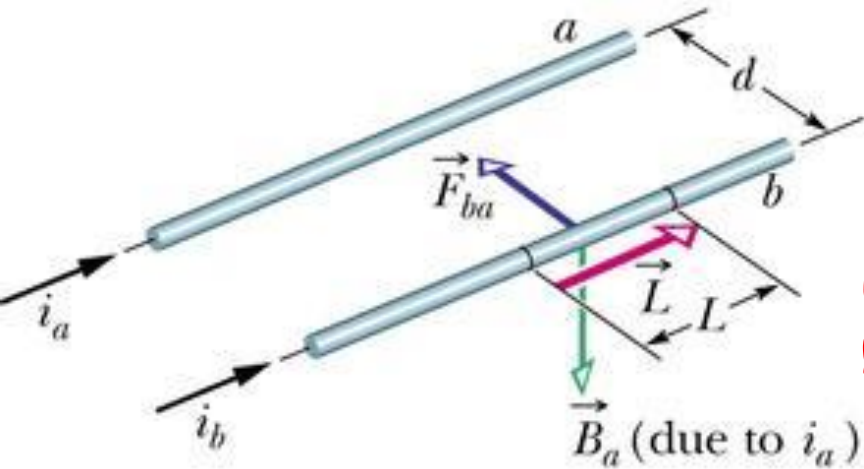


Magnetno polje u vakuumu

Sila između dva paralelna provodnika

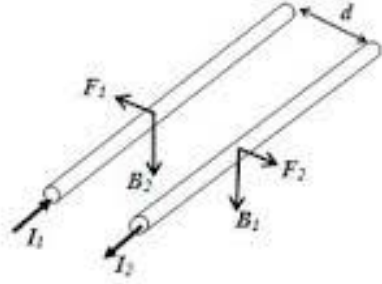
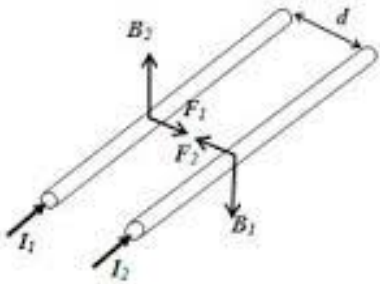
Amperov zakon

$$F_{ab} = 2k' \frac{i_a i_b}{d} L$$



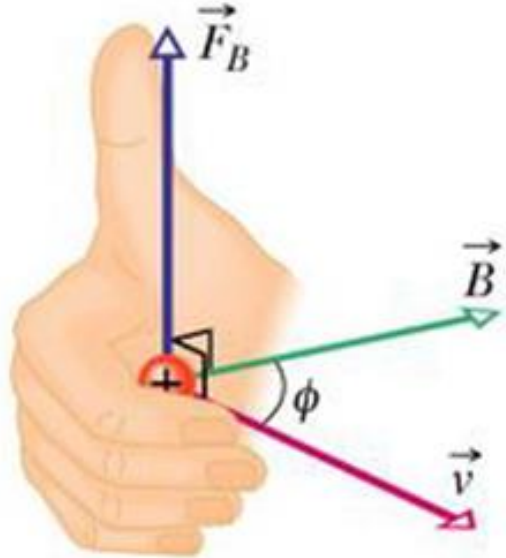
Elektromagnetna ili elektrodinamička sila μ_0 je magnetna permeabilnost vakuma.

$$k' = \frac{\mu_0}{4\pi} = 10^{-7} \text{ N/A}^2 \Rightarrow \mu_0 = 4\pi \cdot 10^{-7} \text{ N/A}^2$$



