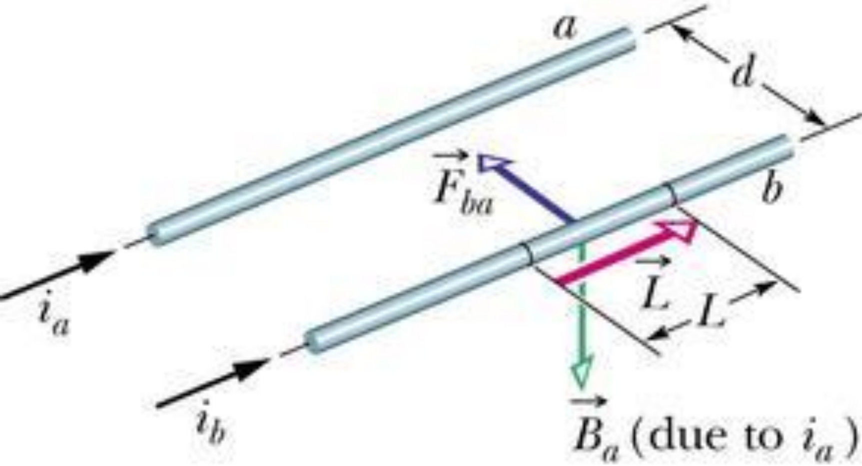
Magnetno polje u vakuumu
Sila između dva paralelna provodnika
Amperov zakon

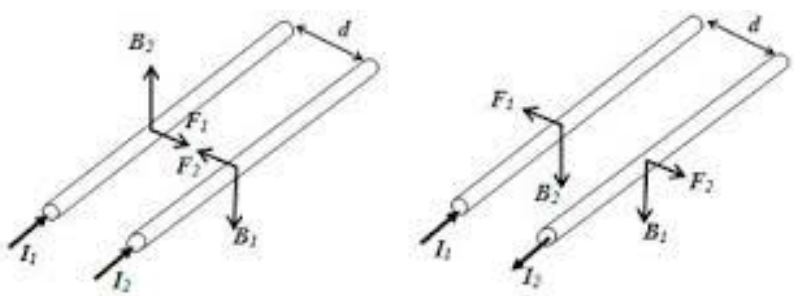


$$F_{ab} = 2k'\frac{i_a i_b}{d}L$$

Elektromagnetna ili elektrodinamička sila

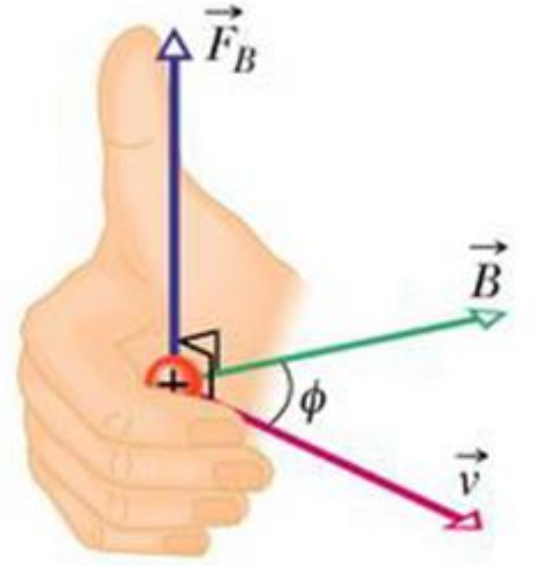
μ_0 je magnetna permeabilnost vakuuma.

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



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

Magnetno polje, magnetna indukcija, Lorencova sila



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

$$F_B = |q|\,vB\sin\phi$$

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

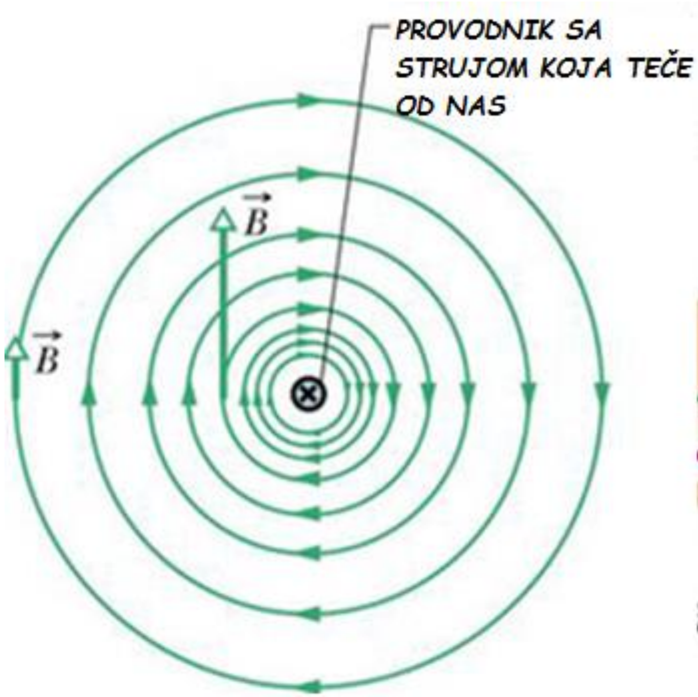
$$1\ \text{tesla} = 1\ \text{T} = 1\frac{\text{newton}}{(\text{coulomb})(\text{meter / second})}$$

