Magnetism

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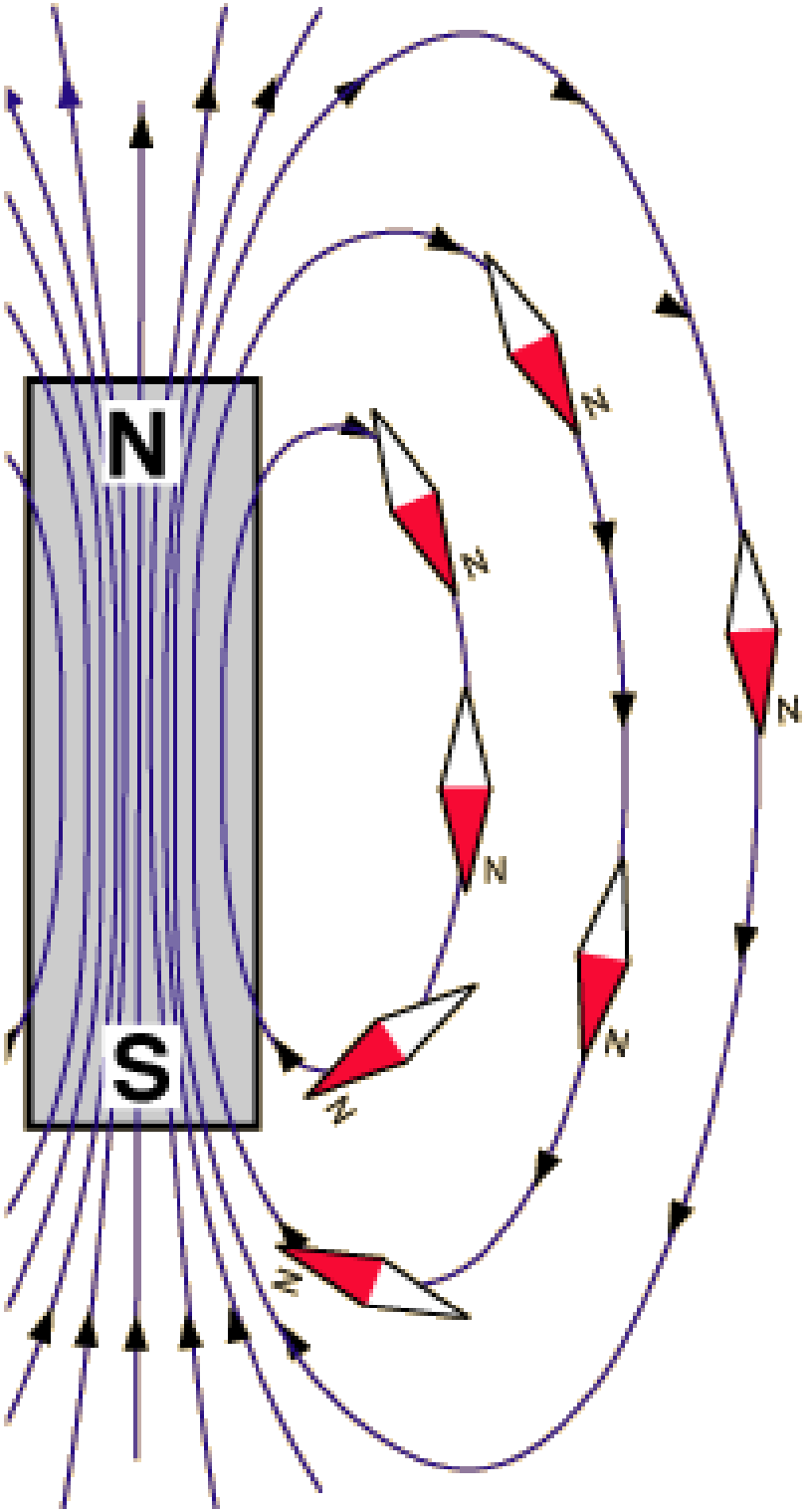
Magnetism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