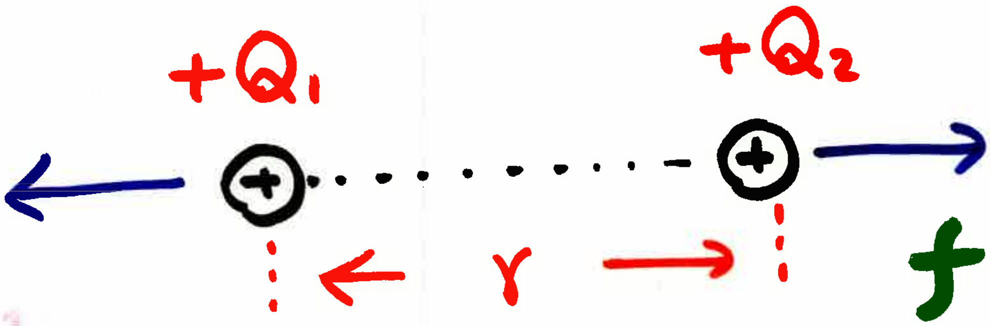
電流に働く力

〝磁気力〟



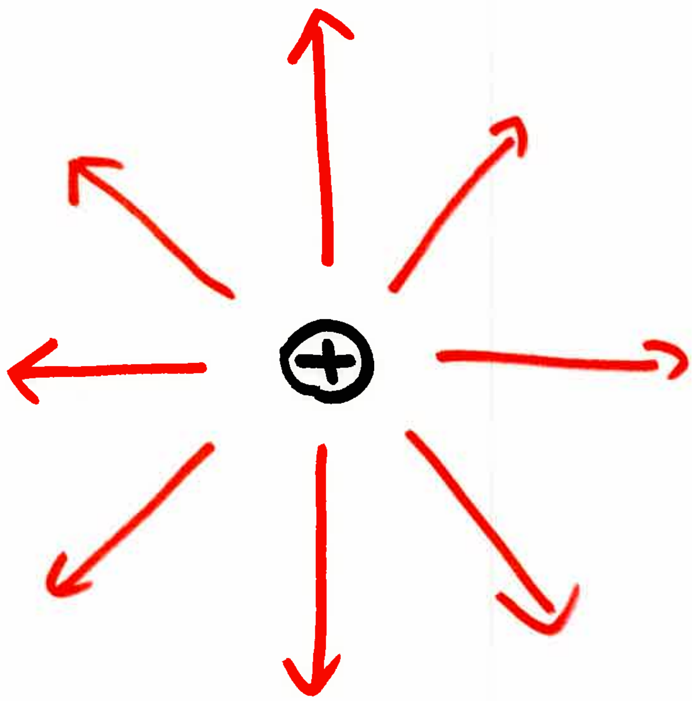
クーロンの法則

$$f = k\frac{Q_1 Q_2}{r^2}$$

$$k = k_0 \quad (\text{遠距離作用})$$

$$= \frac{1}{4\pi\varepsilon_0} \quad (\text{近接作用})$$

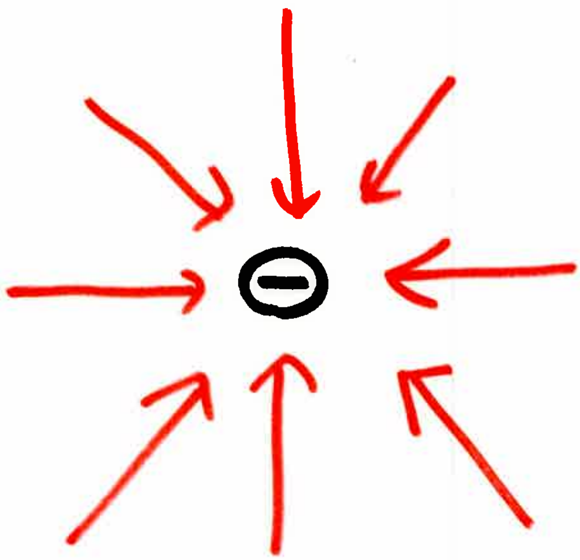
Faraday



$$\vec{E} = \frac{Q}{4\pi\varepsilon_0 r^2}\cdot\frac{\vec{r}}{r}$$

ε_0：真空誘電率

$[8.854\times10^{-12}\ \mathrm{F/m}]$

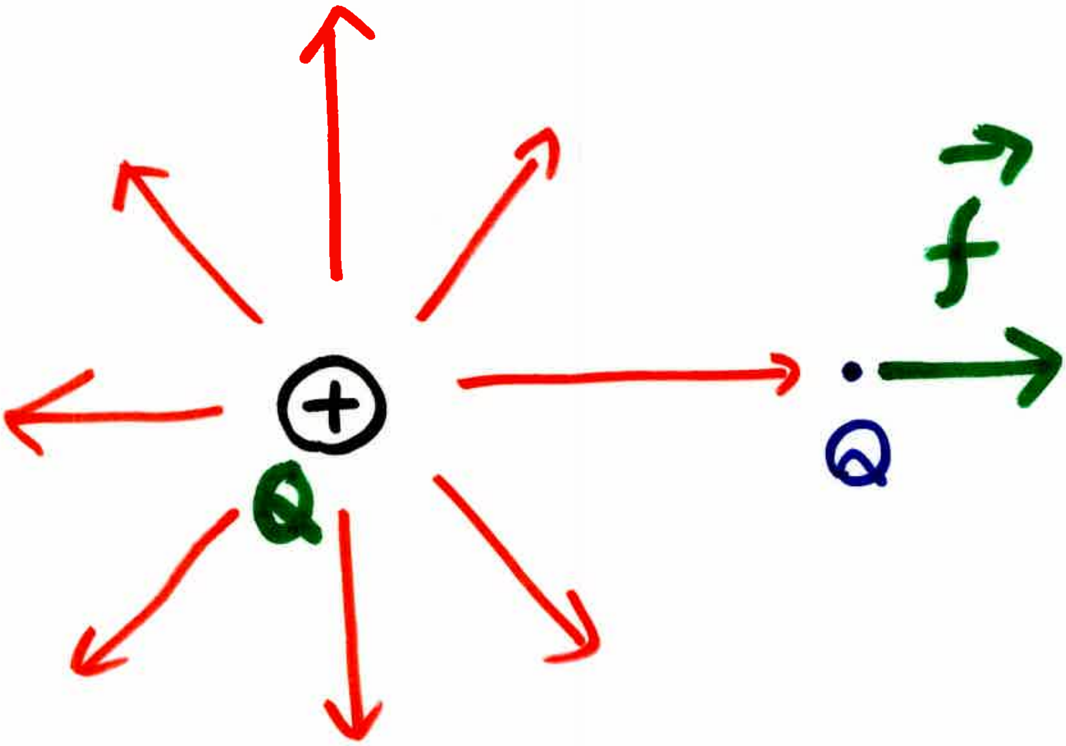


Faradayの考えたこと

"真空中"に"電界"を考えた!!

