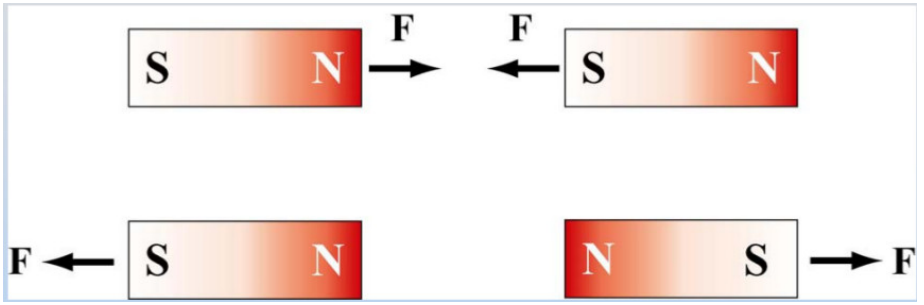
Analogija: gravitacija - elektricitet

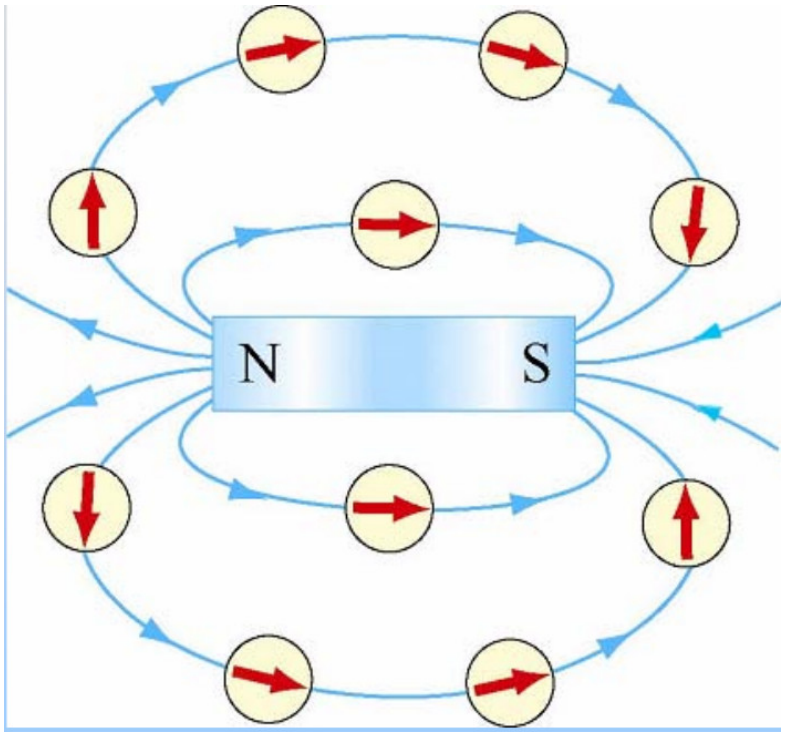
	masa M	naboj q (+-)
stvara	$\vec{\mathbf{g}} = -G\frac{M}{r^2}\hat{\mathbf{r}}$	$\vec{\mathbf{E}} = k_e\frac{q}{r^2}\hat{\mathbf{r}}$
djeluje na	$\vec{\mathbf{F}}_g = m\vec{\mathbf{g}}$	$\vec{\mathbf{F}}_E = q\vec{\mathbf{E}}$