$$F_{ab} = \frac{\mu_0}{2\pi} \frac{L}{d} i_a i_b$$

Magnetno polje, magnetna indukcija, Lorencova sila



$$\vec{F}_B = q \vec{v} \times \vec{B}$$

$$F_B = |q| v B \sin \phi$$

$$B = \frac{F_B}{|q| v}$$

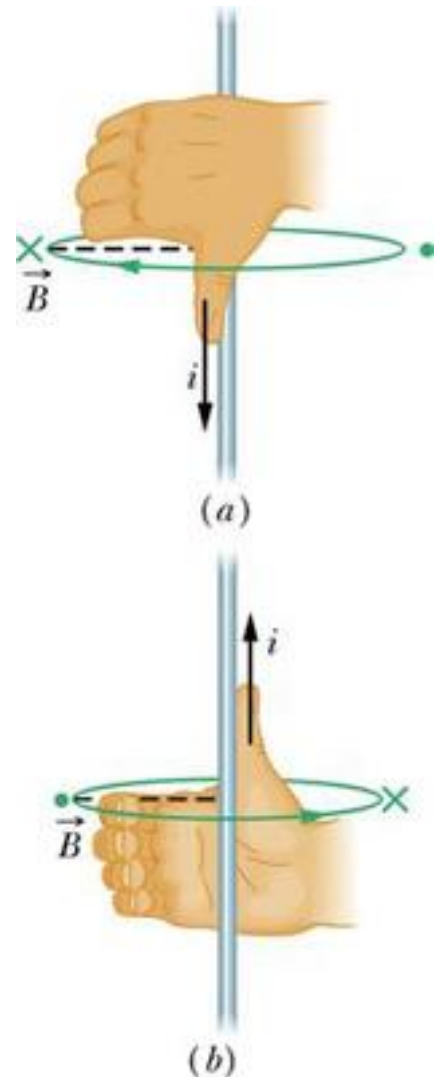
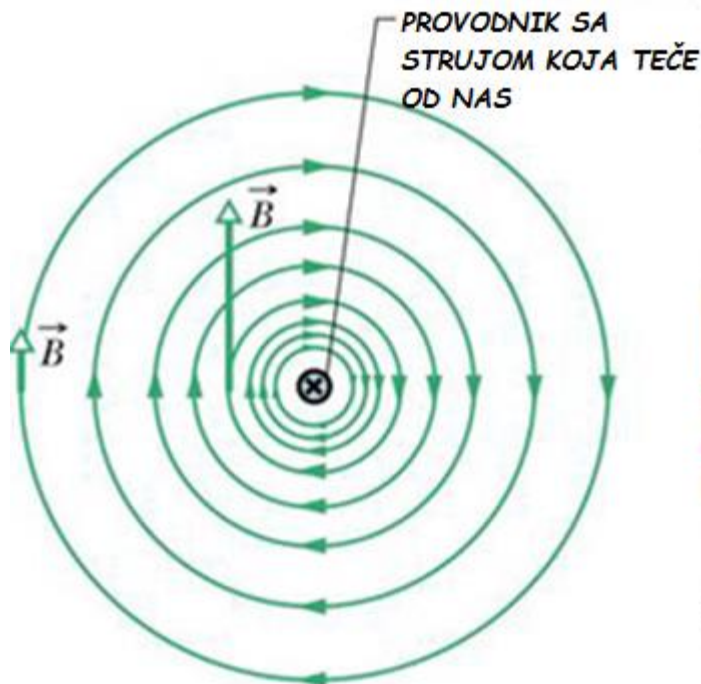
$$1 \text{ tesla} = 1 \text{ T} = 1 \frac{\text{newton}}{(\text{coulomb})(\text{meter} / \text{second})}$$

$$1 \text{ T} = 1 \frac{\text{newton}}{(\text{coulomb} / \text{second})(\text{meter})} = 1 \frac{\text{N}}{\text{A} \cdot \text{m}}$$

Magnetna indukcija je vektorska veličina koja karakteriše magnetno polje.