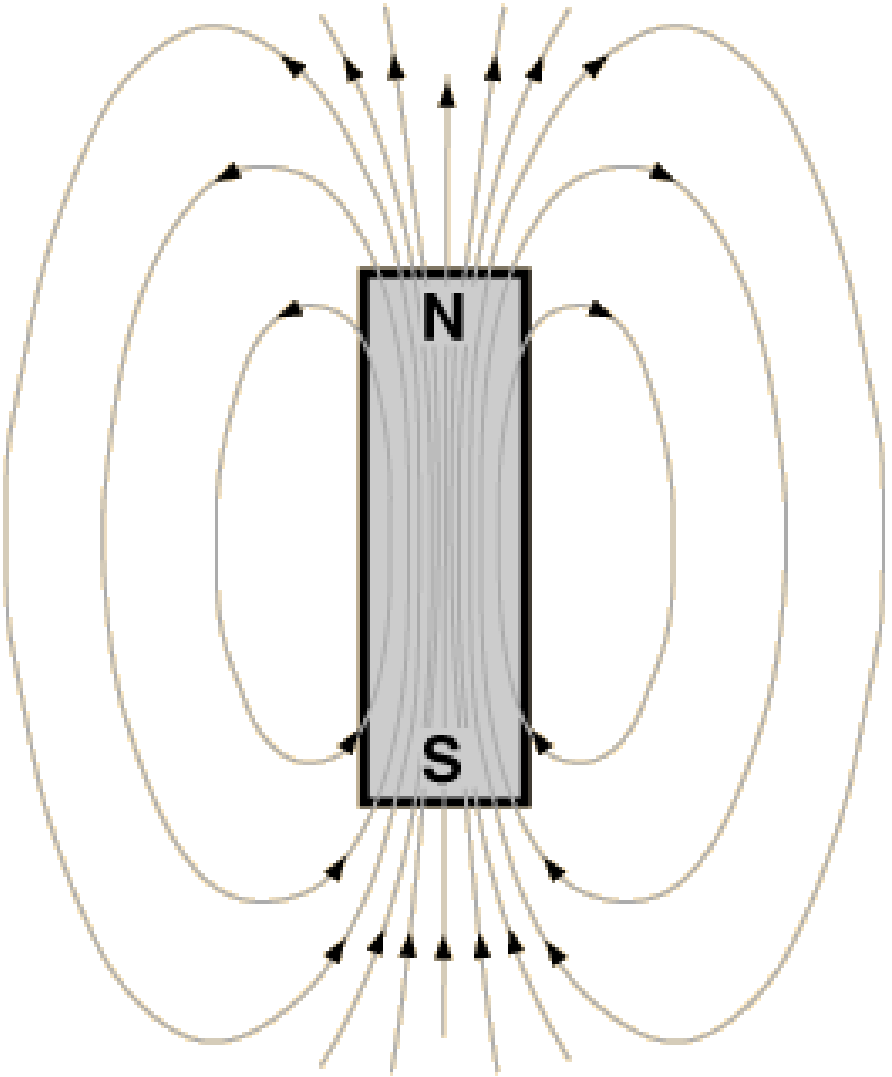
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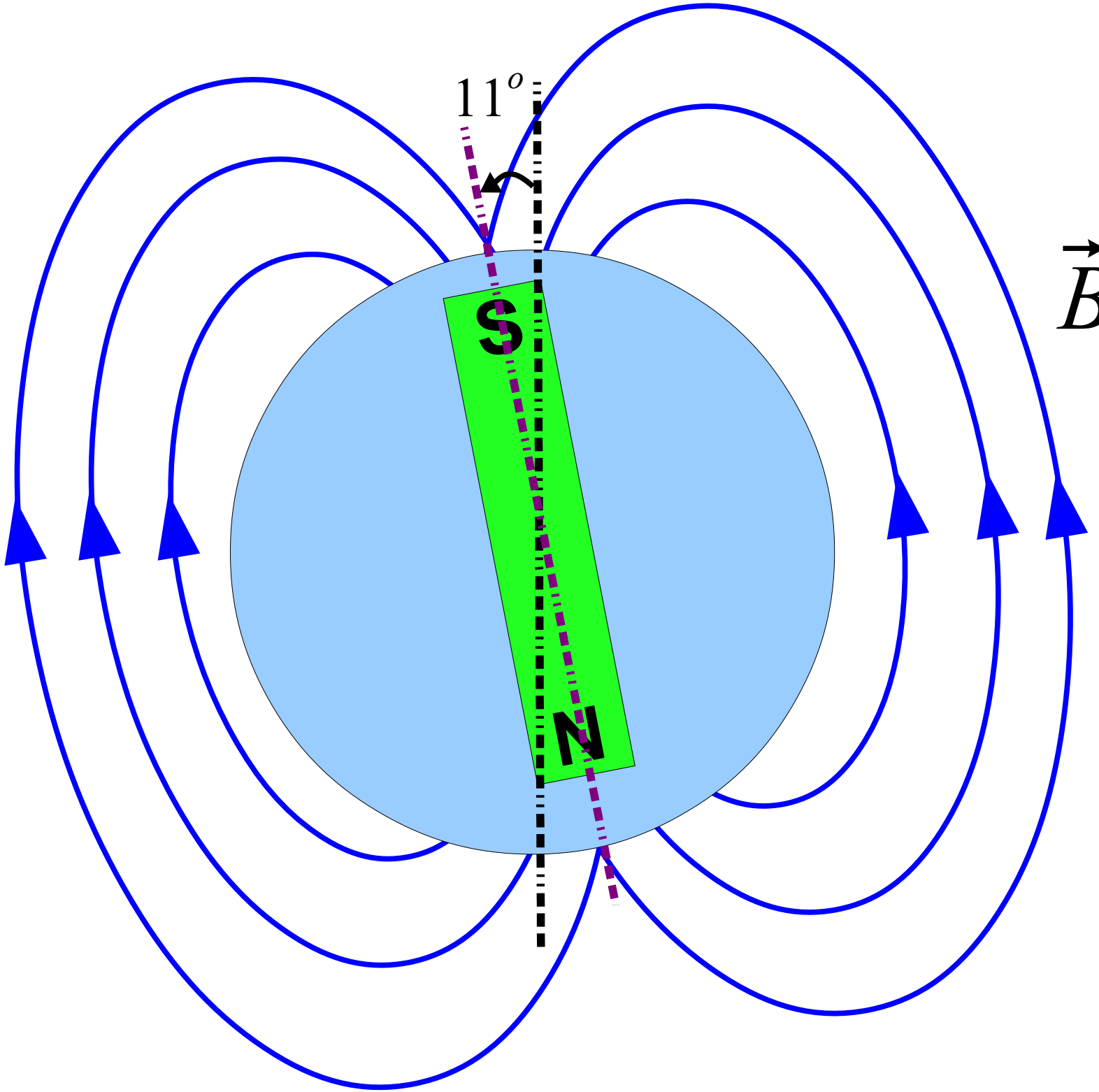