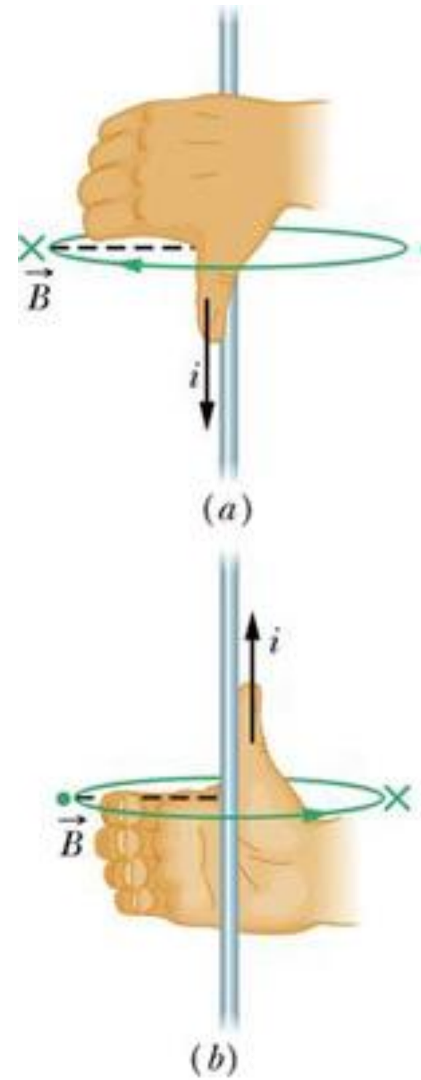
$$1\ \text{T} = 1\frac{\text{newton}}{(\text{coulomb / second})(\text{meter})} = 1\frac{\text{N}}{\text{A}\cdot\text{m}}$$

Magnetna indukcija je vektorska veličina koja karakteriše magnetno polje.

Linije magnetne indukcije

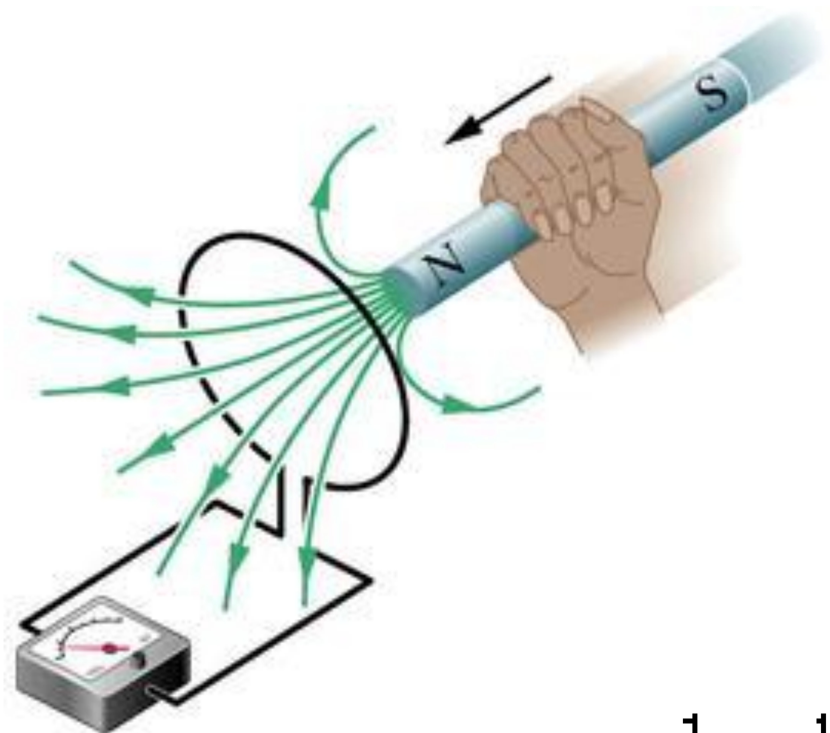
Su takve linije kod kojih tangenta povučena u bilo kojoj tački pokazuje pravac magnetne indukcije, a smer linije pokazuje smer indukcije. Gustina linija magnetnog polja pokazuje intenzitet magnetne indukcije.