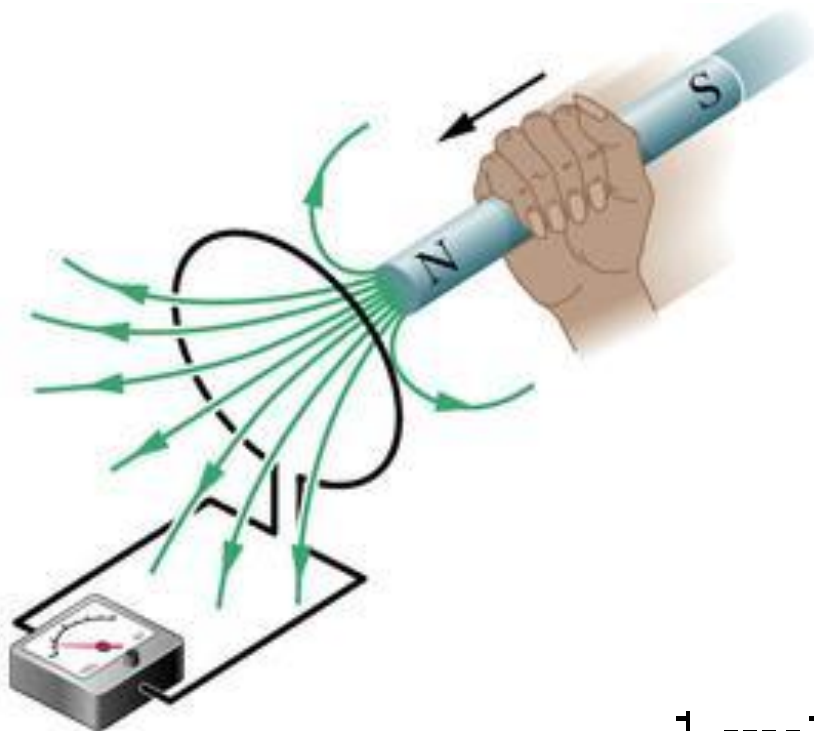
Linije magnetne indukcije

Su takve linije kod kojih tangenta povučena u bilo kojoj tački pokazuje pravac magnetne indukcije, a smer linije pokazuje smer indukcije. Gustina linija magnetnog polja pokazuje intenzitet magnetne indukcije.



Magnetni fluks

Broj linija magnetne indukcije, koja prolazi kroz neku površinu, naziva se magnetni fluks.



$$\Phi_B = \int_S \vec{B} \cdot d\vec{S}$$

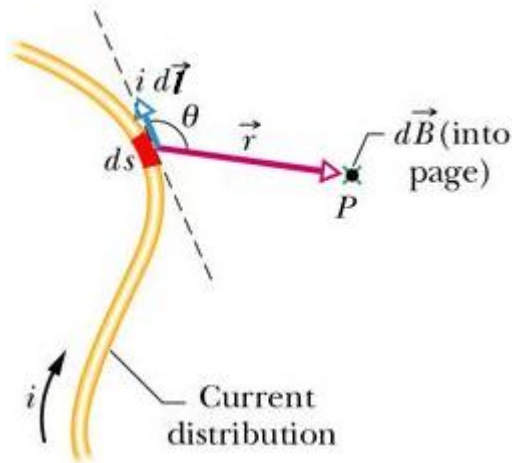
$$\Phi_B = \int_S B \cos \alpha ds = \int_S B_n ds$$

$$\Phi_B = BS$$

$$1 \text{ weber} = 1 \text{ Wb} = 1 \text{ T} \cdot \text{m}^2.$$

Magnetna indukcija strujnog provodnika Bio-Savar-Laplasov zakon

Elementarna strujna kontura dužine ds , kroz koju teče struja jačine i daje u proizvoljnoj tački P elementarnu magnetnu indukciju $d\vec{B}$:



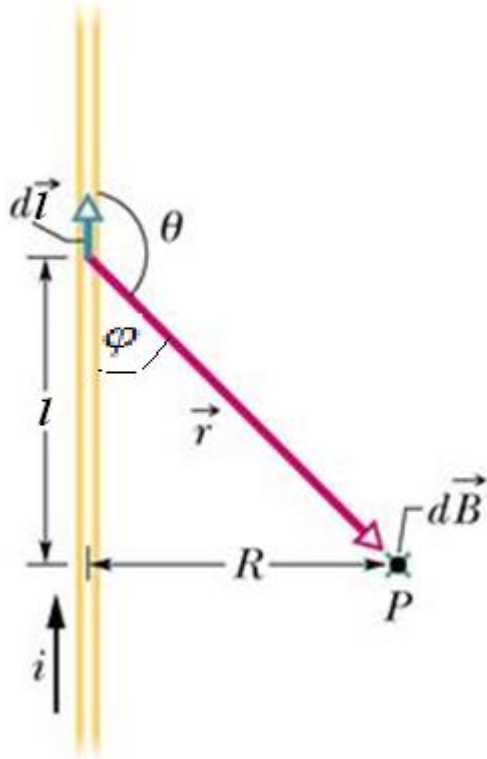
$$dB = \frac{\mu_0}{4\pi} \frac{i dl \sin \theta}{r^2}$$

$$d\vec{B} = \frac{\mu_0}{4\pi} \frac{i d\vec{l} \times \vec{r}}{r^3}$$

$$\vec{B} = \frac{\mu_0 i}{4\pi} \int \frac{d\vec{l} \times \vec{r}}{r^3}$$

(Bio-Savar-Laplasov zakon)