$$[B] = T = \text{Tesla}$$

$$1\,T = 1\,\frac{Wb}{m^2}$$

$$1\,T = 1\,\frac{N}{C\,m/s}$$

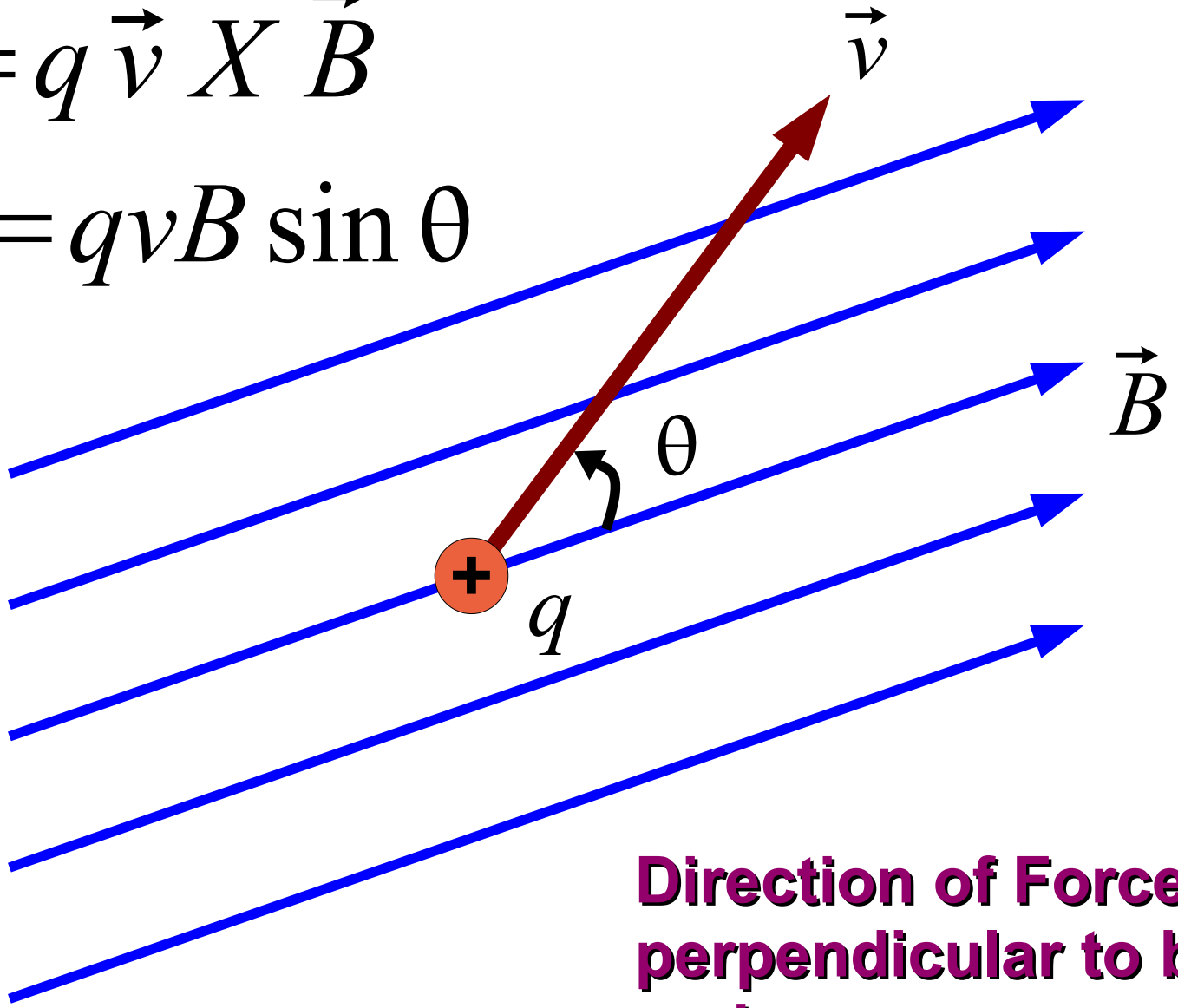
$$1\,T = 1\,\frac{N}{A\,m}$$

$$1\,T = 10^4\,G$$

Forces on a Charge in a Magnetic Field

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

$$|F_B| = qvB\sin\theta$$



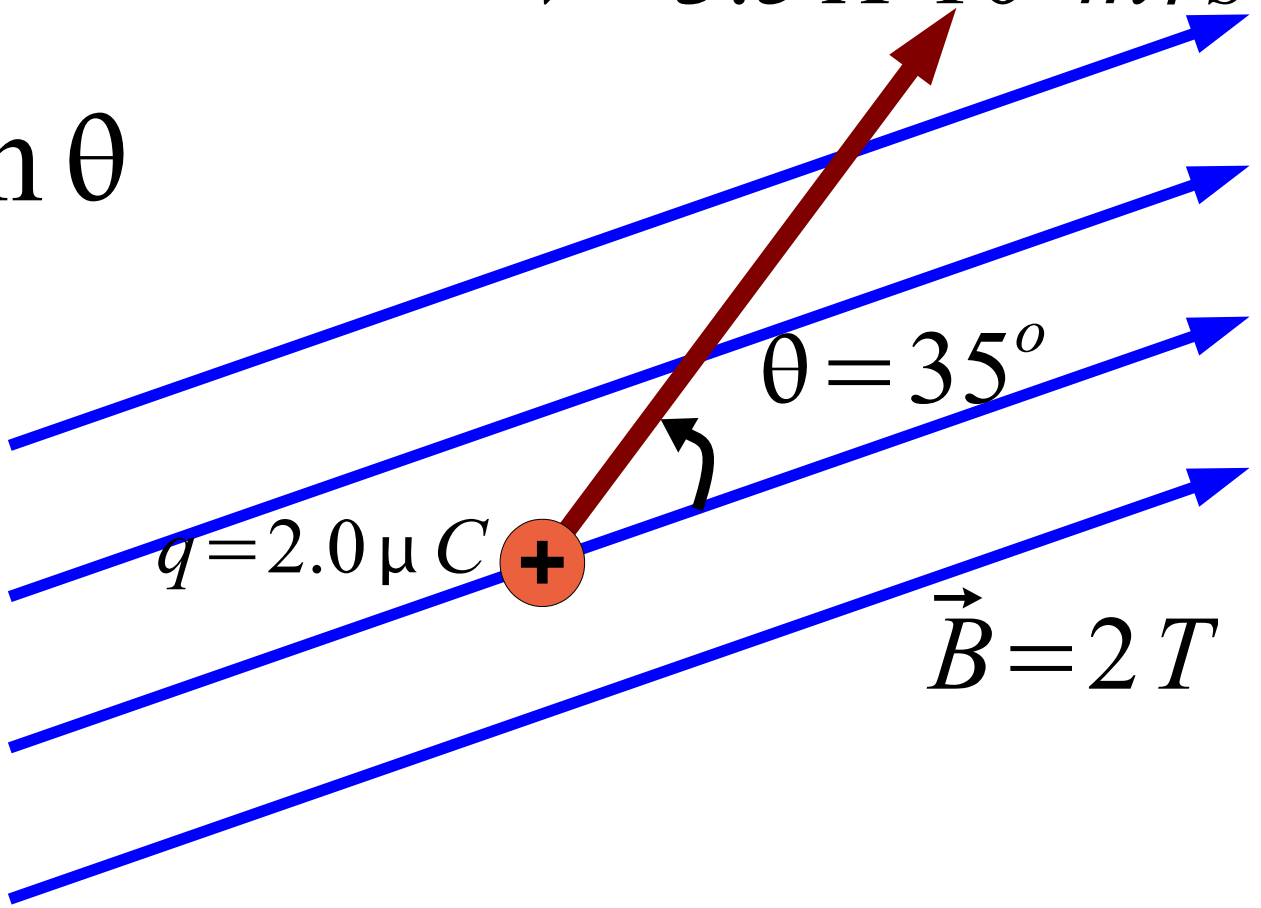
Direction of Force is perpendicular to both B and v.