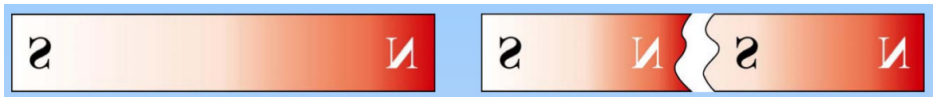
Štapićasti magnet



* dipol

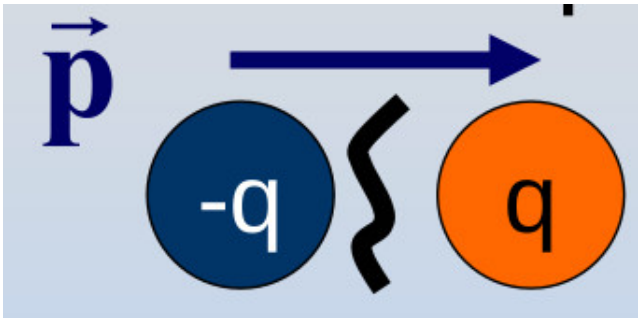
* ne da se svesti na magnetski monopol





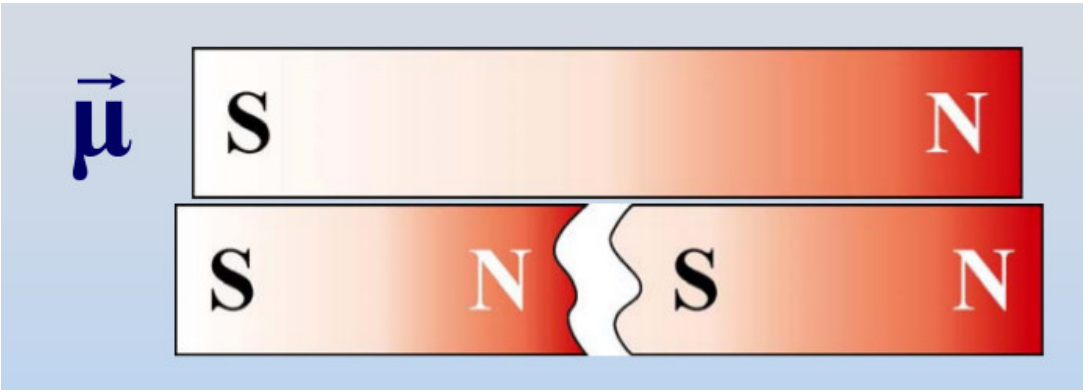
Magnetski monopol?

električni dipol



prerezan → dva monopola (naboja)

magnetski dipol



Prerezan: dva dipola

$$\oiint_S \vec{\mathbf{E}} \cdot d\vec{\mathbf{A}} = \frac{q_{in}}{\varepsilon_0}$$

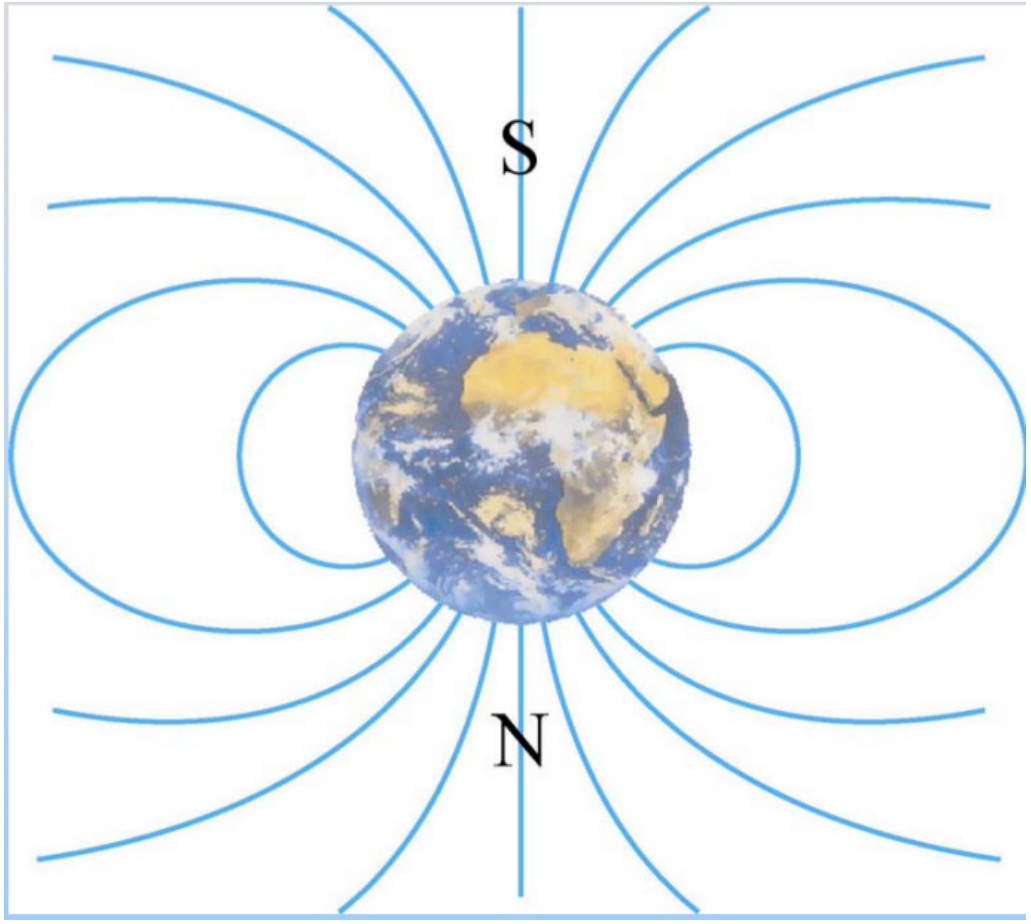
Gaussov zakon

$$\oiint_S \vec{\mathbf{B}} \cdot d\vec{\mathbf{A}} = 0$$

magnetski Gaussov zakon

Gravitacijsko polje	–	električno polje	–	magnetsko polje
masa M		naboj q (+-)		nema magnetskih monopola
stvara	$\vec{\mathbf{g}} = -G\frac{M}{r^2}\hat{\mathbf{r}}$		$\vec{\mathbf{E}} = k_e\frac{q}{r^2}\hat{\mathbf{r}}$	
djeluje na	$\vec{\mathbf{F}}_g = m\vec{\mathbf{g}}$		$\vec{\mathbf{F}}_E = q\vec{\mathbf{E}}$	