Magnetna indukcija beskonačno dugog pravog provodnika



$$dB = \frac{\mu_0}{4\pi} \frac{i dl \sin \theta}{r^2}$$

kako je $(\pi - \theta) = \varphi$ to je $\sin \varphi = \sin \theta$

$$dB = \frac{\mu_0}{4\pi} \frac{idl}{r^2} \sin \varphi$$

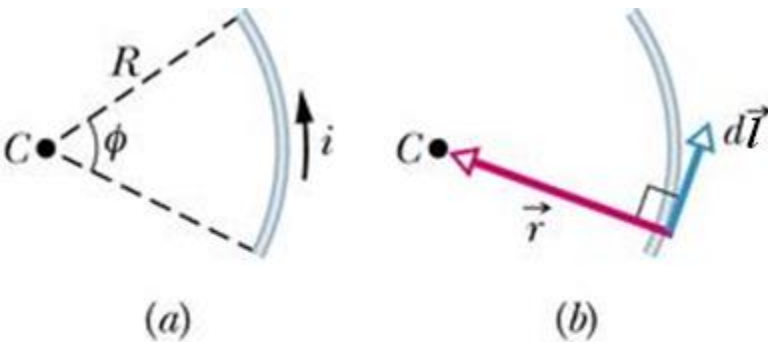
$$l = R \cot \varphi \text{ i } r = R / \sin \varphi$$

$$dl = -\frac{R d\varphi}{\sin^2 \varphi}$$

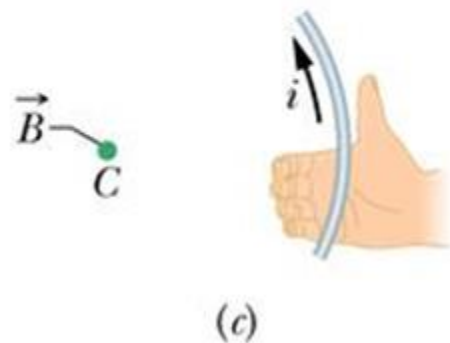
$$dB = -\frac{\mu_0 i}{4\pi} \frac{R d\varphi / \sin^2 \varphi}{R^2 / \sin^2 \varphi} \sin \varphi = -\frac{\mu_0 i}{4\pi R} \sin \varphi d\varphi$$

$$B = -\frac{\mu_0 i}{4\pi R} \int_{\pi}^0 \sin \varphi d\varphi = \frac{\mu_0 i}{4\pi R} \cos \varphi \Big|_{\pi}^0 = \frac{\mu_0 i}{2\pi R}$$

Magnetna indukcija u centru kružnog provodnika



$$dB = \frac{\mu_0}{4\pi} \frac{i dl \sin 90^\circ}{R^2} = \frac{\mu_0}{4\pi} \frac{i dl}{R^2}$$



$$B = \int dB = \int_0^\phi \frac{\mu_0}{4\pi} \frac{i R d\phi}{R^2} = \frac{\mu_0 i}{4\pi R} \int_0^\phi d\phi$$

$$B = \frac{\mu_0 i \phi}{4\pi R}$$

$$B = \frac{\mu_0 i (2\pi)}{4\pi R} = \frac{\mu_0 i}{2R}$$

Amperova teorema

$$B = \frac{\mu_0 i}{2\pi R}, \text{ kako je } l = 2\pi R$$

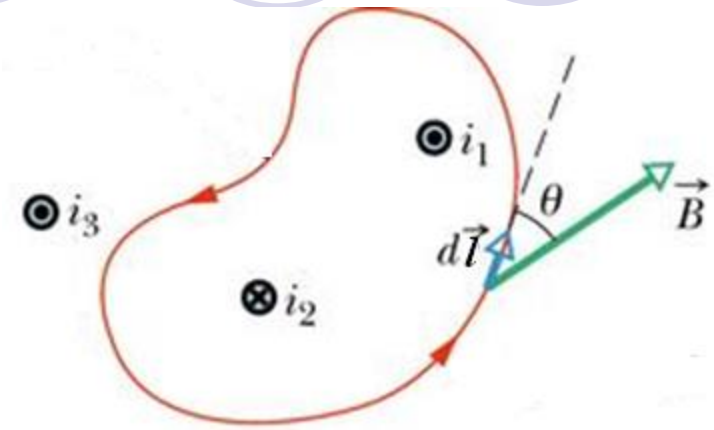
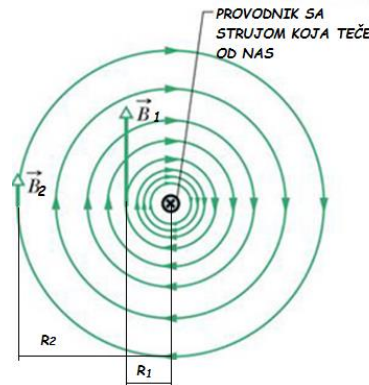
$$Bl = \mu_0 i$$