"真空"は性質を持つ

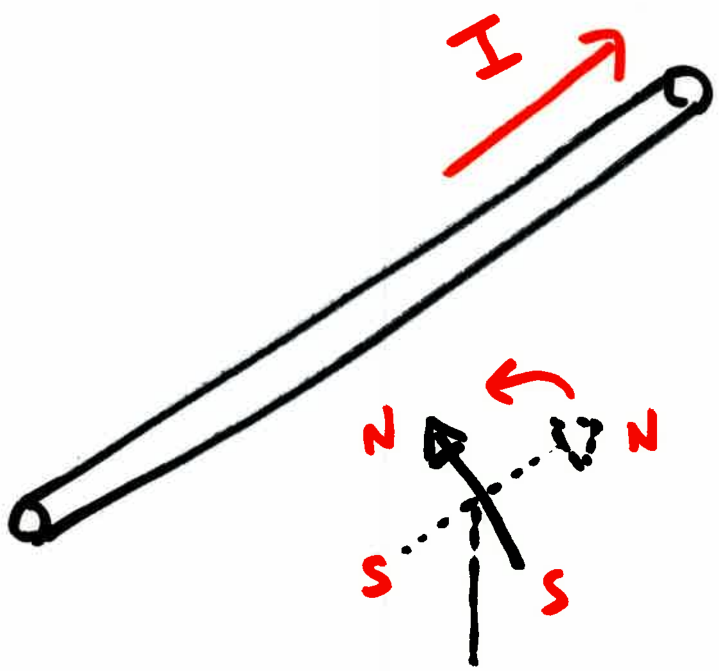
$$\vec{f} = Q\vec{E}$$



$\vec{f}$の方向は$\vec{E}$の方向

発散型

エルステッド(1820, コペンハーゲン)



$\vec{I} = en\mu\vec{E}$
$= \sigma\vec{E}$

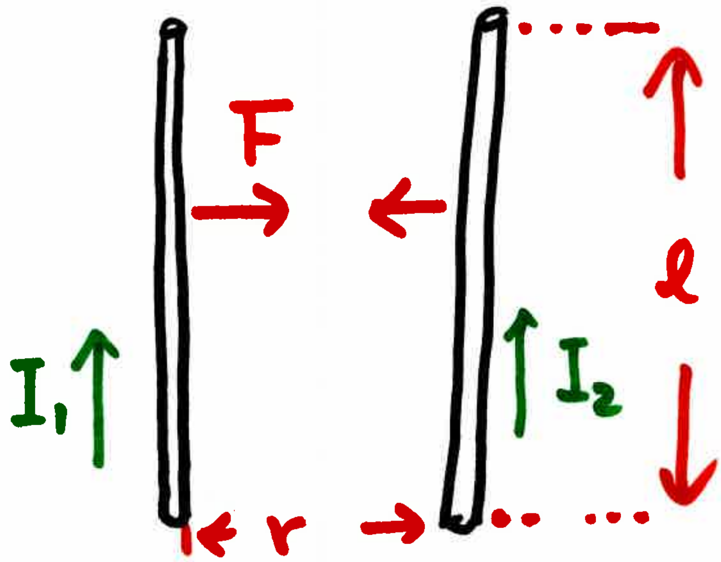
磁針

"新しい力"の発見

"なぜ新しい力"と考えるか

電流に働く力

アンペアの実験



引力

k' : 定数 ?

$$F=\frac{\mu_0}{2\pi}\frac{I_1 I_2}{r}l$$

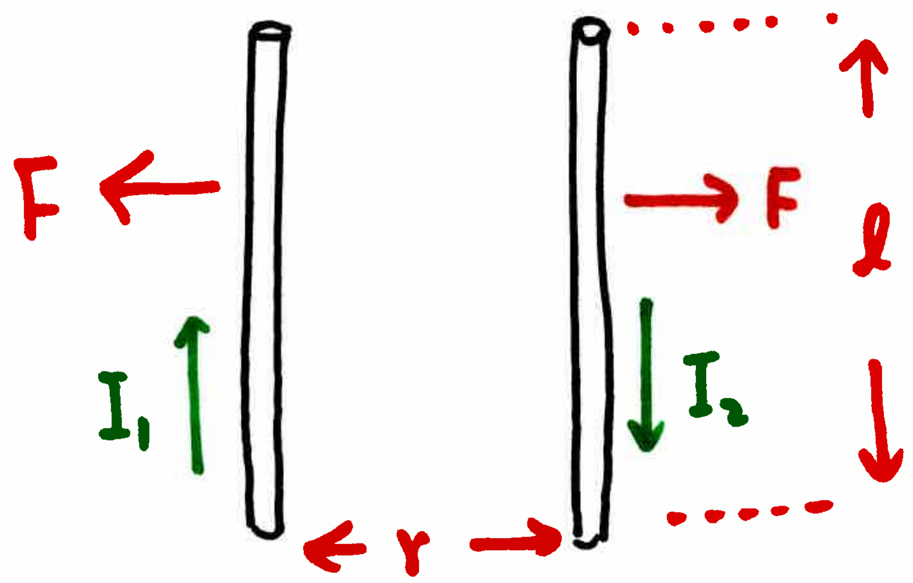
μ_0 : 定数

$$[F] = [\mu_0]\frac{[A][A]}{[m]}[m]$$

$\vdots$

N

$$[\mu_0] = \frac{N}{A^2} = H/m$$



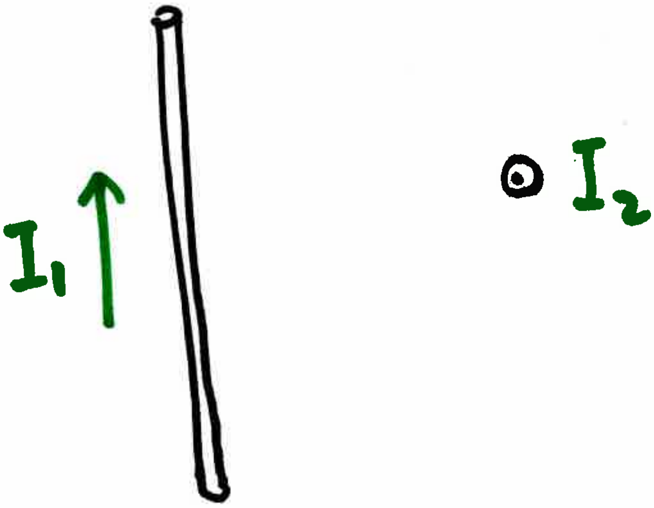
$$F = \frac{\mu_0}{2\pi}\frac{I_1 I_2}{r}\ell$$