Magnetni fluks

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



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

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

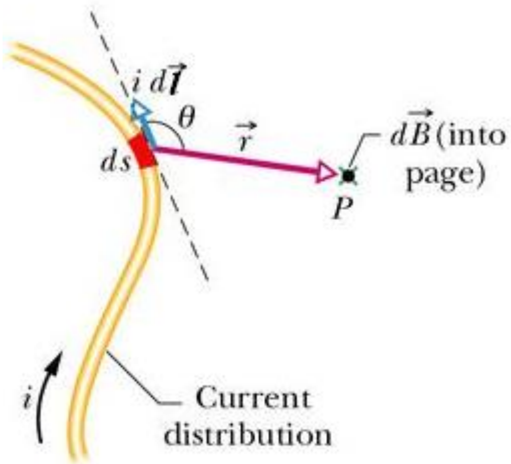
$$\Phi_B = BS$$

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

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 dB:

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

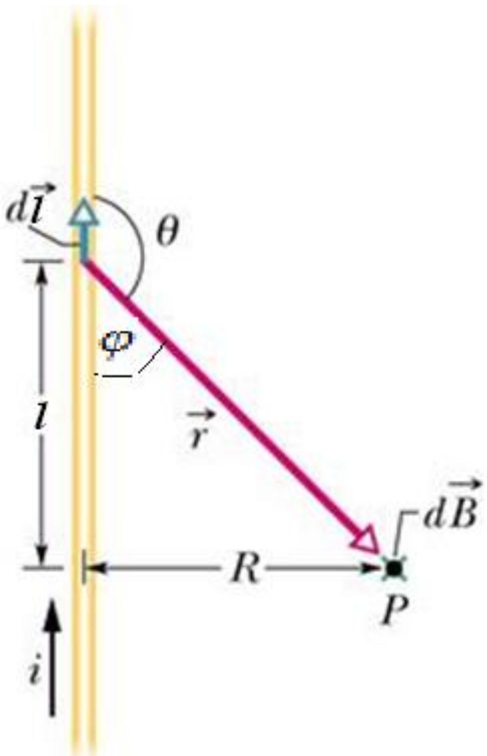


$$d\vec{B} = \frac{\mu_0}{4\pi}\frac{i\,d\vec{l} \times \vec{r}}{r^3}$$

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

(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 $\sin\varphi = \sin\theta$

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

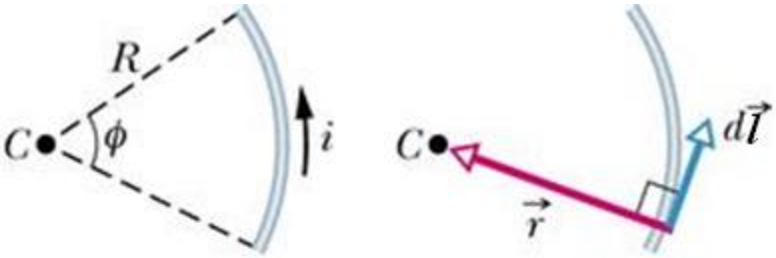
$l = Rctg\varphi$ i $r = R/\sin\varphi$

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

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

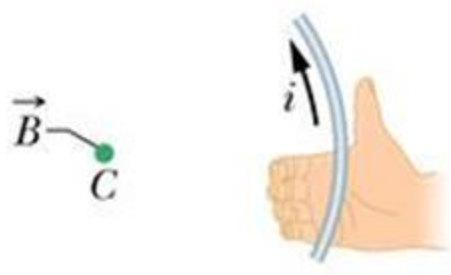
$$B = -\frac{\mu_0 i}{4\pi R}\int_{\pi}^{0}\sin\varphi d\varphi = \frac{\mu_0 i}{4\pi R}\cos\varphi\Big|_{\pi}^{0} = \frac{\mu_0 i}{2\pi R}$$

Magnetna indukcija u centru kružnog provodnika



(a) (b)

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



(c)