$$B_1 l_1 = B_2 l_2 = \mu_0 i$$

$$B_l dl = B \cos \theta dl = \vec{B} d\vec{l}$$

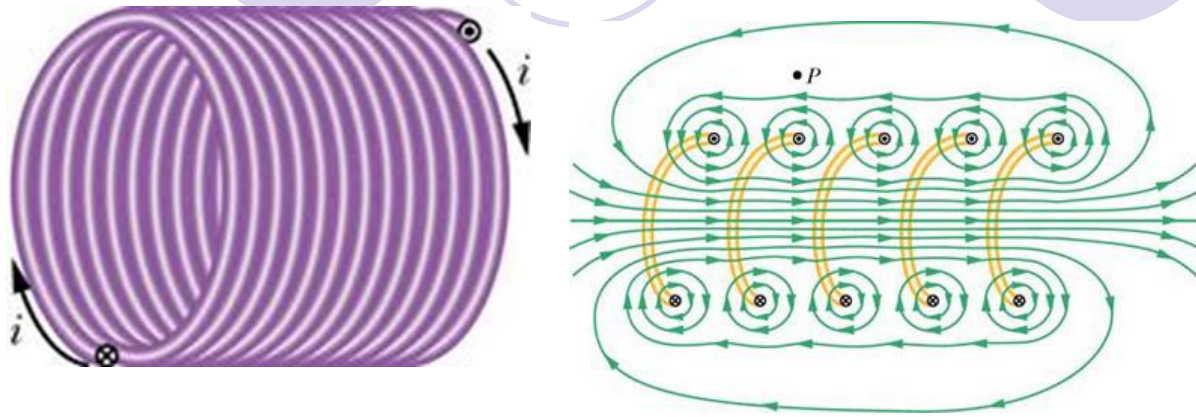
$$\oint_l \vec{B} d\vec{l} = \mu_0 (i_1 - i_2)$$

$$\oint_l \vec{B} d\vec{l} = \mu_0 \sum_{i=1}^n i_i$$



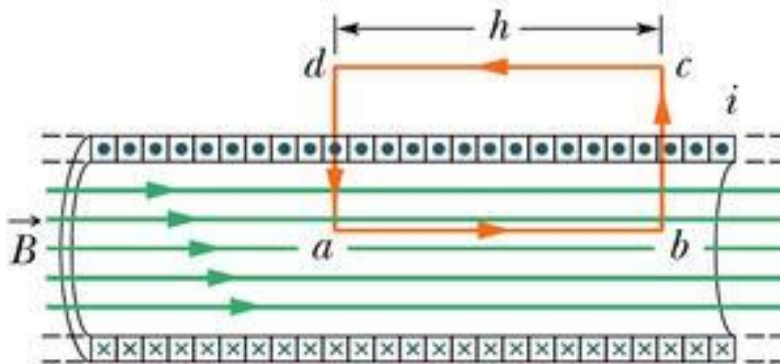
Amperova teorema ili zakon ukupne struje glasi: Linijski integral magnetne indukcije po bilo kojoj zatvorenoj konturi jednak je proizvodu iz magnetne permeabilnosti i ukupne struje koja kroz tu konturu prolazi.

Magnetna indukcija solenoida



$$\oint_l \vec{B} d\vec{l} = \mu_0 \sum_{i=1}^n i_1$$

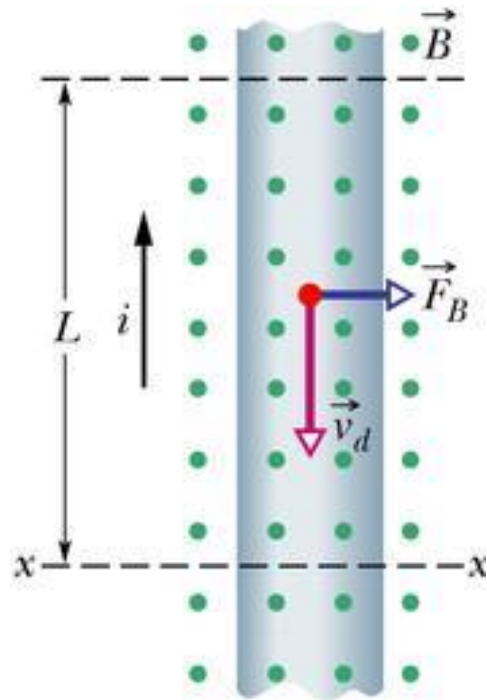
$$\oint \vec{B} \cdot d\vec{l} = \int_a^b \vec{B} \cdot d\vec{l} + \int_b^c \vec{B} \cdot d\vec{l} + \int_c^d \vec{B} \cdot d\vec{l} + \int_d^a \vec{B} \cdot d\vec{l}$$