$\boxed{\mu_0:\text{真空透磁率}}$

⇩

"真空"は磁気的な性質を持つ

↳ 磁気的場も近接作用



(I_1と直角)

$$F = 0$$

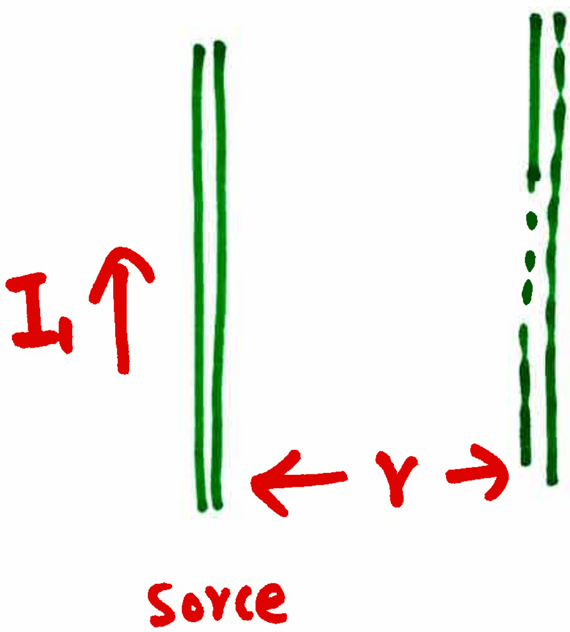
$$F = \frac{\mu_0}{2\pi} \frac{I_1 I_2}{r} \ell$$

source と考える

$$= \underbrace{\left(\frac{\mu_0}{2\pi} \frac{I_1}{r} \right)}_{B} I_2 \ell$$

磁束密度

$$B = \frac{\mu_0}{2\pi r} I_1$$ ← r の位置の場



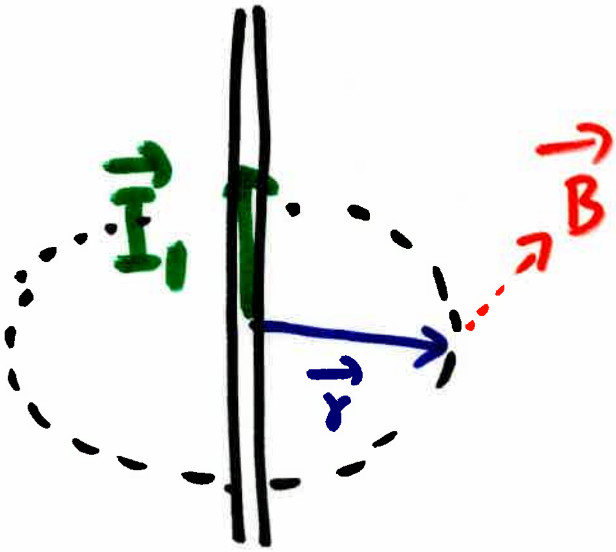
$$B = \frac{F}{I_2 \ell}$$

$$[B] = \frac{N}{Am}$$

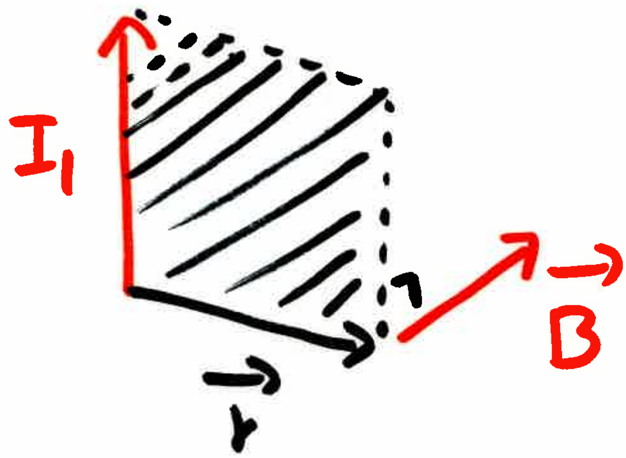
$$= T$$

テスラ

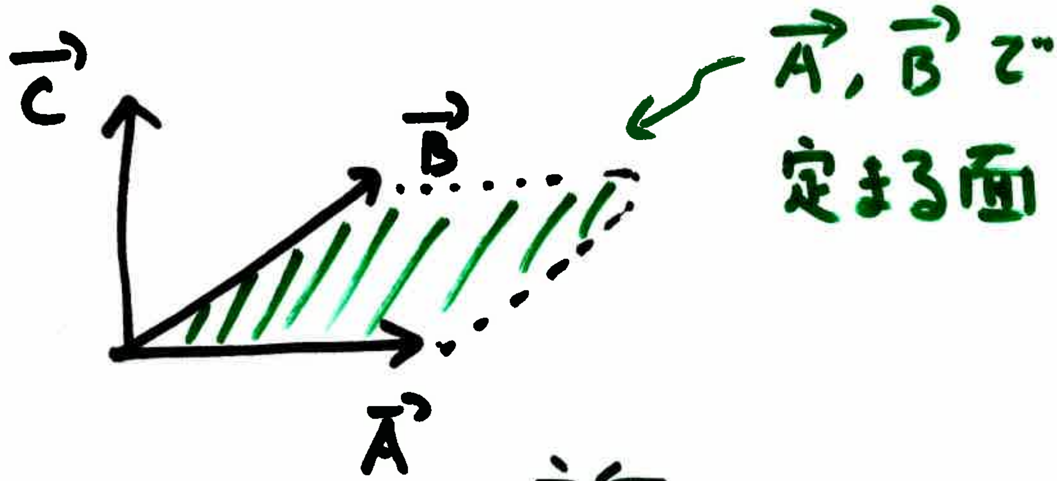
$[Wb/m^2]$



$$\vec{B} = \frac{\mu_0}{2\pi}\left(\vec{I}_1 \times \frac{\vec{r}}{r}\right)\frac{1}{r}$$