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

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

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

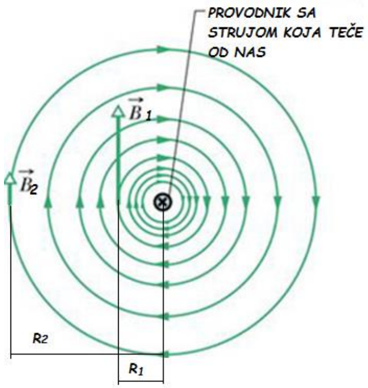
Amperova teorema

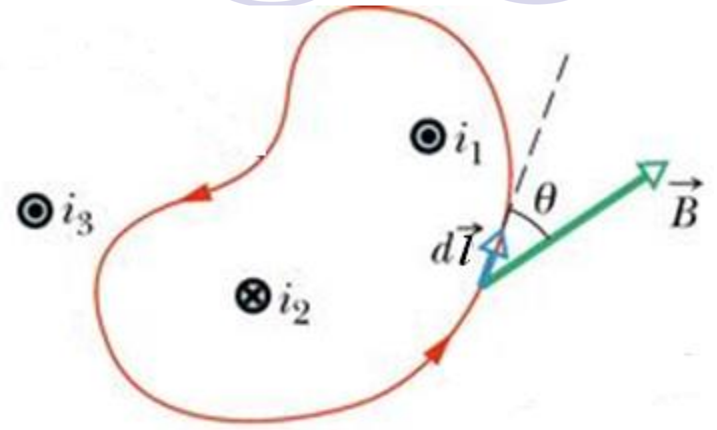
$$B = \frac{\mu_0 i}{2\pi R}, \text{kako je } l = 2\pi R$$

$$Bl = \mu_0 i$$

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

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



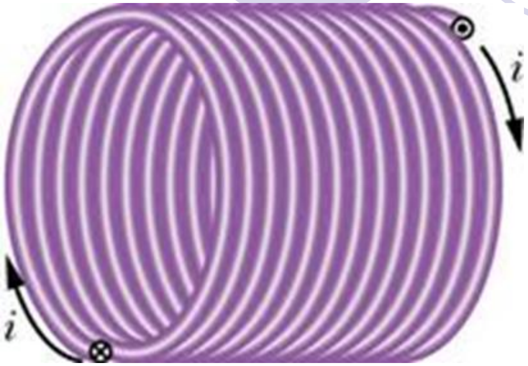


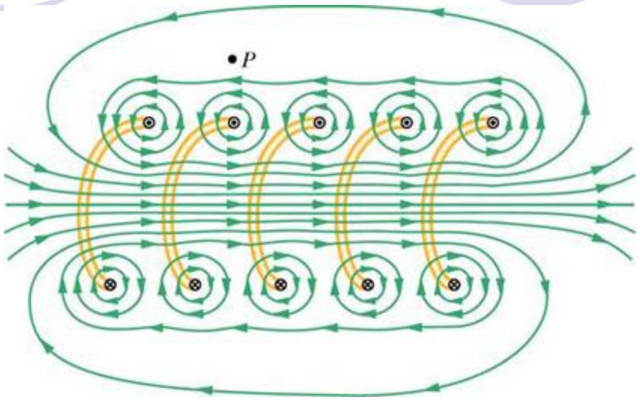
$$\oint_l \vec{B}d\vec{l} = \mu_0 (i_1 - i_2)$$

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

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.