$$Bh = \mu_0 in h$$

$$B = \mu_0 in$$

Dejstvo magnetnog polja na strujni provodnik



$\vec{F}_B = -e\vec{v}_d \times \vec{B}$, sila koja deluje na jedan elektron

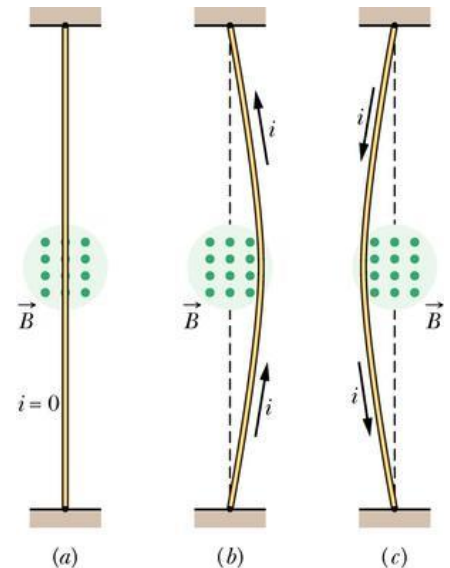
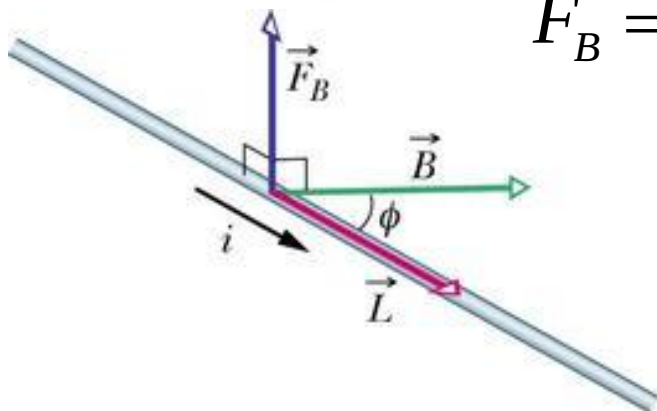
$\vec{F}_B = -nsLe\vec{v}_d \times \vec{B}$, kako je $i = nse v_d$

$$\vec{F}_B = i\vec{L} \times \vec{B}$$

$$F_B = iLB \sin \phi$$

$$d\vec{F}_B = id\vec{L} \times \vec{B}$$

$$\vec{F}_B = \int d\vec{F}_B = i \int (d\vec{L} \times \vec{B})$$

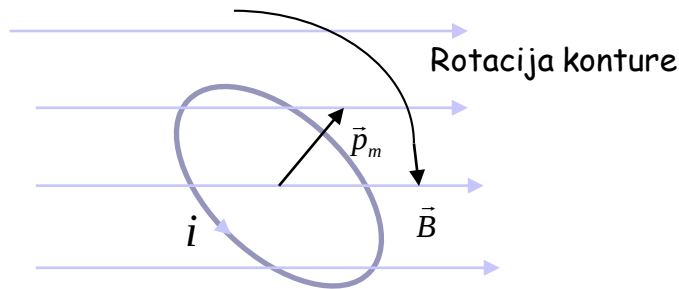


Magnetni dipolni moment

$$p_m = iS$$

$$\vec{M} = \vec{p}_m \times \vec{B}$$

$$M = p_m B \sin \alpha, \text{ gde je } \alpha = \angle[\vec{p}_m, \vec{B}]$$



$$p_m = iS$$

$$S = r^2 \pi, \text{ a } i = \frac{e}{T} = e v$$

$$v = \frac{2\pi r}{T} = 2\pi r \nu$$

$$p_m = e \frac{v}{2\pi r} r^2 \pi = \frac{1}{2} e r v$$

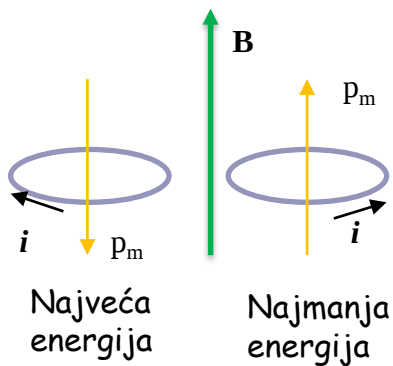
$$p_{m,l} = \frac{e}{2m} m v r = \frac{e}{2m} L$$