According to right hand rule.

Forces on a Charge in a Magnetic Field

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

$$|F_B| = qvB\sin\theta$$



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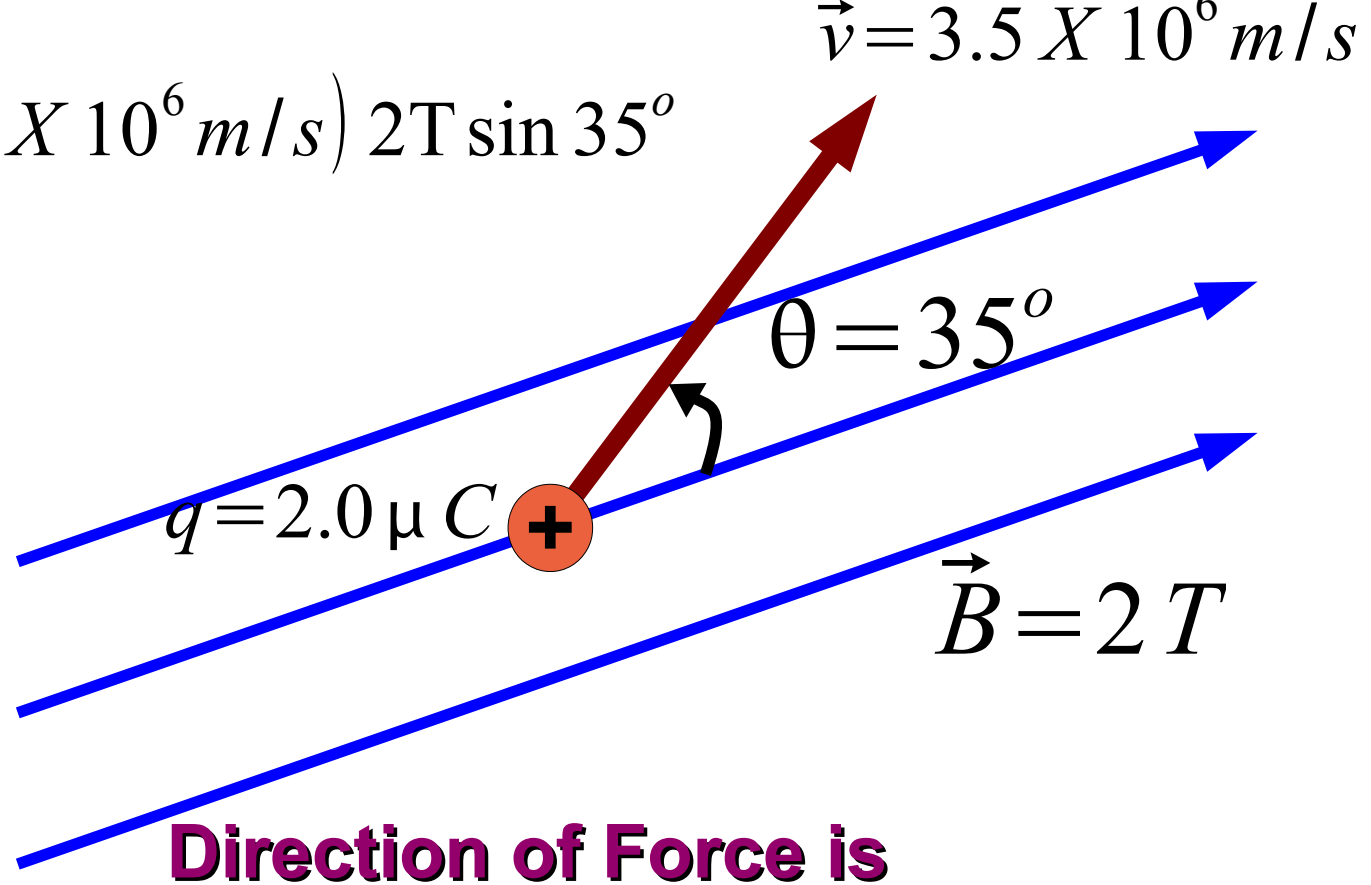
Forces on a Charge in a Magnetic Field

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

$$|F_B| = qvB\sin\theta$$

$$|F_B| = 2\mathrm{X}\,10^{-6}\,C\left(3.5\,X\,10^{6}\,m/s\right)2\mathrm{T}\sin 35^{o}$$