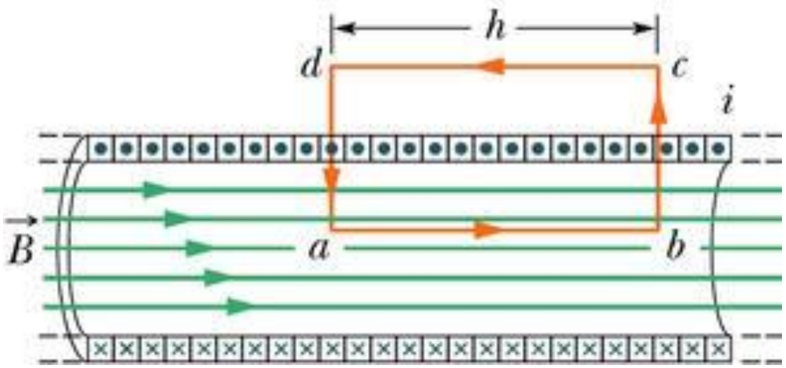
Magnetna indukcija solenoida





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

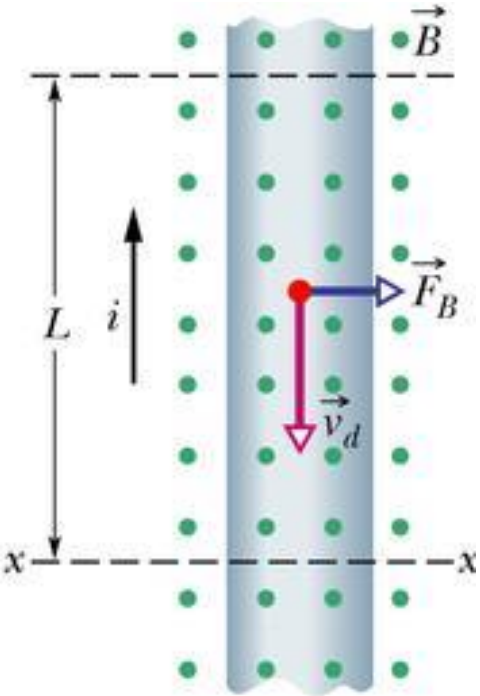
$$\oint \vec{B} \cdot d\vec{l} = \int_a^b \vec{B} \cdot d\vec{l} + \int_b^c \vec{B} \cdot d\vec{l} + \int_c^d \vec{B} \cdot d\vec{l} + \int_d^a \vec{B} \cdot d\vec{l}$$

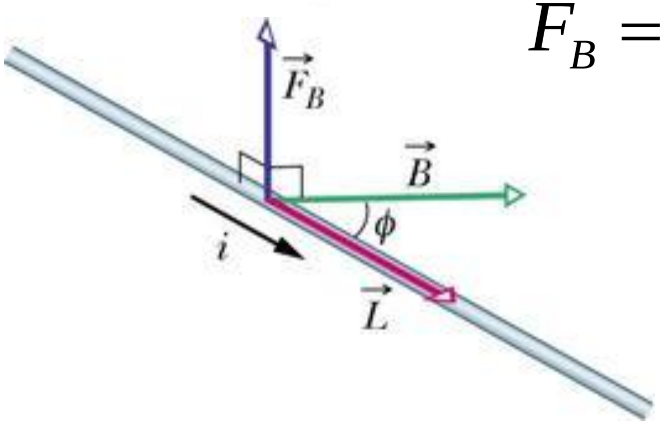


$$Bh = \mu_0 inh$$

$$B = \mu_0 in$$

Dejstvo magnetnog polja na strujni provodnik





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

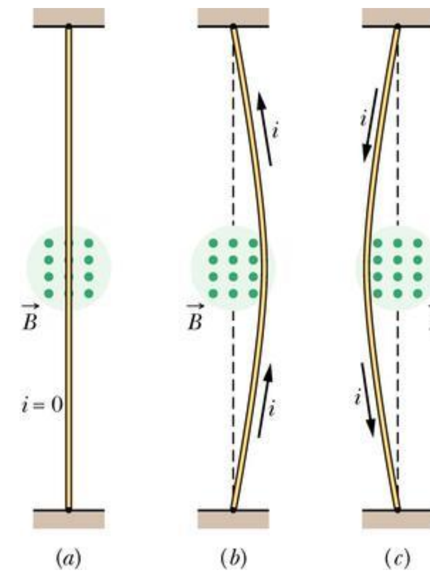
$$\vec{F}_B = -nsLe\vec{v}_d \times \vec{B}, \text{ kako je } i = nsev_d$$

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

$$F_B = iLB \sin \phi$$

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

$$\vec{F}_B = \int d\vec{F}_B = i\int \left(d\vec{L} \text{x} \vec{B}\right)$$

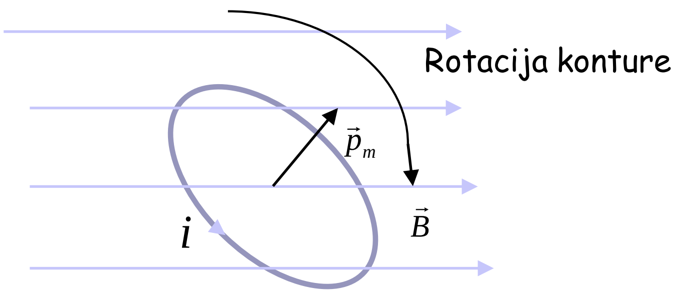


Magnetni dipolni moment

$$p_m = iS$$

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

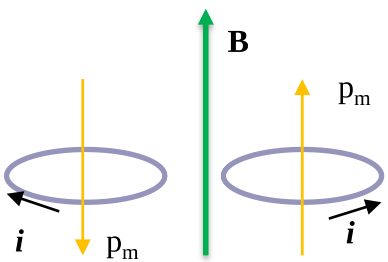
$$M = p_m B \sin\alpha, \text{ gde je } \alpha = \angle\left[\vec{p}_m, \vec{B}\right]$$