$\vec{B}$: $\vec{I}_1$ と $\vec{r}$ で作られる面に垂直な方向



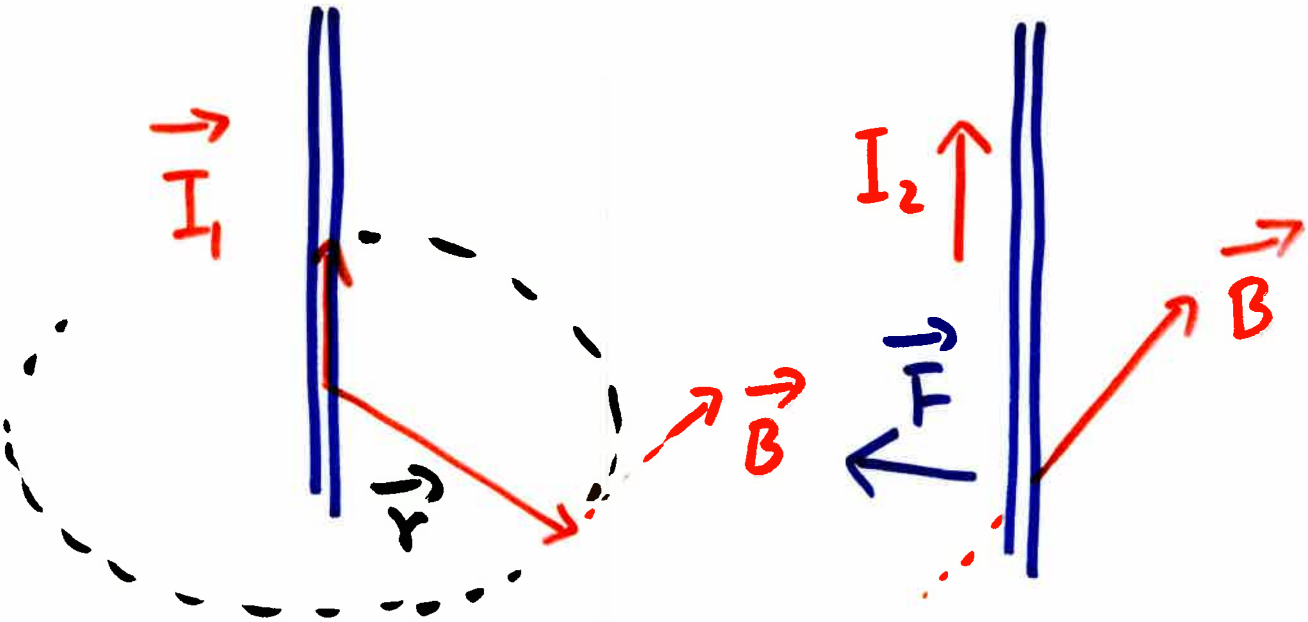
$\vec{C} = \vec{A} \times \vec{B}$

方向

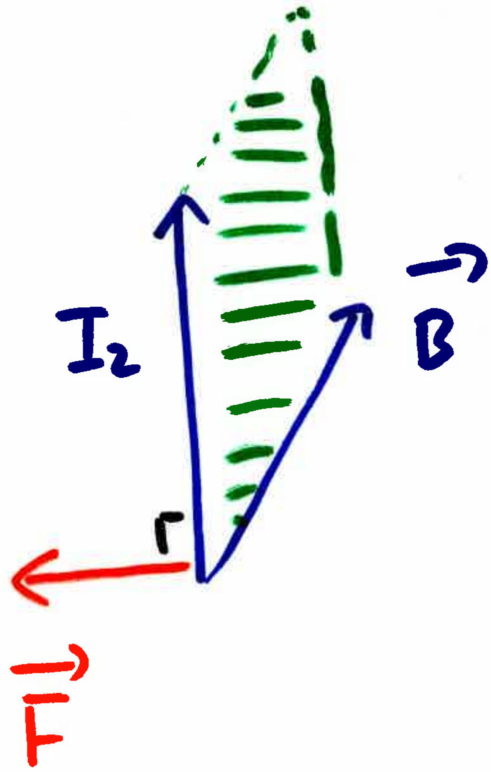
$\vec{A}, \vec{B}$で定まる面に垂直

大きさ

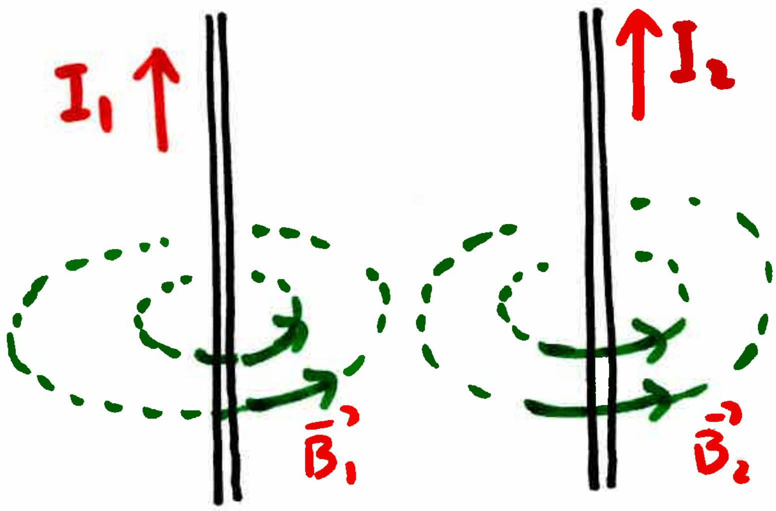
$$|\vec{C}| = |\vec{A} \times \vec{B}| = |\vec{A}||\vec{B}| \sin\theta$$

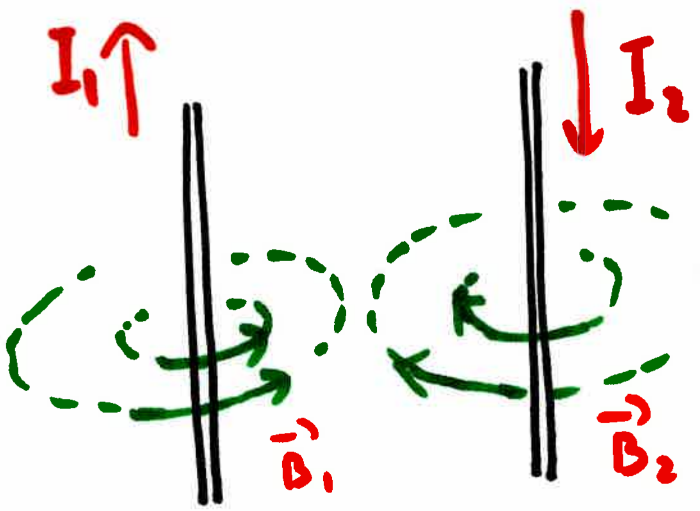


$\vec{F}$の方向は
$\vec{I_2}$と$\vec{B}$の
作る面に
垂直



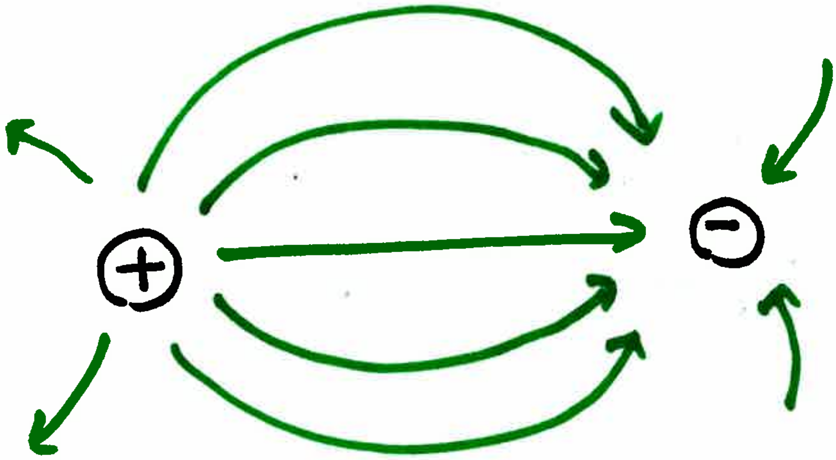
$$\vec{F}=(\vec{I_2}\times\vec{B})\ell$$