$$E = -\vec{p}_m \vec{B}$$

$$E_{\min} = -p_m B \cos 0 = -p_m B$$

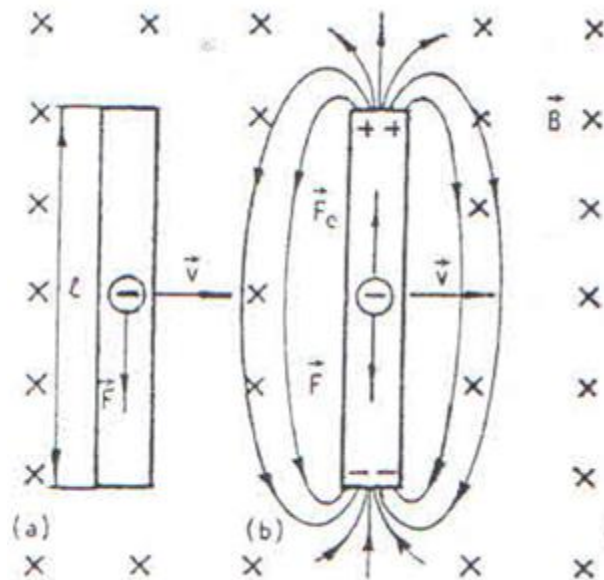
$$E_{\max} = -p_m B \cos 180 = +p_m B$$

$$\Delta E = E_{\max} - E_{\min} = 2 p_m B$$



$p_{m,l}$ -Orbitalni magnetni dipolni moment

Faradejev zakon indukcije



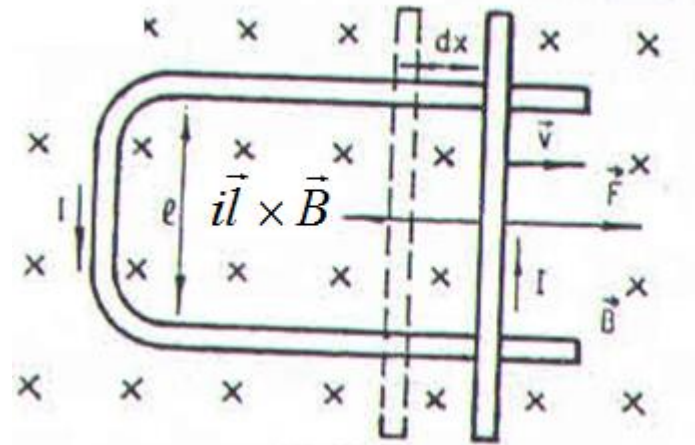
$$\mathcal{E} = - \frac{d\Phi_B}{dt}$$

$$\mathcal{E} = \frac{dA}{dq}$$

$$F = ilB$$

$$dA = Fdx = ilBdx$$

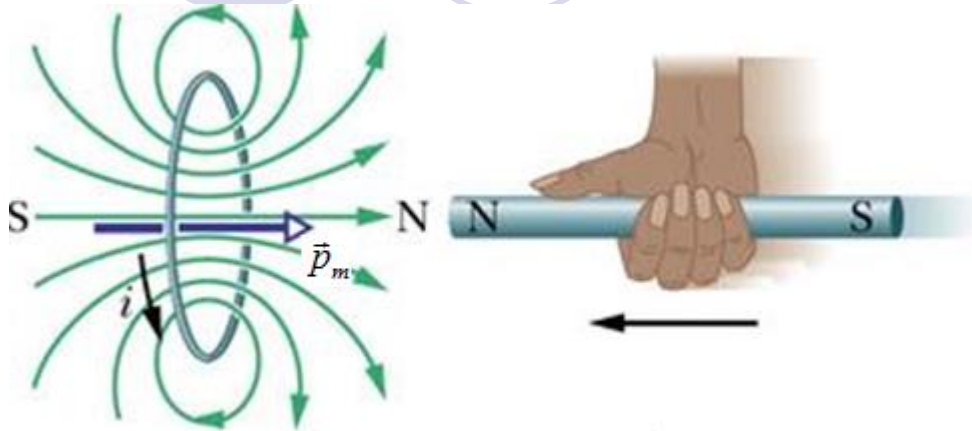
$$\mathcal{E} = \frac{dA}{dq} = ilB \frac{dx}{dq} = iB \frac{ds}{dq} = \frac{dq}{dt} \frac{d\Phi}{dq} = \frac{d\Phi}{dt}$$