$$p_m = iS$$

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

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



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

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

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

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

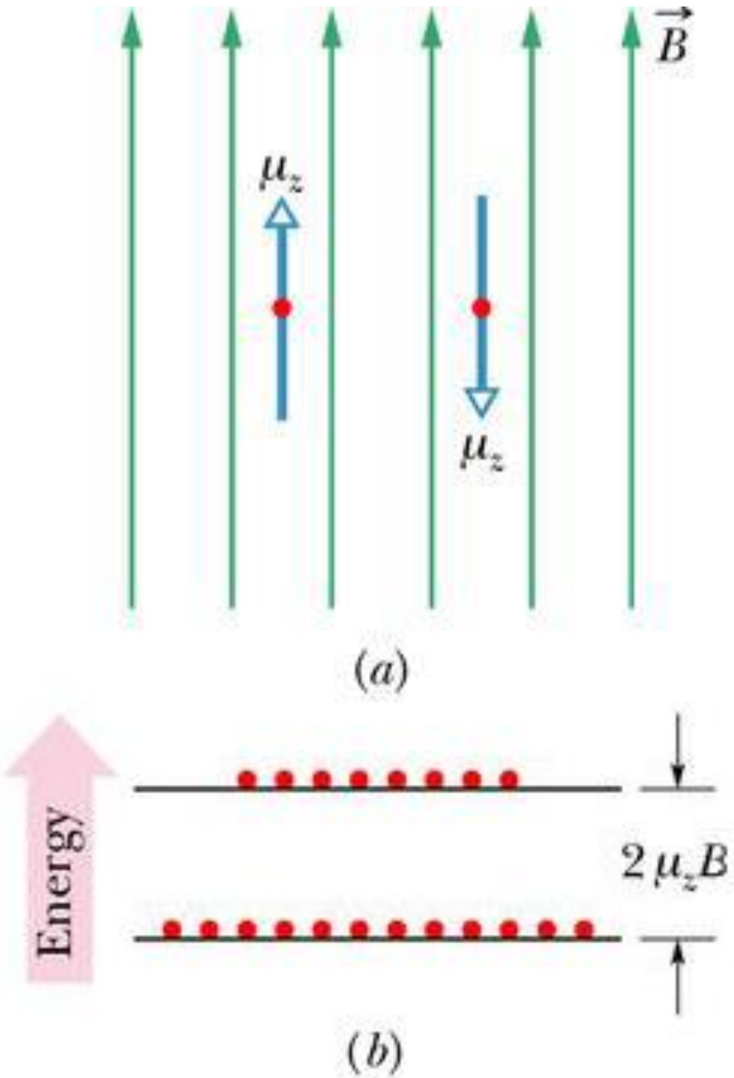
$$p_m = -e\frac{v}{2\pi r} r^2 \pi = -\frac{1}{2} erv$$

$$p_{m,l} = -\frac{e}{2m} mvr = -\frac{e}{2m} L$$

$$\vec{p}_{m,l} = -\frac{e}{2m}\vec{L}$$

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

Nuklearna magnetna rezonansa



$$\vec{\mu}_l = -\frac{e}{2m}\vec{L}$$

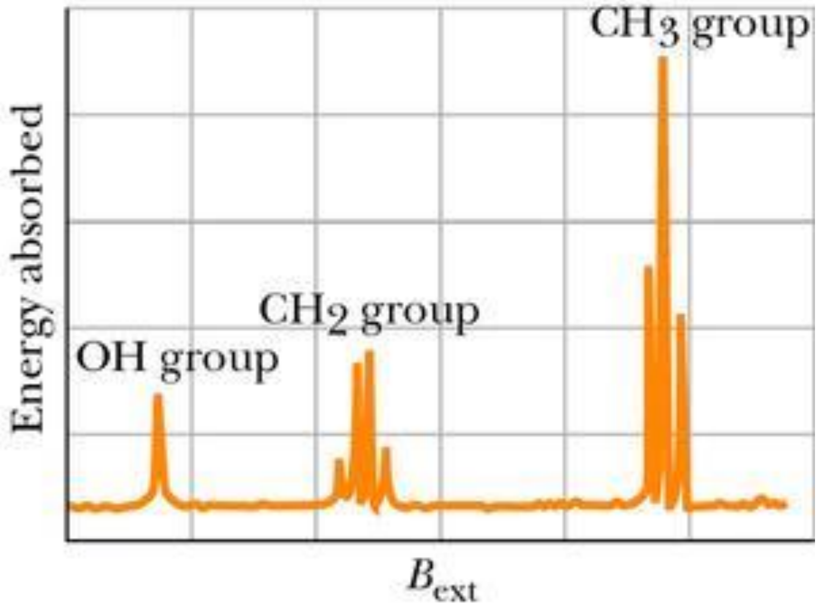
$$\mu_{l\,z} = -\frac{e}{2m}L_z = -\frac{e}{2m}m_l\hbar = -m_l\mu_B$$