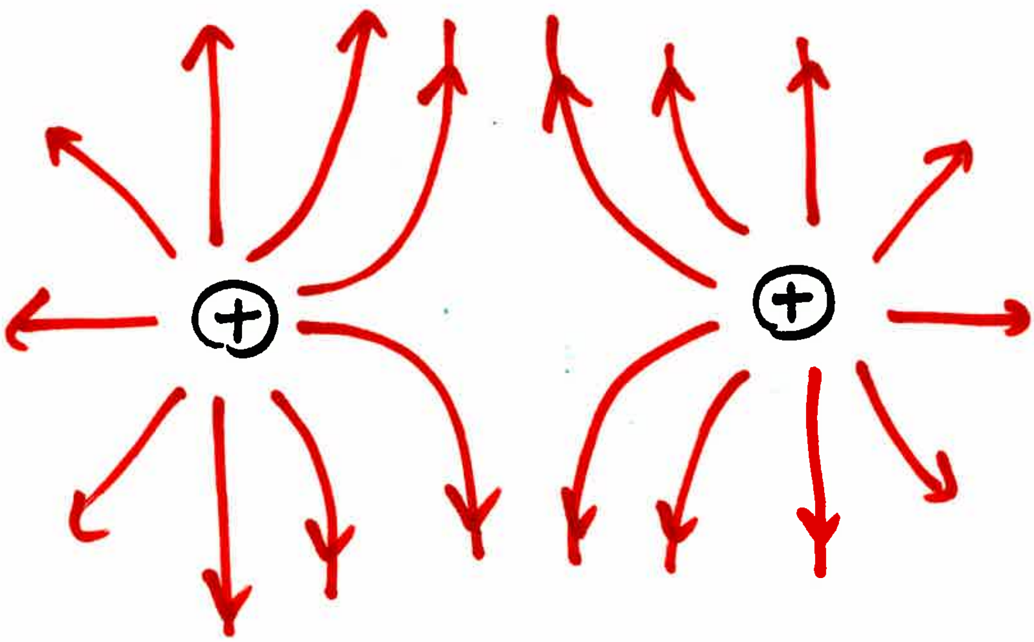


磁界の方向に注目

静電気現象



引力



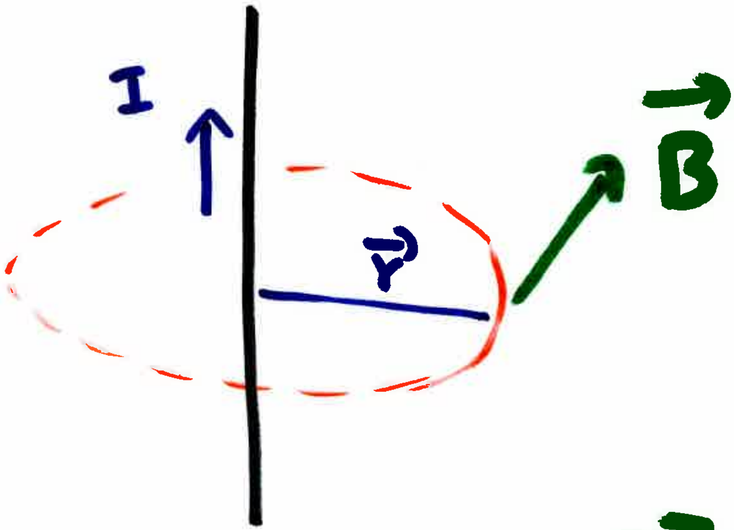
斥力

反撥力

ビオサバールの法則

$$B = \frac{\mu_0}{2\pi}\frac{I_1}{r}$$

無限の電流線による $\vec{B}$

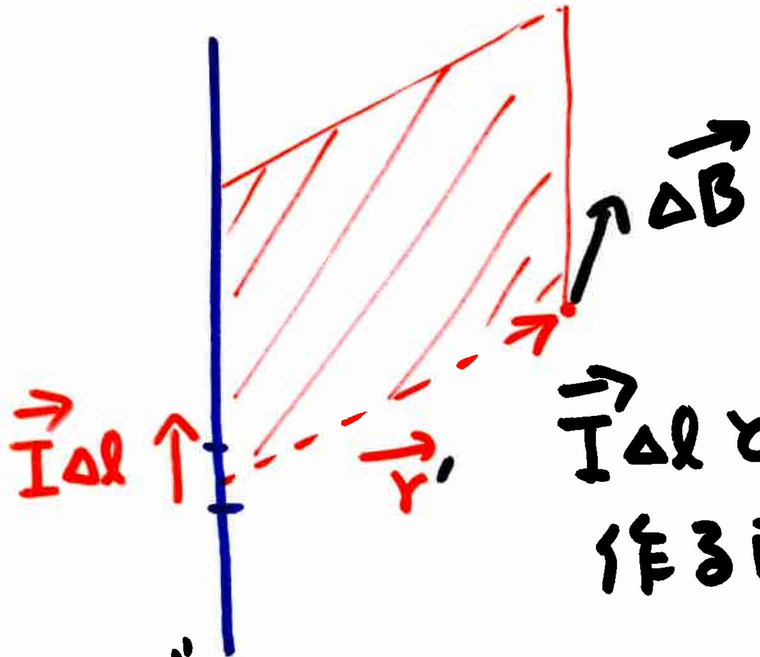


$$\vec{B} = \frac{\mu_0}{2\pi}\frac{\vec{I_1}\times\vec{r}}{r}\frac{1}{r}$$

素電流 $I\Delta l$ に対する磁束密度は？

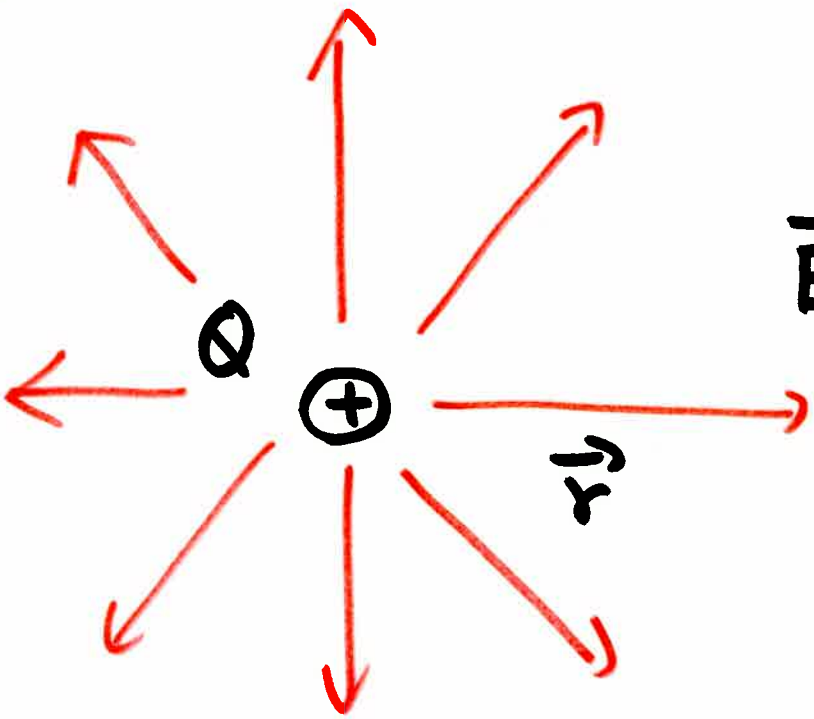
$\Delta\vec{B}$

$$\Delta\vec{B} = \frac{\mu_0}{4\pi}\frac{\vec{I}_1\Delta l}{r'^2}\times\frac{\vec{r}'}{r'}$$