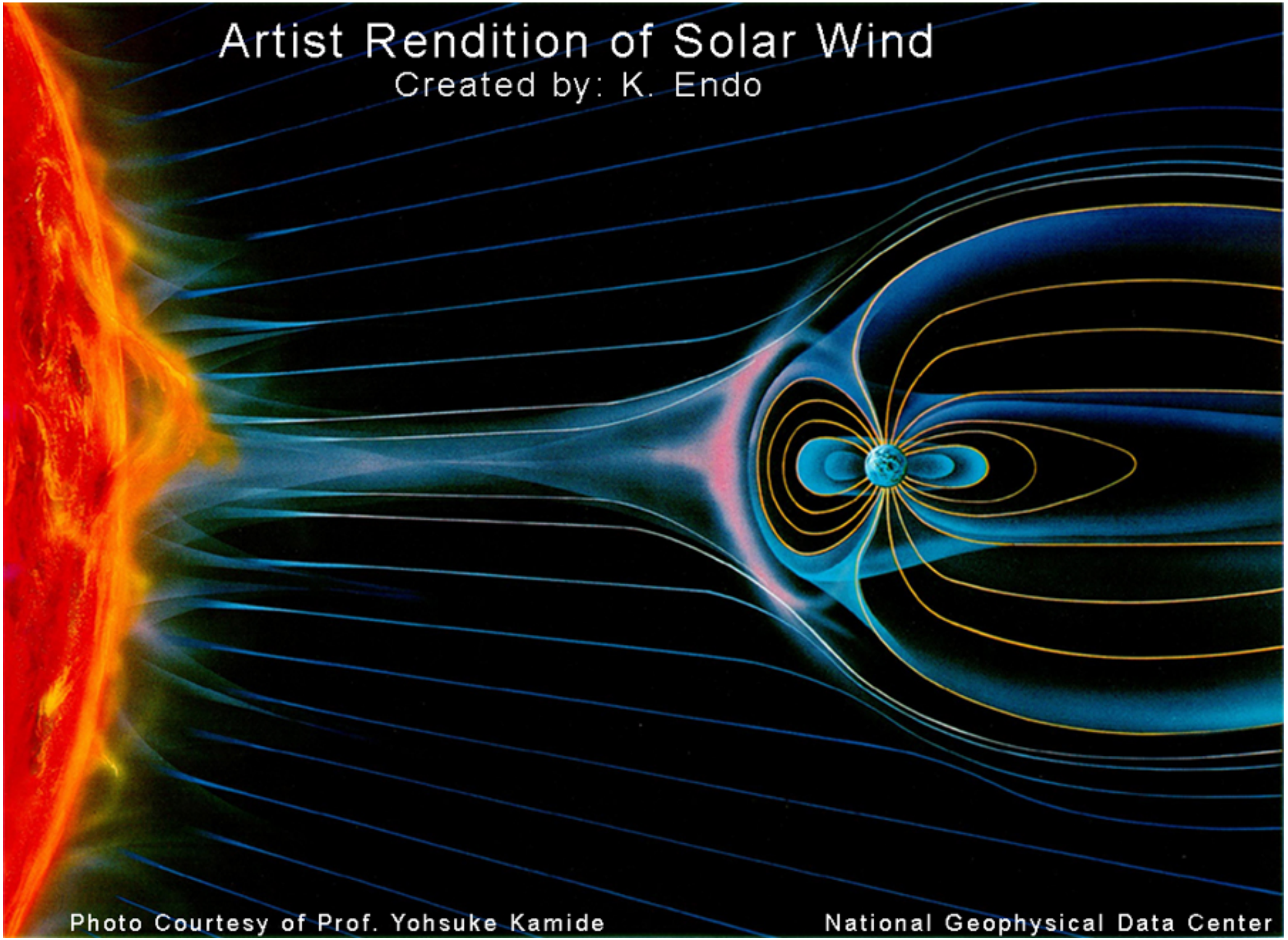
Magnetsko polje Zemlje



* relativno blizu površine aprokisimirano dipolnim poljem

* u vanjskom prostoru, tj. dalje od površine, modificirano djelovanjem Sunčevog vjetra

* sjeverni magnetski pol nalazi se na južnoj hemisferi


Artist Rendition of Solar Wind
Created by: K. Endo
Photo Courtesy of Prof. Yohsuke Kamide
National Geophysical Data Center