$$|F_B| = 8.03\,N$$



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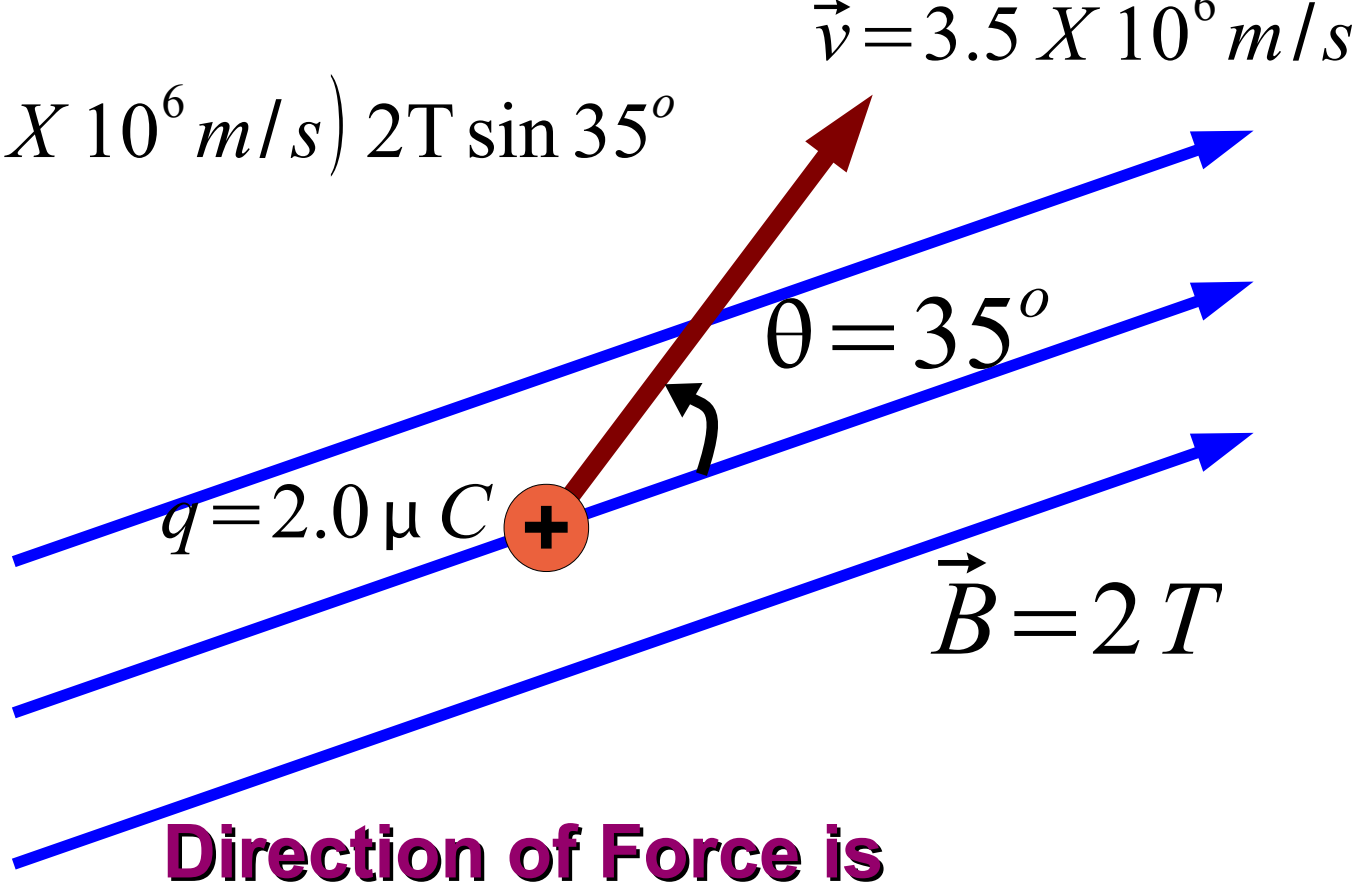


Direction of Force is perpendicular to both B and v.

INTO THE PAGE (AWAY FROM YOU).

$q = 5\,C$

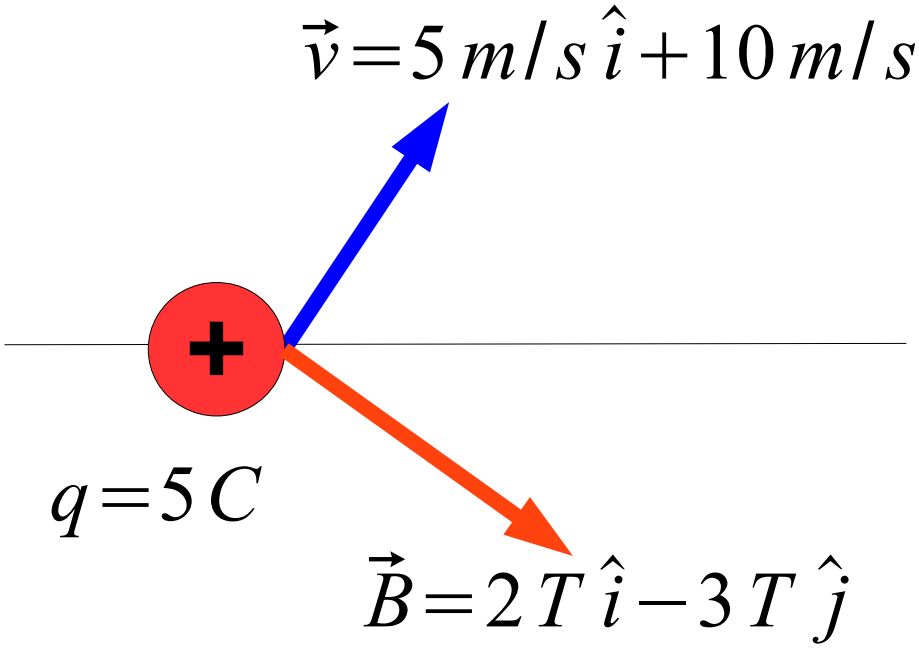
$\vec{v} = 5\,m/s\,\hat{i} + 10\,m/s\,\hat{j}$

$\vec{B} = 2\,T\,\hat{i} - 3\,T\,\hat{j}$

$1\,TC\,m/s = 1\,N$

Find: $\vec{F}_B = q\,\vec{v}\,X\,\vec{B}$

$$\vec{F}_B = q \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ v_x & v_y & v_Z \\ B_x & B_y & B_z \end{vmatrix}$$



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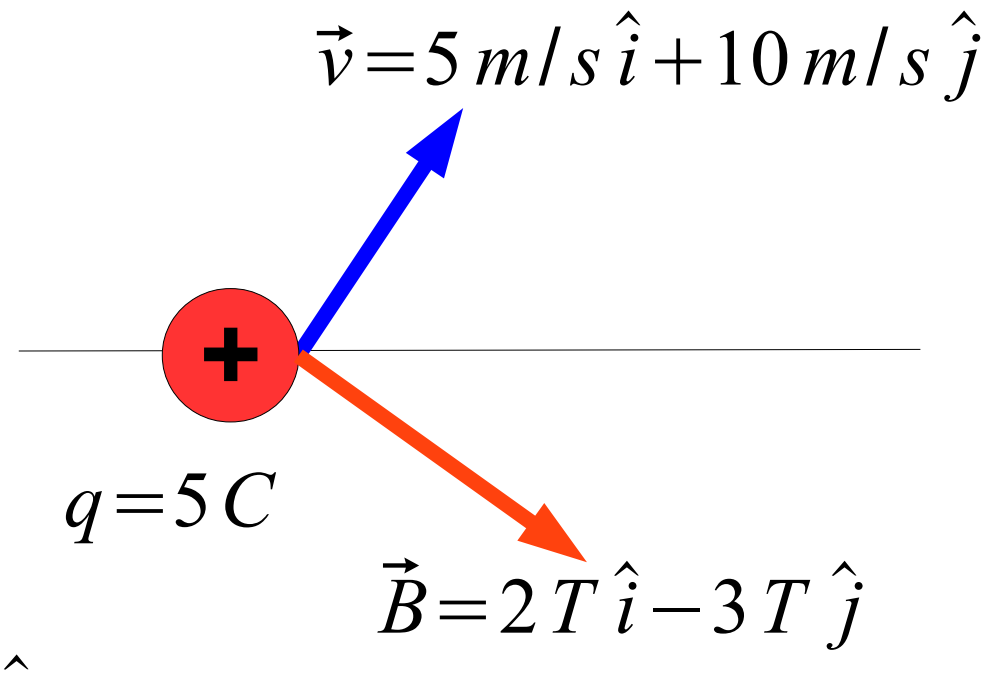