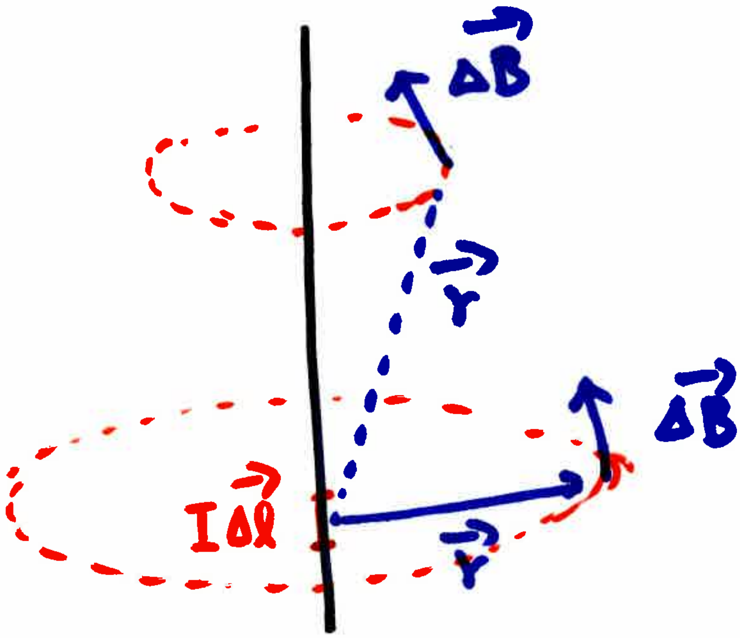
$\vec{I}\Delta l$ と $\vec{r}'$ の作る面に垂直

$(\vec{I}_1\Delta l)$ から発散的な大きさの場

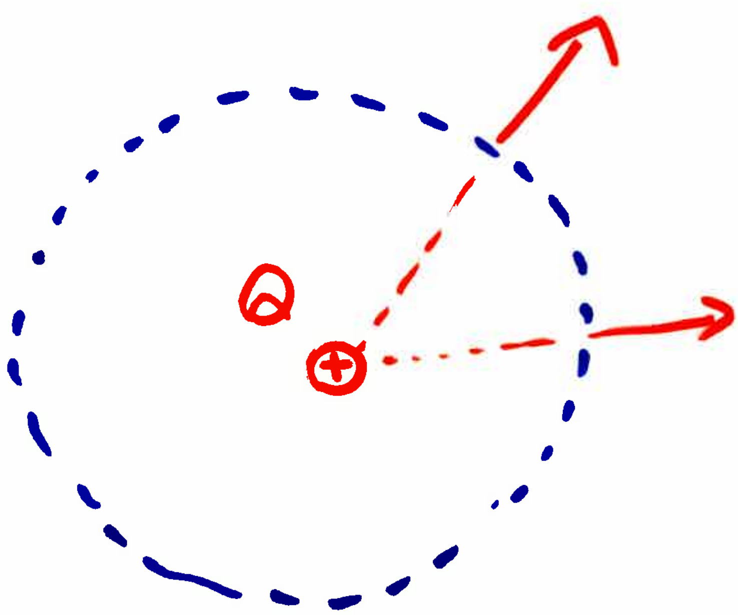


$$\vec{E} = \frac{Q}{4\pi\varepsilon_0 r^2}\frac{\vec{r}}{r}$$

$$\Delta \vec{B} = \frac{\mu_0}{4\pi}\cdot\frac{I_1 \Delta\vec{l}}{r'^2}\times\frac{\vec{r}'}{r'}$$

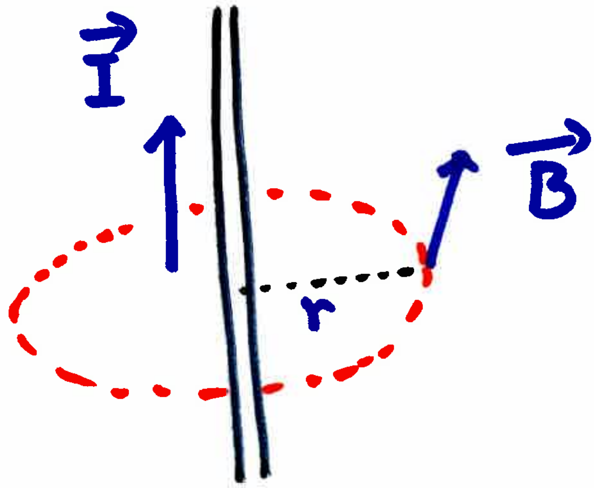


$$\Delta\vec{B} = \frac{\mu_0}{4\pi}\frac{I\Delta\vec{l}}{r^2}\times\frac{\vec{r}}{r}$$