Lorentzova sila

$$\vec{\mathbf{F}}_E = q\vec{\mathbf{E}}$$

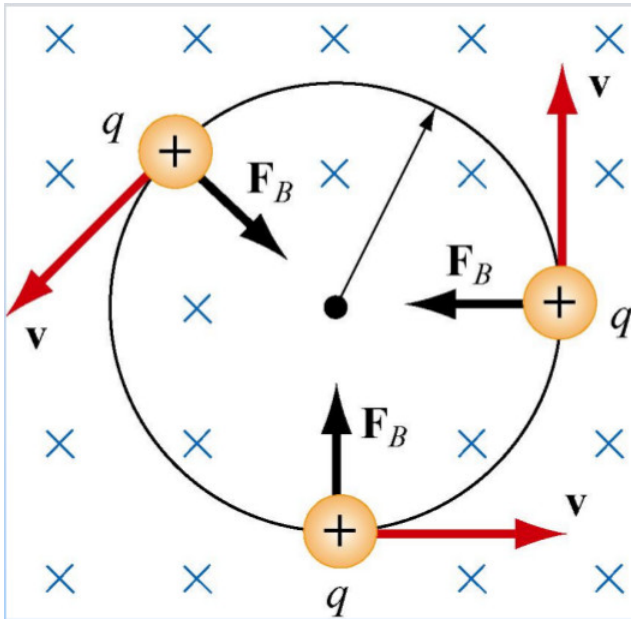
električna

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

magnetska

$$\vec{\mathbf{F}} = q\left(\vec{\mathbf{E}} + \vec{\mathbf{v}}\times\vec{\mathbf{B}}\right)$$

Ciklotronsko gibanje



1. *r* je polumjer kruga

$$qvB = \frac{mv^2}{r} \Rightarrow r = \frac{mv}{qB}$$

2. *T* je period gibanja

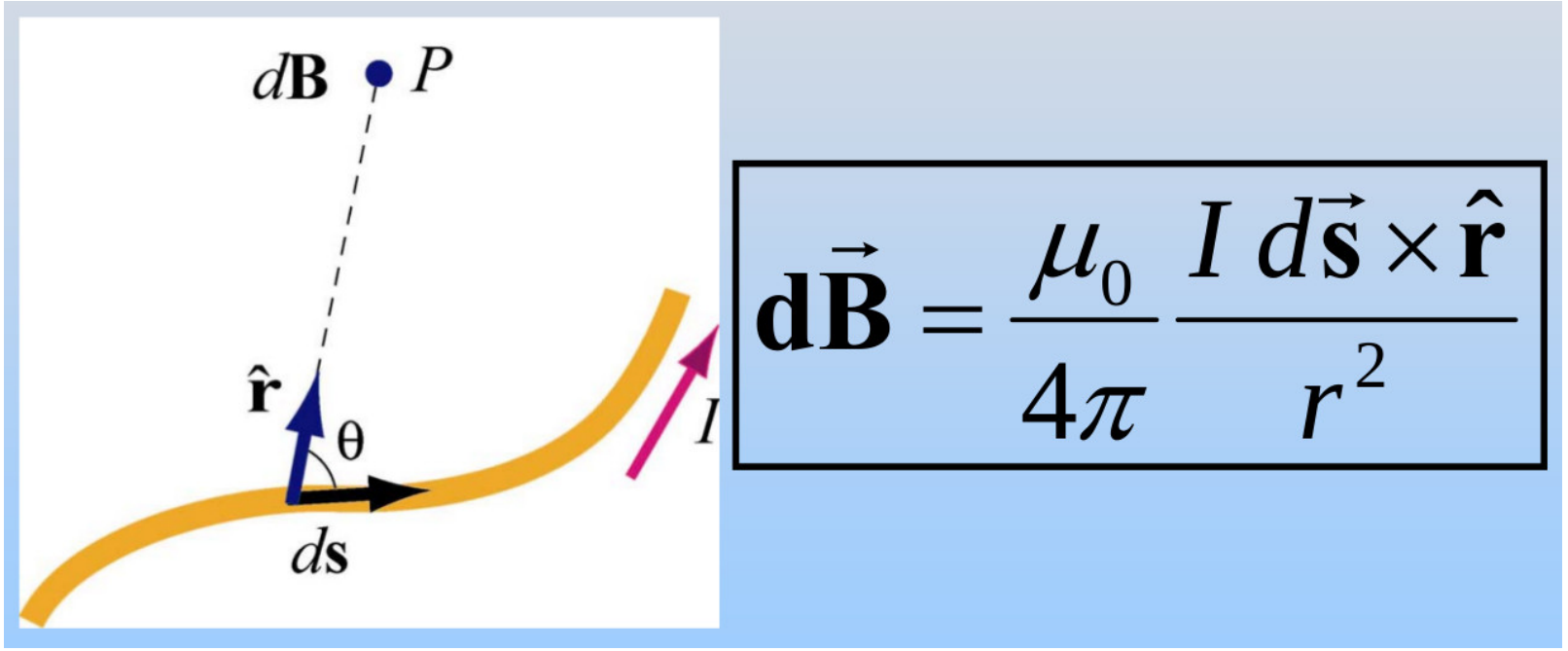
$$T = \frac{2\pi r}{v} = \frac{2\pi m}{qB}$$