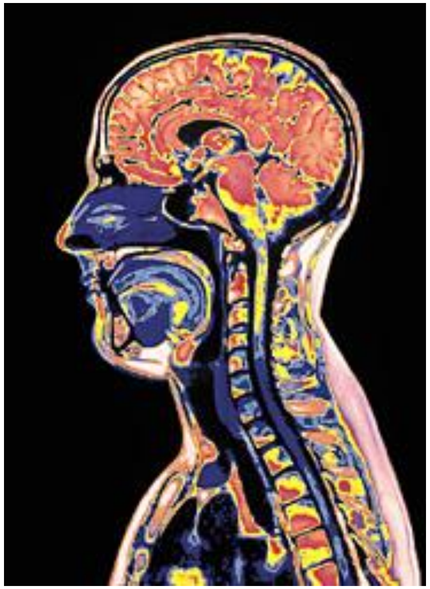
$$\text{jer je } \frac{e\hbar}{2m} = \mu_B = 9{,}27\cdot 10^{-24}\,J/T$$

$$\mu_{s\,z} = -g_s m_s \mu_B$$

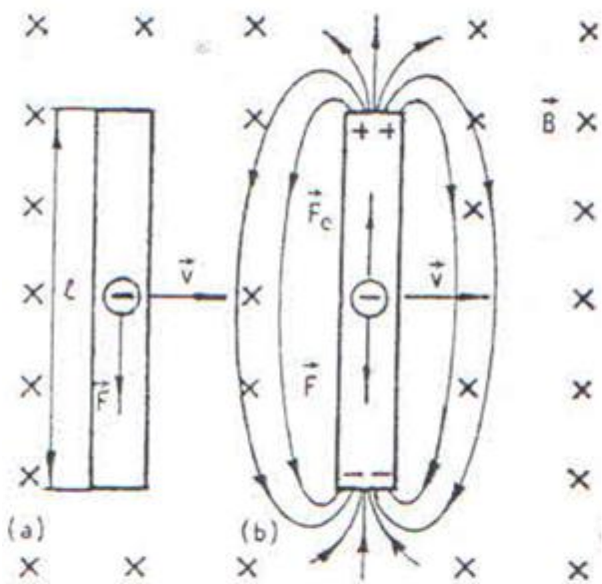
$$h\nu = 2\mu_{sz}B_z$$

$$h\nu = 2\mu_{sz}\left(B_{ext} + B_{\text{int}}\right)$$


CH3 group
CH2 group
OH group
Energy absorbed
B_{ext}

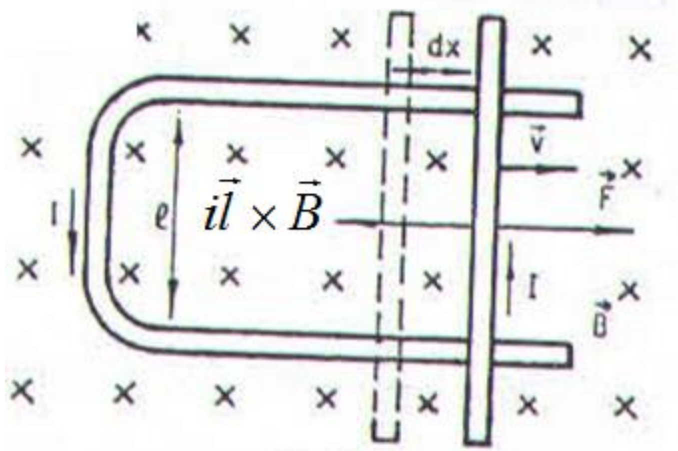


Faradejev zakon indukcije



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

$$F = ilB$$



$$dA = Fdx = ilBdx$$

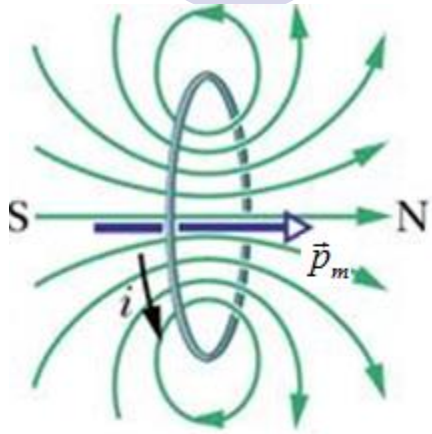
$$\varepsilon = \frac{dA}{dq} = ilB\frac{dx}{dq} = iB\frac{ds}{dq} = \frac{dq}{dt}\frac{d\Phi}{dq} = \frac{d\Phi}{dt}$$