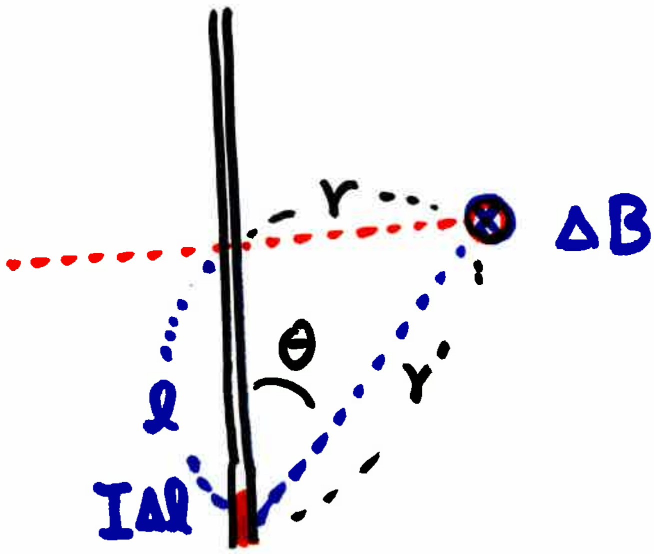


$$\vec{E} = \frac{Q}{4\pi\varepsilon_0 r^2}\cdot\frac{\vec{r}}{r}$$

ビオサバールの法則



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

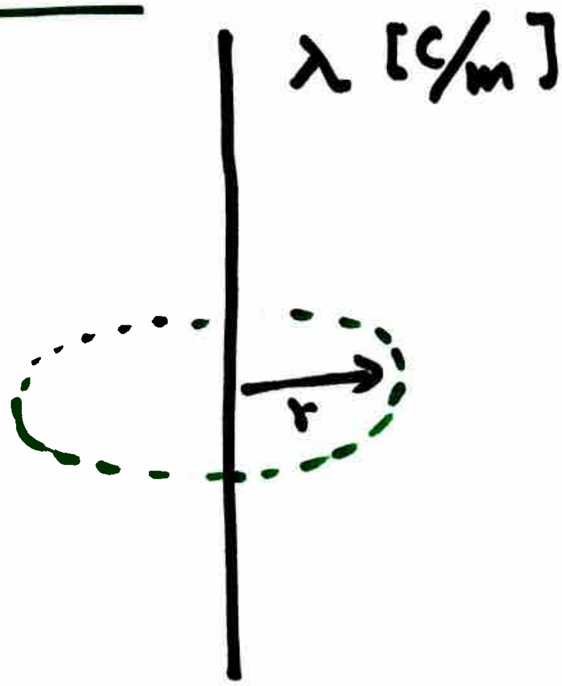


$$r=r'\sin\theta$$

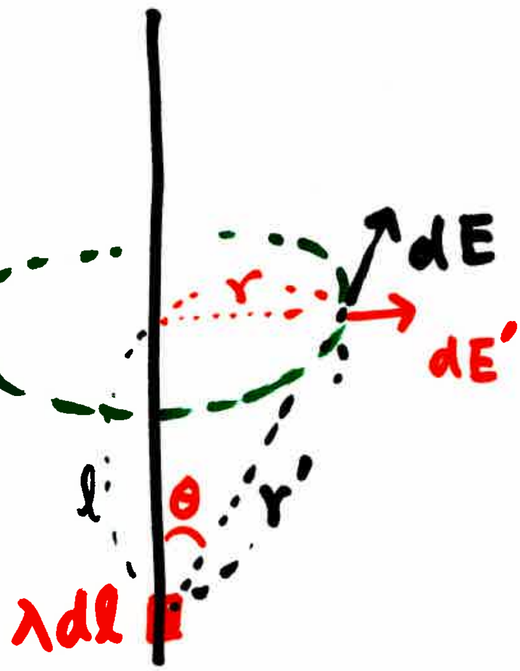
$$\Delta B=\frac{\mu_0}{4\pi}\cdot\frac{I_1\Delta l}{r'^2}\sin\theta$$

[電荷の場合]

補足



$$E = \frac{\lambda}{2\pi\varepsilon_0 r}$$



$$dE = \frac{\lambda dl}{4\pi\varepsilon_0 r'^2}$$

$$dE' = \frac{\lambda dl}{4\pi\varepsilon_0 r'^2} \cdot \frac{r}{r'}$$

$$dE' = dE\cos\left(\frac{\pi}{2} - \theta\right) = dE\sin\theta$$

$$= dE\,\frac{r}{r'}$$

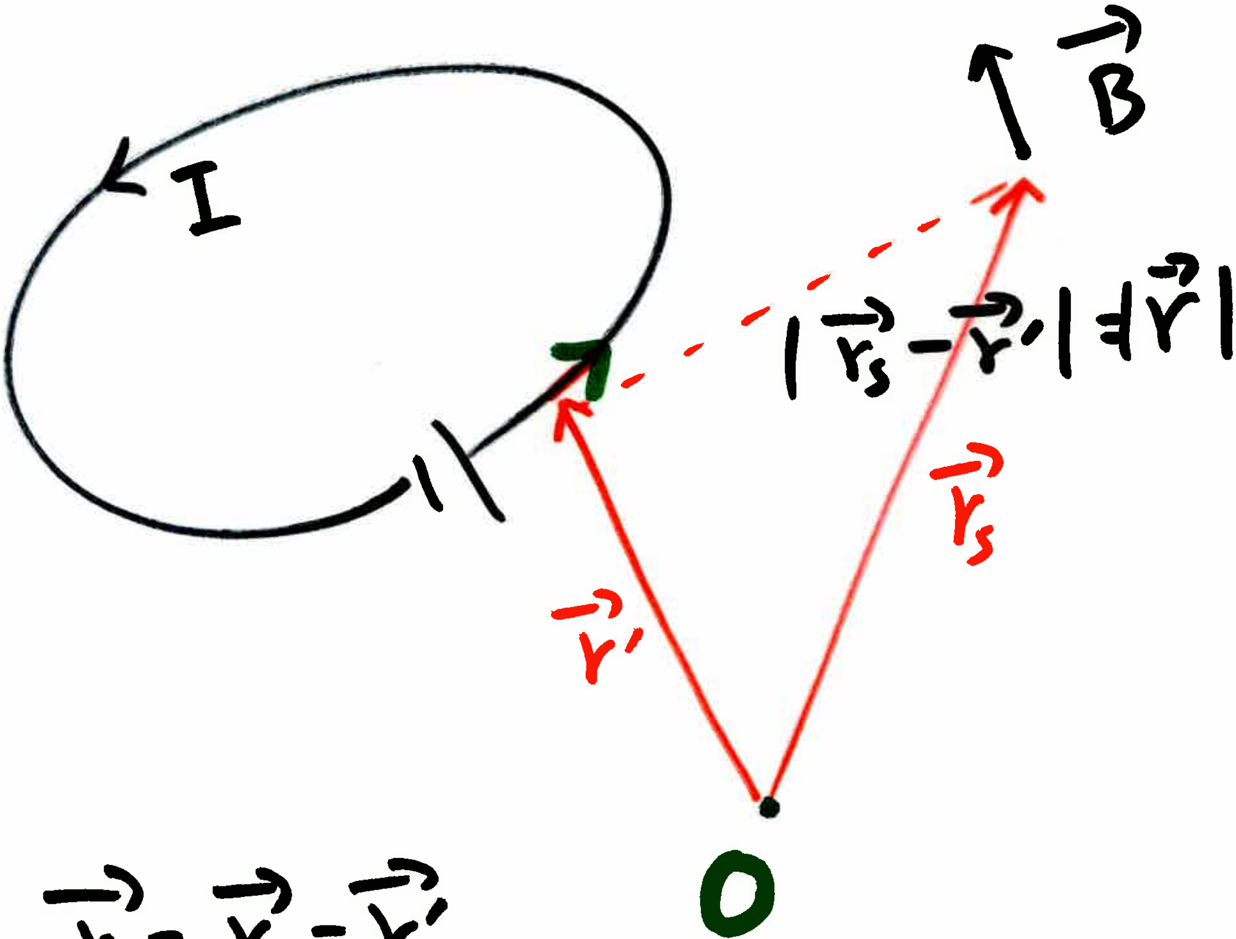
$$E = \int_{-\infty}^{+\infty} \frac{1}{4\pi\varepsilon_0} \frac{\lambda\, dl}{r'^2} \frac{r}{r'}$$

$$= \int_{-\infty}^{+\infty} \frac{1}{4\pi\varepsilon_0} \frac{\lambda r}{(r^2+l^2)^{3/2}}\, dl$$

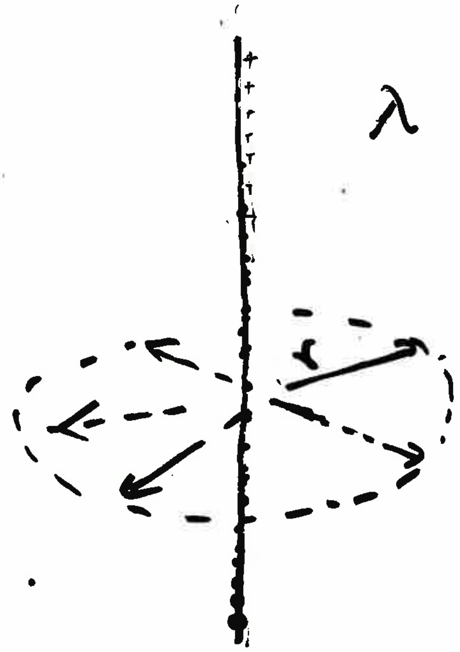
$$= \frac{\lambda}{2\pi\varepsilon_0 r}$$

$$\vec{B} = \frac{\mu_0}{4\pi}\oint_C \frac{I\,d\vec{l}}{r^2}\times\frac{\vec{r}}{r}$$

$$= \frac{\mu_0}{4\pi}\oint_C \frac{I\,d\vec{l}\times(\vec{r}_s-\vec{r}\,')}{|\vec{r}_s-\vec{r}\,'|^3}$$