3. ω je ciklotronska frekvencija

$$\omega = 2\pi f = \frac{v}{r} = \frac{qB}{m}$$

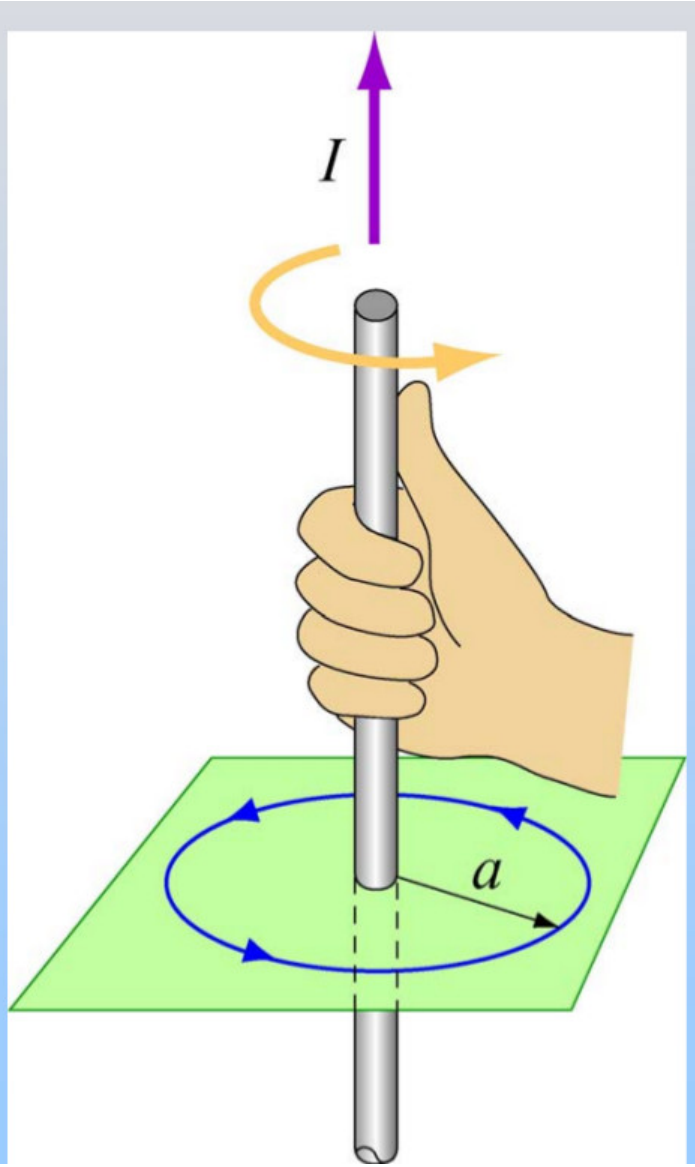
Biot-Savartov zakon

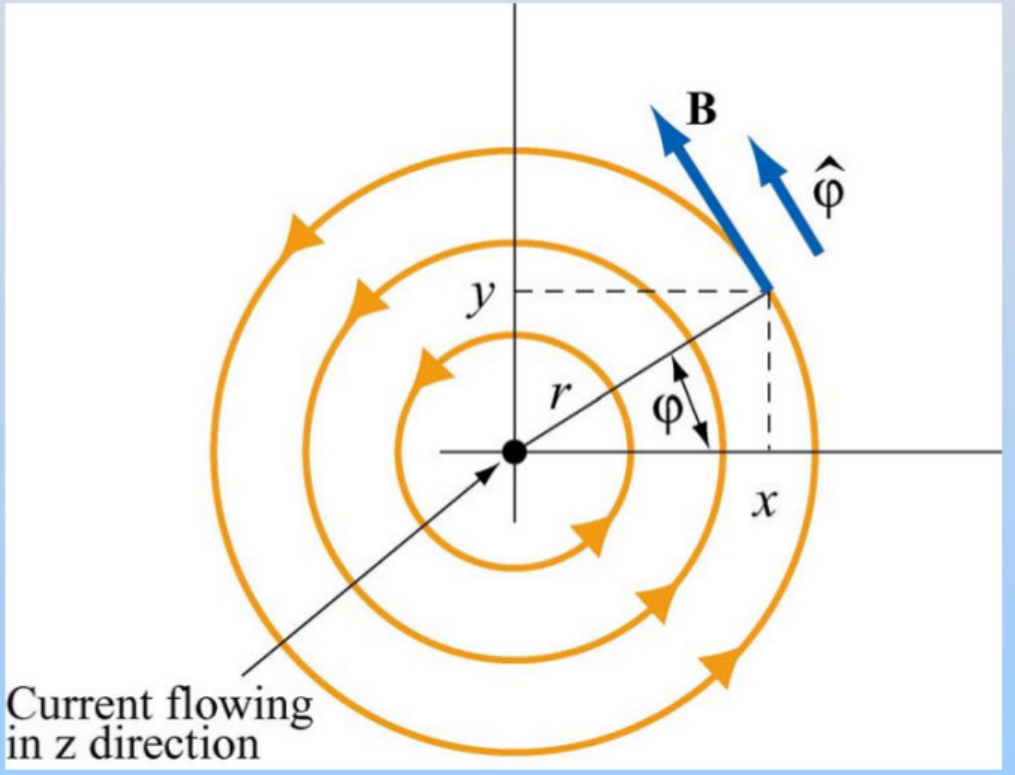
* strujni element duljine ds kojim prolazi struja I stvara magnetsko polje