$$\vec{F}_B = q \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ v_x & v_y & v_Z \\ B_x & B_y & B_z \end{vmatrix} \begin{matrix} \hat{i} & \hat{j} \\ v_x & v_y \\ B_x & B_y \end{matrix}$$

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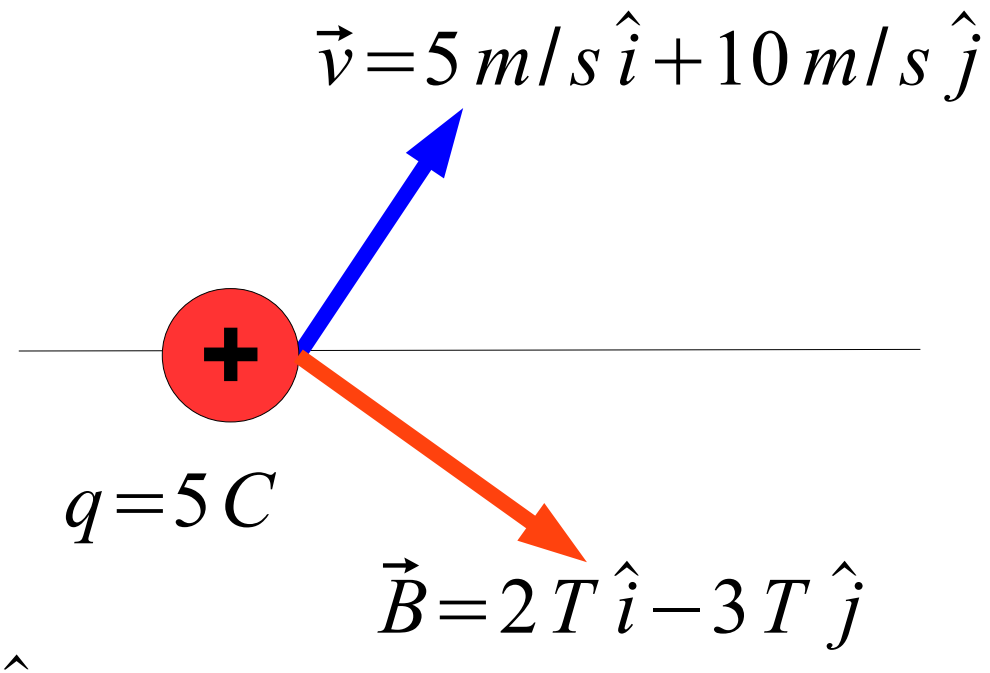

$$\vec{F}_B = q \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ v_x & v_y & v_Z \\ B_x & B_y & B_z \end{vmatrix} \begin{matrix} \hat{i} & \hat{j} \\ v_x & v_y \\ B_x & B_y \end{matrix}$$

$$\vec{F}_B = q\left[v_y B_z \hat{i} + \right]$$

$q = 5\,C$

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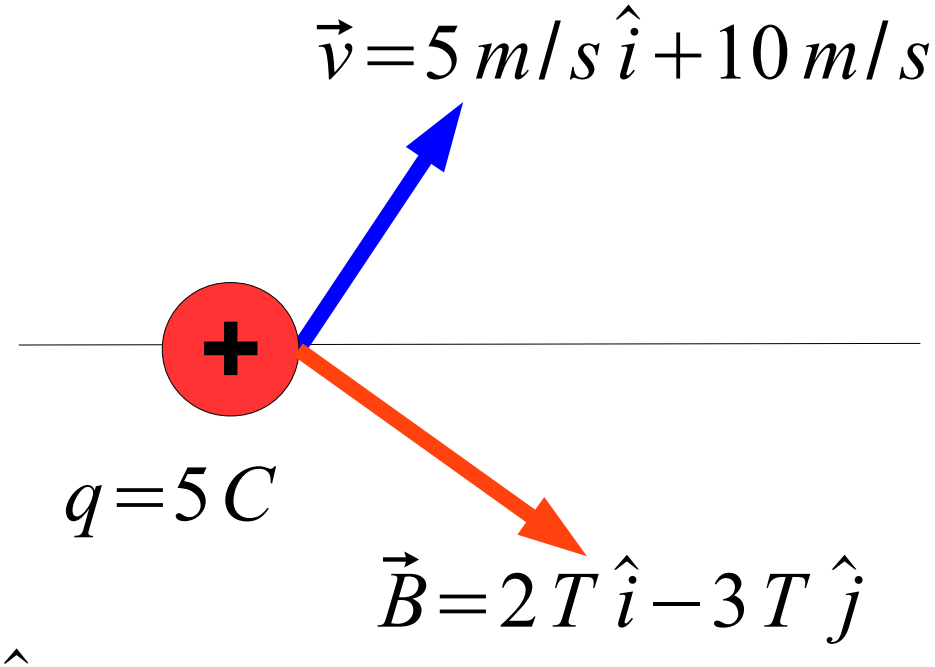

$$\vec{F}_B = q\begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ v_x & v_y & v_z \\ B_x & B_y & B_z \end{vmatrix} \begin{matrix} \hat{i} & \hat{j} \\ v_x & v_y \\ B_x & B_y \end{matrix}$$

$$\vec{F}_B = q\left[v_y B_z \hat{i} + v_z B_x \hat{j} + v_x B_y \hat{k}\right]$$

