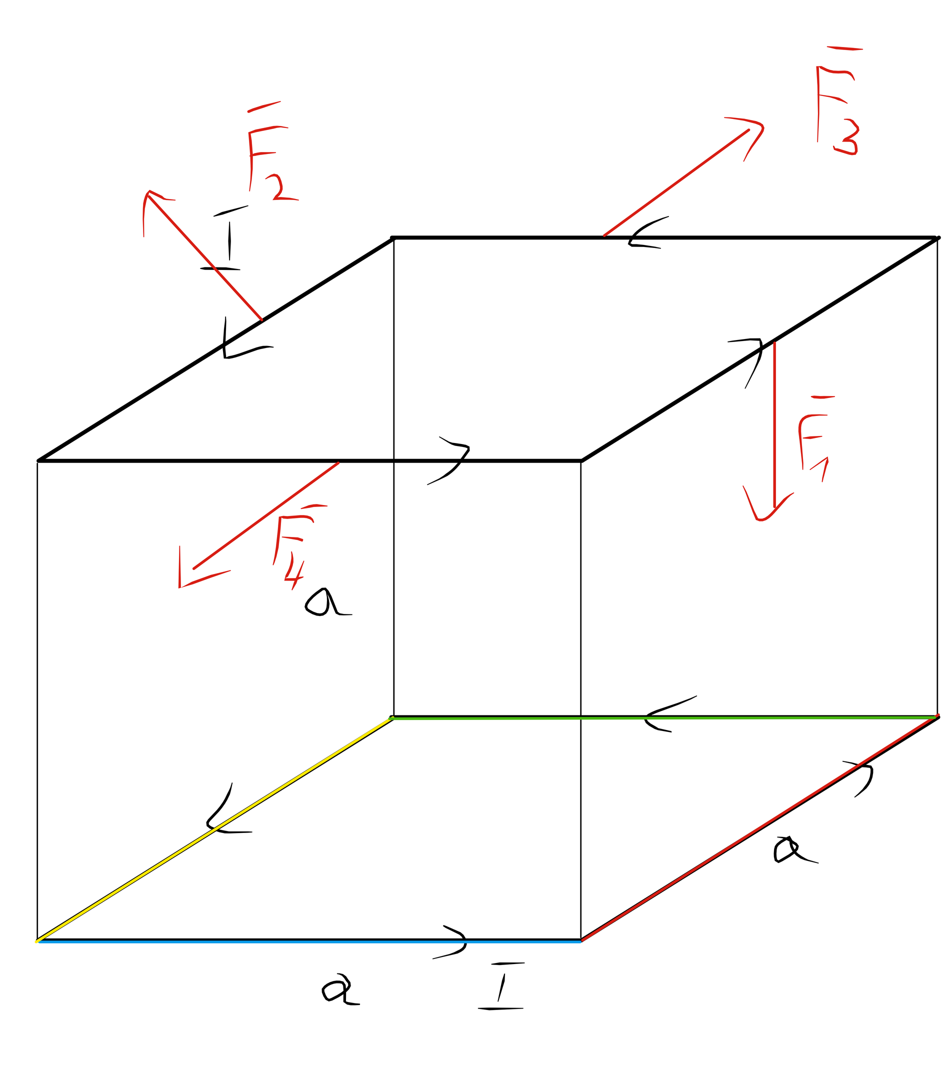
$$\bar{F} = \frac{\mu_0 I^2\hat{e}_x}{4\pi d}\int_{-a}^{0}\left(\frac{y+a}{\sqrt{d^2+(y+a)^2}} - \frac{y}{\sqrt{d^2+y^2}}\right)dy = \left\{\begin{matrix} u = d^2+(y+a)^2 & t = d^2+y^2 \\ \frac{du}{2} = (y+a)\,dy & \frac{dt}{2} = y\,dy \\ -a\to d^2 \quad 0\to d^2+a^2 & -a\to d^2+a^2 \quad 0\to d^2\end{matrix}\right\} =$$

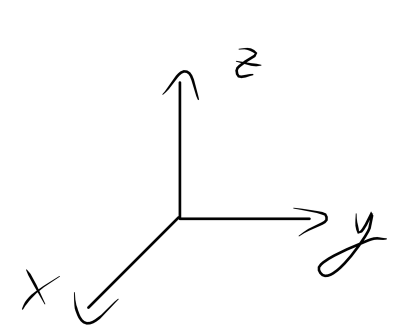
$$= \frac{\mu_0 I^2\hat{e}_x}{8\pi d}\left[\int_{d^2}^{d^2+a^2}\frac{1}{\sqrt{u}}\,du + \int_{d^2}^{d^2+a^2}\frac{1}{\sqrt{t}}\,dt\right] = \frac{\mu_0 I^2\hat{e}_x}{4\pi d}\left[2\sqrt{u}\right]_{d^2}^{d^2+a^2} = \frac{\mu_0 I^2\hat{e}_x}{2\pi d}\left[\sqrt{d^2+a^2} - d\right]$$

$$= \frac{\mu_0 I^2\hat{e}_x}{2\pi d}\cdot\frac{a^2}{\sqrt{d^2+a^2}+d} \xrightarrow{a\gg d} \frac{\mu_0 I^2 a}{2\pi d}$$

czyli jak dla dwóch nieskończonych prętów, więc się zgadza

$$\bar{F}(d) = \frac{\mu_0 I^2\hat{e}_x}{2\pi d}\,\frac{a^2}{\sqrt{d^2+a^2}+d}$$





Siły działające na prostopadłe boki będą się równoważyć z racji symetrii i przeciwnych zwrotów prądów.

$$\bar{F}_4 + \bar{F}_3 = 0$$

$$\bar{F}_1(a) = \frac{-\mu_0 I^2}{2\pi a}\,\frac{a^2}{\sqrt{a^2+a^2}+a}\,\hat{e}_z = \frac{\mu_0 I^2}{2\pi}\left(-\sqrt{2}+1\right)\hat{e}_z$$

$$\bar{F}_2(a\sqrt{2}) = \frac{\mu_0 I^2}{2\pi a\sqrt{2}}\left(\sqrt{2a^2+a^2} - a\right)\left[0;\ -\frac{\sqrt{2}}{2};\ \frac{\sqrt{2}}{2}\right] =$$

$$= \frac{\mu_0 I^2}{2\pi}\,\frac{\sqrt{3}-1}{2}\left[0;\ -1;\ 1\right]$$

$$\bar{F} = \frac{\mu_0 I^2}{\pi}\left(\sqrt{3}+1-2\sqrt{2}\right)\hat{e}_z$$

$$\bar{F}_c = \frac{\mu_0 I^2}{2\pi}\left[0;\ \frac{1-\sqrt{3}}{2};\ \frac{\sqrt{3}+1}{2} - \sqrt{2}\right]$$

$$\bar{F}_c = \frac{\mu_0 I^2}{2\pi}\left[\frac{-1+\sqrt{3}}{2};\ 0;\ \frac{\sqrt{3}+1}{2} - \sqrt{2}\right]$$

$$\bar{F}_c = \frac{\mu_0 I^2}{2\pi}\left[0;\ \frac{-1+\sqrt{3}}{2};\ \frac{\sqrt{3}+1}{2} - \sqrt{2}\right]$$

$$\bar{F}_c = \frac{\mu_0 I^2}{2\pi}\left[\frac{1-\sqrt{3}}{2};\ 0;\ \frac{\sqrt{3}+1}{2} - \sqrt{2}\right]$$