$$\mathbf{d\vec{B}} = \frac{\mu_0}{4\pi} \frac{I\, d\vec{\mathbf{s}} \times \hat{\mathbf{r}}}{r^2}$$

Pravilo desne ruke



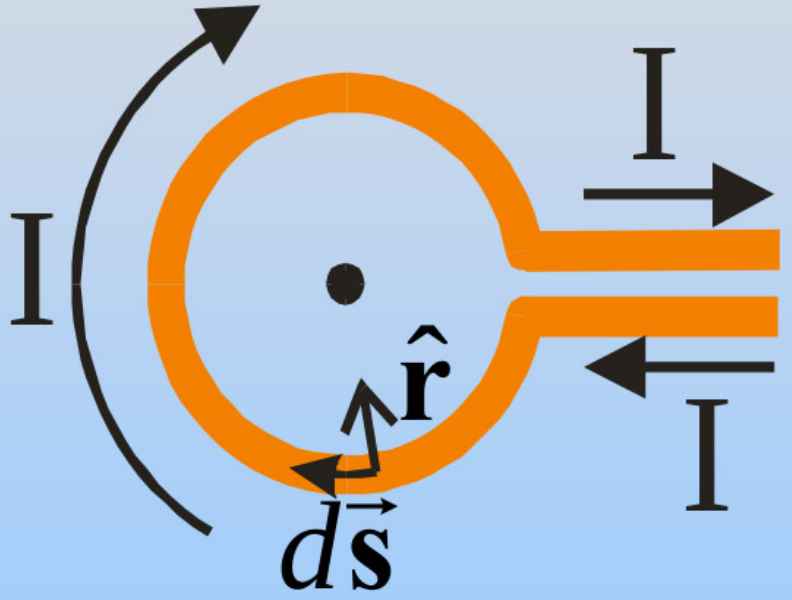


$$\hat{\mathbf{z}} \times \hat{\boldsymbol{\rho}} = \hat{\boldsymbol{\varphi}}$$

Namotana žica polumjera R i struje I

* u kružnom dijelu

$$d\vec{\mathbf{s}} \perp \hat{\mathbf{r}} \quad \rightarrow \quad \left| d\vec{\mathbf{s}} \times \hat{\mathbf{r}} \right| = ds$$



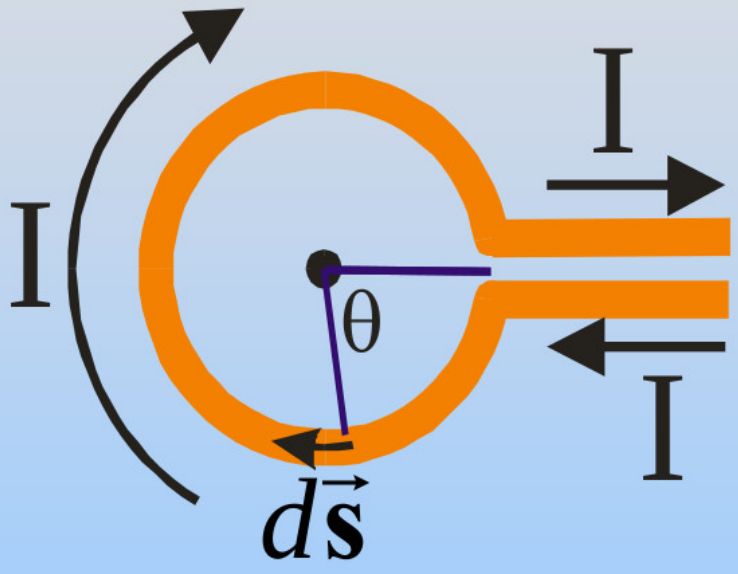
Biot-Savart:

$$dB = \frac{\mu_0 I}{4\pi} \frac{\left| d\vec{\mathbf{s}} \times \hat{\mathbf{r}} \right|}{r^2} = \frac{\mu_0 I}{4\pi} \frac{ds}{r^2}$$

$$= \frac{\mu_0 I}{4\pi} \frac{R\, d\theta}{R^2}$$

$$= \frac{\mu_0 I}{4\pi} \frac{d\theta}{R}$$

Namotana žica polumjera R i struje I



$$dB = \frac{\mu_0 I}{4\pi}\frac{d\theta}{R}$$

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

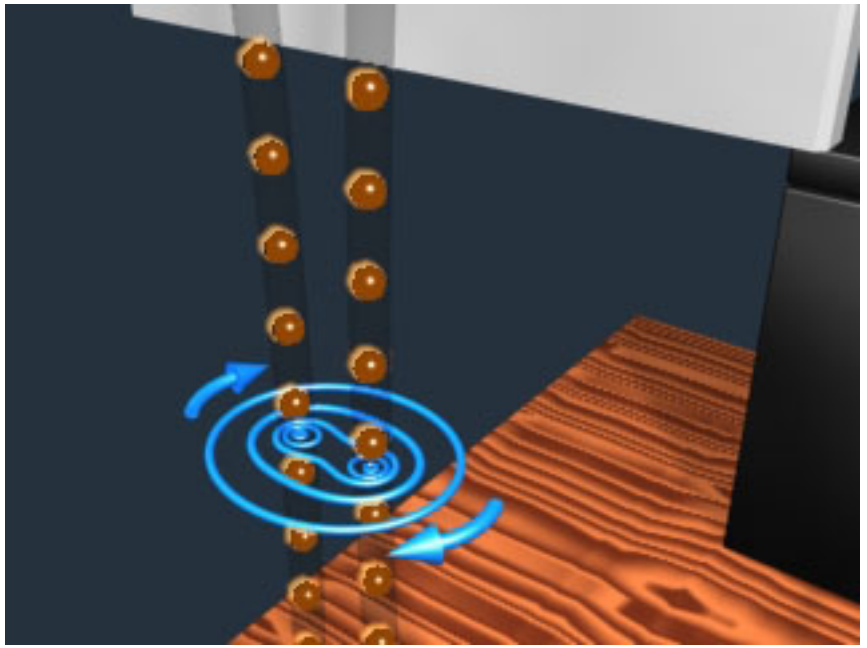
$$= \frac{\mu_0 I}{4\pi R}\int_0^{2\pi} d\theta = \frac{\mu_0 I}{4\pi R}(2\pi)$$