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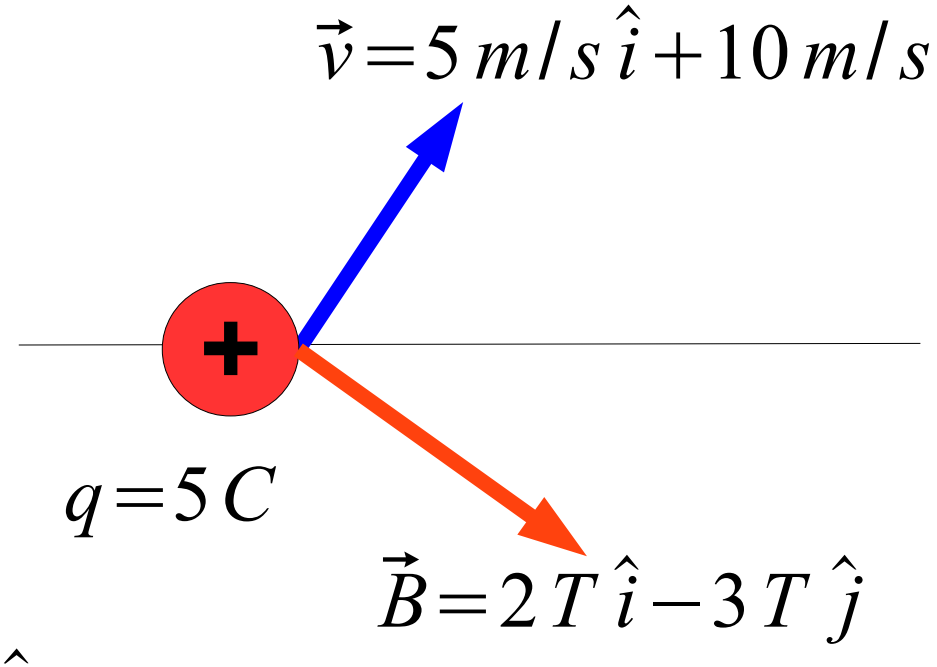

$$\vec{F}_B = q \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ v_x & v_y & v_z \\ B_x & B_y & B_z \end{vmatrix} \begin{matrix} \hat{i} & \hat{j} \\ v_x & v_y \\ B_x & B_y \end{matrix}$$

$$\vec{F}_B = q\left[v_y B_z \hat{i} + v_z B_x \hat{j} + v_x B_y \hat{k} - v_y B_x \hat{k}\right]$$

$q = 5\,C$

$\vec{v} = 5\,m/s\,\hat{i} + 10\,m/s\,\hat{j}$

$\vec{B} = 2\,T\,\hat{i} - 3\,T\,\hat{j}$

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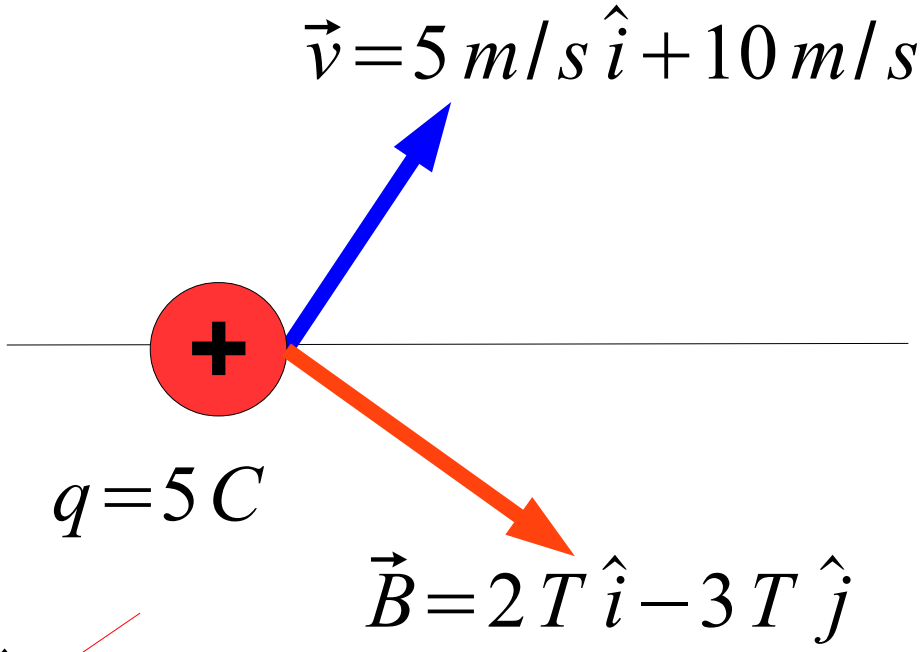
Find: $\vec{F}_B = q\,\vec{v}\,X\,\vec{B}$



$$\vec{F}_B = q \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ v_x & v_y & v_z \\ B_x & B_y & B_z \end{vmatrix} \begin{matrix} \hat{i} & \hat{j} \\ v_x & v_y \\ B_x & B_y \end{matrix}$$

$$\vec{F}_B = q\left[v_y B_z \hat{i} + v_z B_x \hat{j} + v_x B_y \hat{k} - v_y B_x \hat{k} - v_z B_y \hat{i} - v_x B_z \hat{j}\right]$$