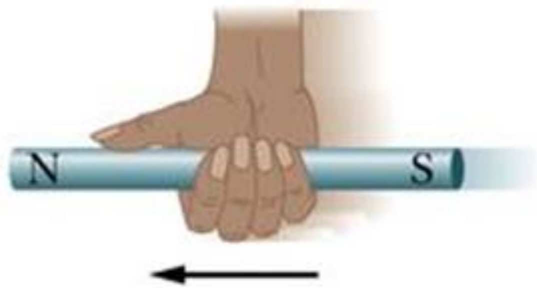
$$\mathcal{E} = -\frac{d\Phi_B}{dt}$$

EMS pri indukciji jednaka je negativnoj brzini promene magnetnog fluksa.

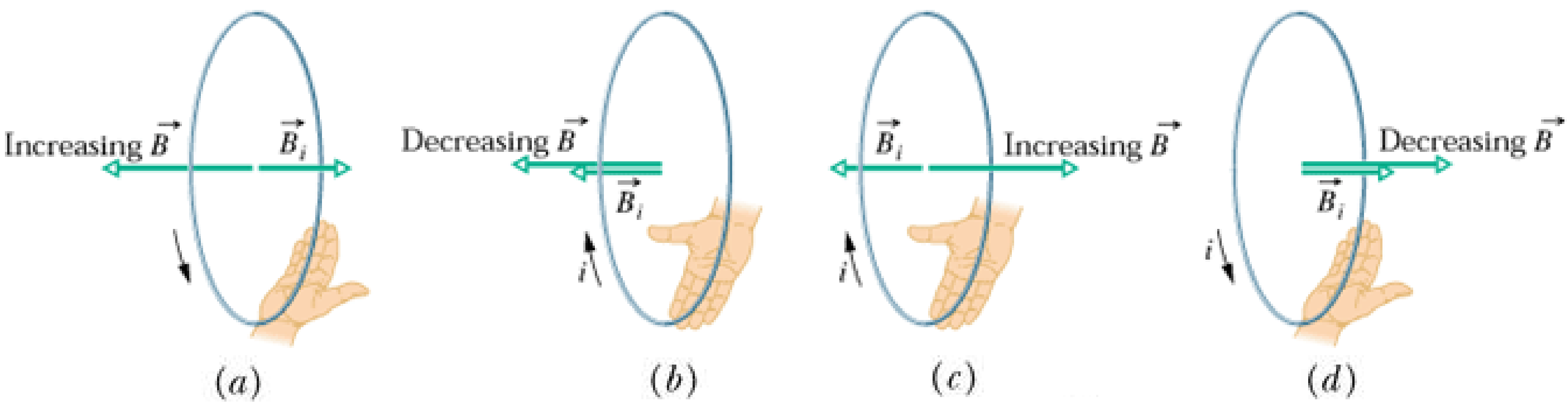
$$\mathcal{E} = -N\frac{d\Phi_B}{dt}$$

Lencovo pravilo

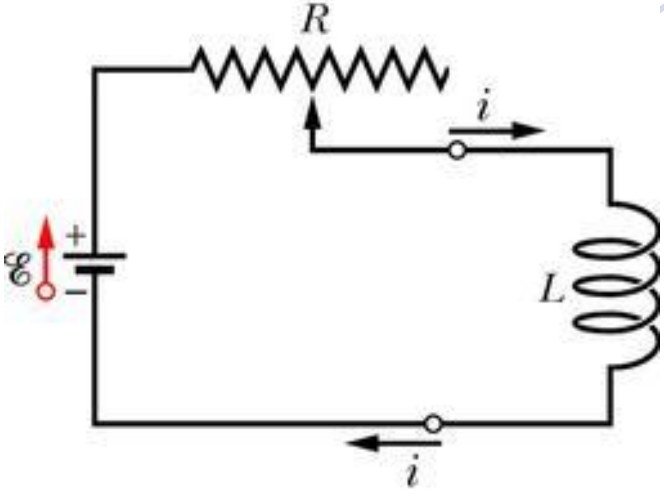




Indukovana EMS, odnosno struja uvek ima takav smer da se suprotstavlja uzroku koji je proizvodi.



Samoindukcija



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

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

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

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

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

1 henry = 1 H = 1 T · m^2 / 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:

$$dW = \xi_L dq = \xi_L idt = -iL\frac{di}{dt}dt = -Lidi$$

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

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

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

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

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