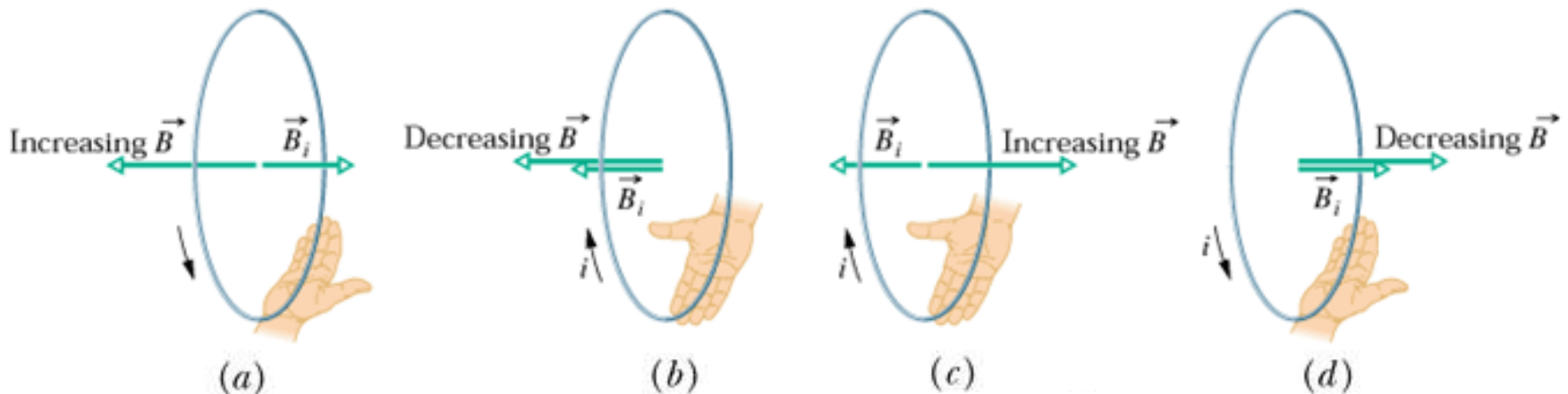
EMS pri indukciji jednaka je negativnoj brzini promene magnetnog fluksa.

$$\mathcal{E} = - N \frac{d\Phi_B}{dt}$$

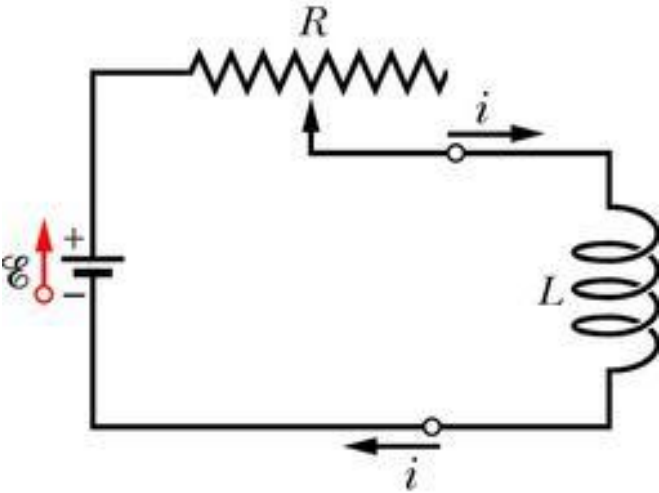
Lencovo pravilo



Indukovana EMS, odnosno struja uvek ima takav smer da se suprotstavlja uzroku koji je proizvodi.



Samoi indukciija



$$\mathcal{E}_L = -L \frac{di}{dt}$$

$$B = \mu_0 i \frac{N}{l}$$

$$\Phi = BS = \mu_0 i \frac{N}{l} S$$

$$\mathcal{E}_L = -N \frac{d\Phi}{dt} = -\mu_0 \frac{N^2}{l} S \frac{di}{dt}$$

$$L = \mu_0 \frac{N^2}{l} S$$

$$1 \text{ henry} = 1 \text{ H} = 1 \text{ T} \cdot \text{m}^2 / \text{A}.$$

Energija magnetnog polja

Opadanjem struje u kalemu, smanjuje se magnetna indukcija, odnosno opada magnetni fluks kroz kalem, zbog čega se indukuje EMS samoindukcije, koja sprečava opadanje struje. Na pomeranje naelektrisanja dq kroz kolo, za vreme dt , utroši se energija:

$$dW = \xi_L dq = \xi_L i dt = -iL \frac{di}{dt} dt = -L i di$$

$$W = \int dW = -L \int_i^0 i di = \frac{1}{2} L i^2$$

$$W = \frac{B^2 s l}{2\mu_0} = \frac{B^2}{2\mu_0} V$$

$$w = \frac{W}{V} = \frac{B^2}{2\mu_0}$$

$$B = \mu_0 i \frac{N}{l}$$

$$L = \mu_0 \frac{N^2}{l} S$$