$$\vec{\mathbf{B}} = \frac{\mu_0 I}{2R}$$

u stranicu

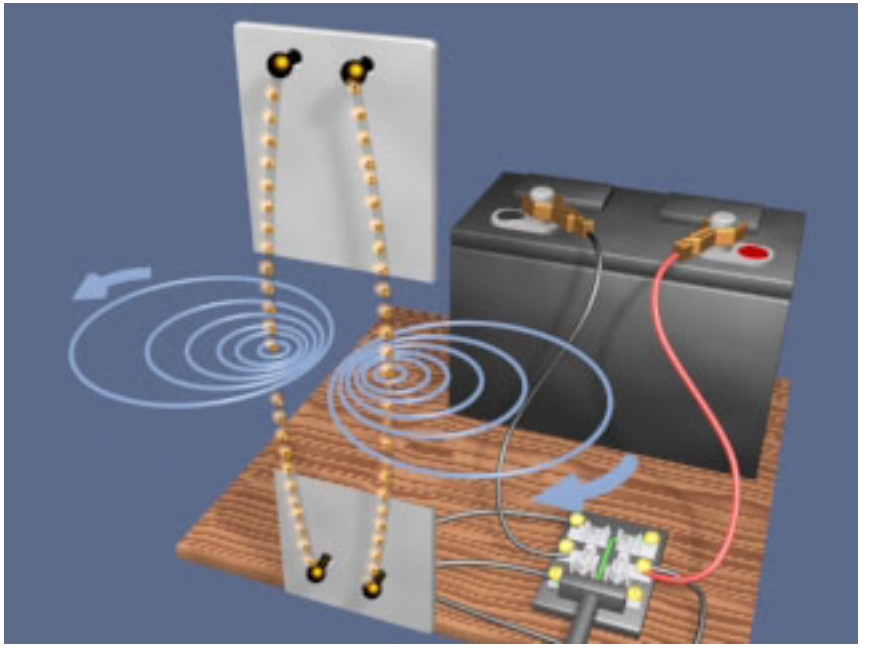
Dva usporedna vodiča kojima teku struje

a) istim smjerom



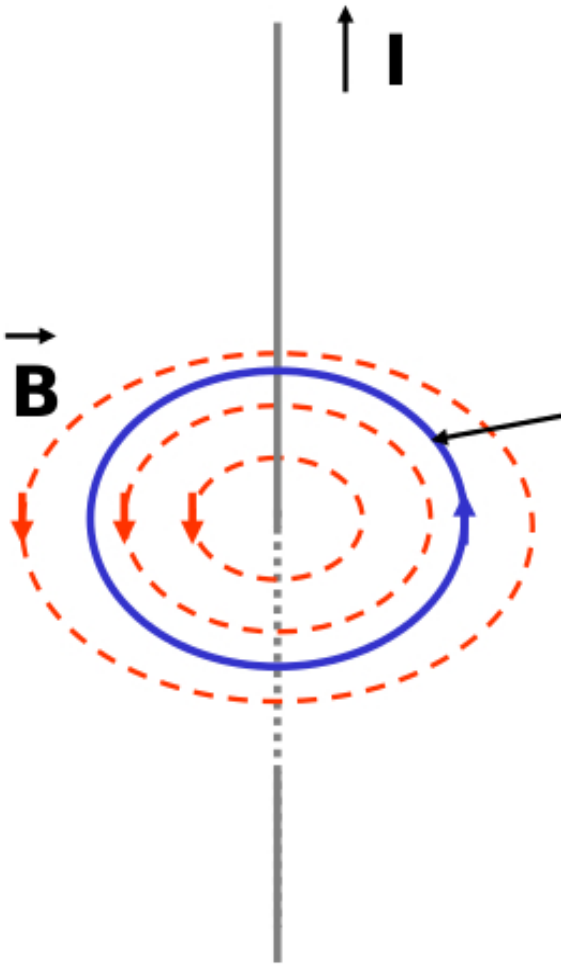
privlače se

b) suprotnim smjerom



odbijaju se

Ampèreov zakon



Ampèreova ideja: povezati magnetsko polje $\vec{B}$
sa njegovim izvorom, strujom *I*

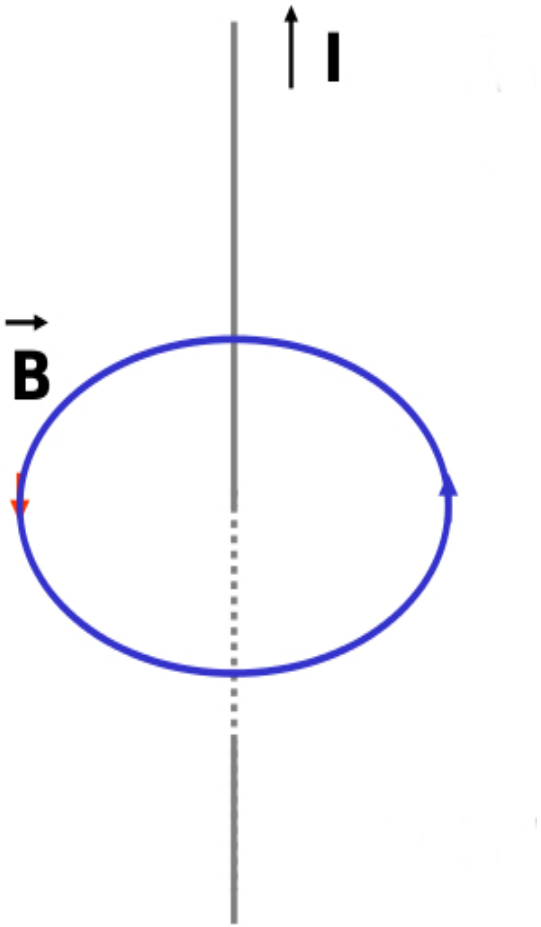
zatvorena linija

- magnetske silnice su zatvorene
- pravilo desne ruke

Ampèreov zakon: $\oint_L \vec{B} \cdot d\vec{l} = \mu_0 I_{obuhv}$

$$\vec{\nabla} \times \vec{B} = \mu_0 \vec{J}$$

Ampèreov zakon



Krivuljni integral magnetskog polja duž bilo kojeg puta ovisi samo o obuhvaćenoj struji.

Ampèreov zakon omogućuje biranje puta integracije

$$\vec{B} \perp d\vec{l} \Rightarrow \vec{B} \cdot d\vec{l} = 0$$
$$\vec{B} \parallel d\vec{l} \Rightarrow \vec{B} \cdot d\vec{l} = B\, dl$$

Magnetsko polje oko ravnog vodiča kojim teče konstantna struja *I*, na udaljenosti *r* od vodiča:

$$\oint_L \vec{B} \cdot d\vec{l} = \mu_0 I_{obuhv}$$

$$B(r) \oint_L d\vec{l} = \mu_0 I_{obuhv}$$

$$B(r) 2\pi r = \mu_0 I_{obuhv}$$

$$B(r) = \mu_0 \frac{I_{obuhv}}{2\pi r}$$