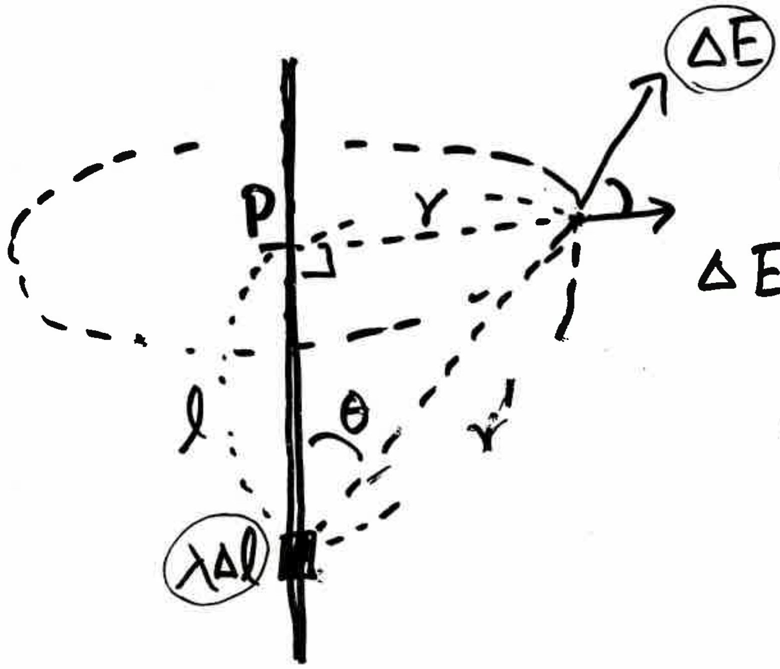


$$\vec{r} = \vec{r}_s - \vec{r}\,'$$



$$E = \frac{\lambda}{2\pi\varepsilon_0 r}$$

線状電荷λの作る界



$\Delta E \sin\theta$

$$\sin\theta = \frac{r}{r'}$$

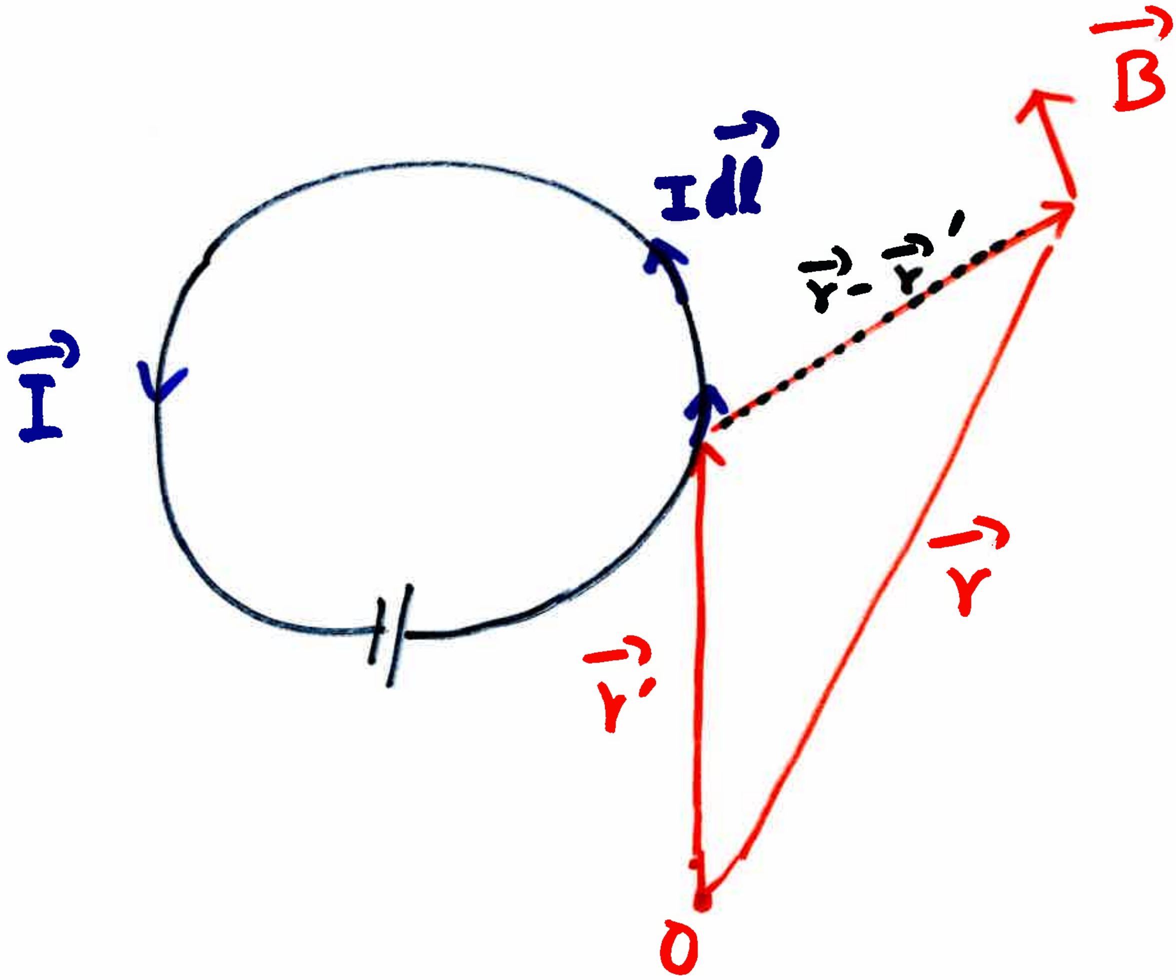
$$E = \sum \Delta E \sin\theta = \sum \frac{1}{4\pi\varepsilon_0} \frac{\lambda \Delta l}{r'^2} \sin\theta$$

$$E = \sum \frac{1}{4\pi\varepsilon_0} \frac{\lambda \Delta l}{r'^2} \frac{r}{r'}$$

$$= \int_{-\infty}^{+\infty} \frac{1}{4\pi\varepsilon_0} \frac{\lambda r \, dl}{(r^2 + l^2)^{3/2}}$$

$$E = \frac{\lambda}{2\pi\varepsilon_0 r}$$

$$\vec{B} = \frac{\mu_0}{4\pi} \oint_c \frac{I}{r^2} \, \vec{dl} \times \frac{\vec{r}}{r}$$



$$\vec{B} = \frac{\mu_0}{4\pi} \oint_c \frac{I\vec{dl} \times (\vec{r} - \vec{r}')}{|\vec{r} - \vec{r}'|^3}$$