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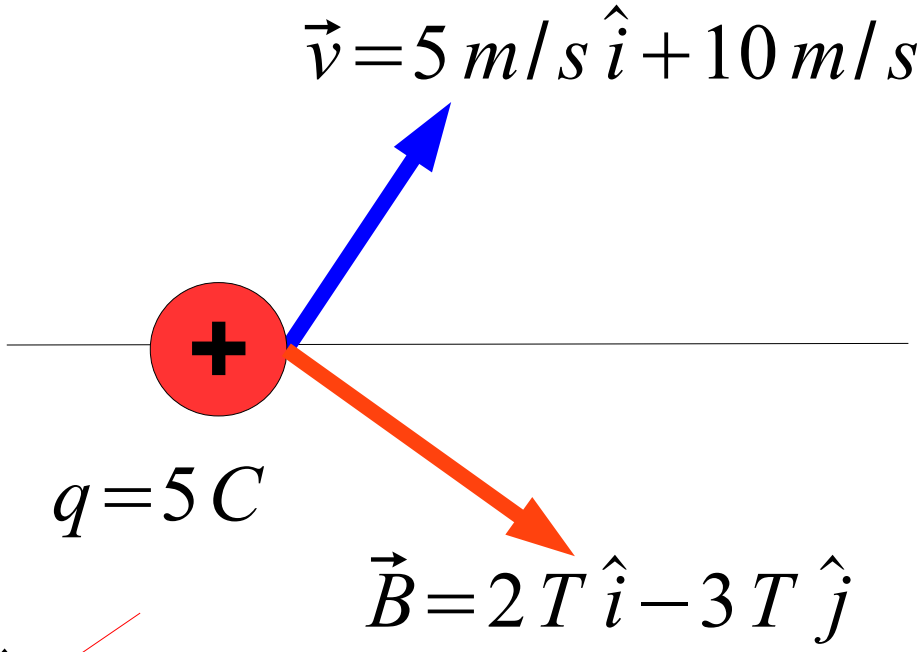

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$$\vec{F}_B = q\left[v_y B_z \hat{i} + v_z B_x \hat{j} + v_x B_y \hat{k} - v_y B_x \hat{k} - v_z B_y \hat{i} - v_x B_z \hat{j}\right]$$

$$\vec{F}_B = q\left[\left(v_y B_z - v_z B_y\right)\hat{i} + \left(v_z B_x - v_x B_z\right)\hat{j} + \left(v_x B_y - v_y B_x\right)\hat{k}\right]$$

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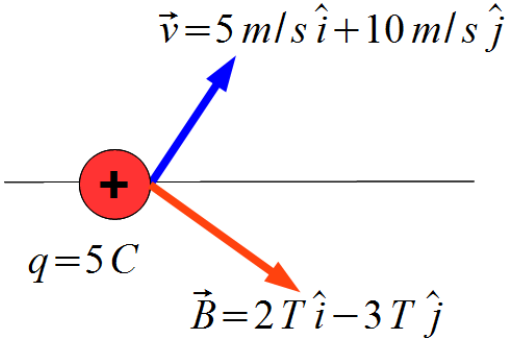

$$\vec{F}_B = q\begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ v_x & v_y & v_z \\ B_x & B_y & B_z \end{vmatrix} = 5\text{C}\begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 5\,m/s & 10\,m/s & 0 \\ 2\text{T} & -3\text{T} & 0 \end{vmatrix}$$

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$$\vec{v} = 5\,m/s\,\hat{i} + 10\,m/s\,\hat{j}$$

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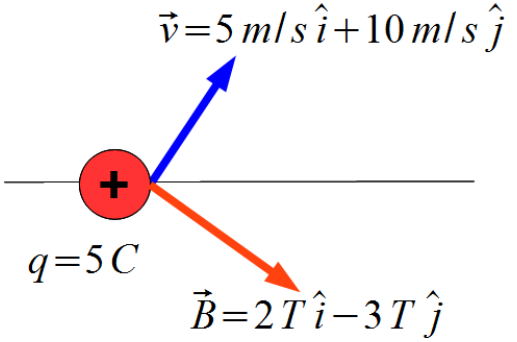

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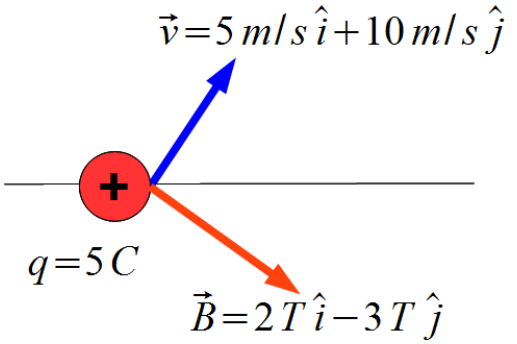

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$$\vec{F}_B = 5\text{C}\left[0\,\hat{i}\right.$$

$\left.\right]$

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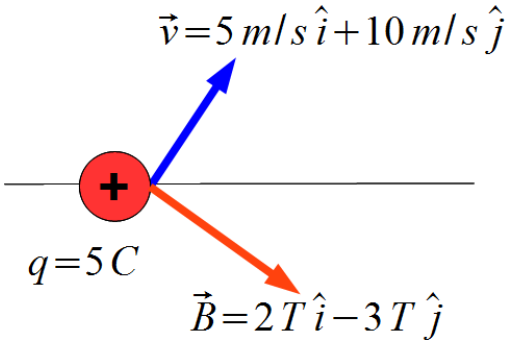

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$$\vec{F}_B = 5\text{C}\left[0\,\hat{i} + 0\,\hat{j} \right.$$]

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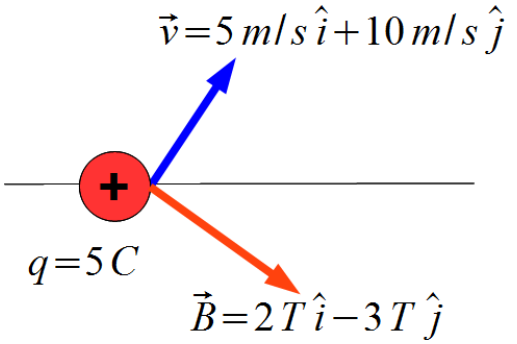

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$$\vec{F}_B = 5\text{C}\left[0\,\hat{i} + 0\,\hat{j} - 15\,T\,m/s\,\hat{k}\right]$$

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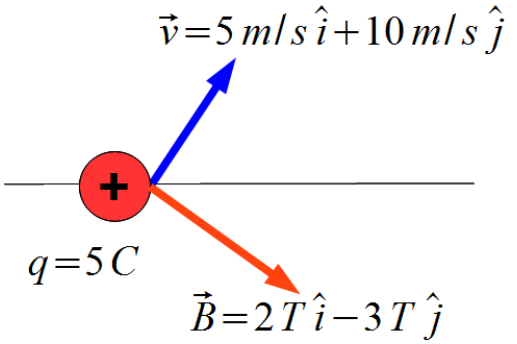

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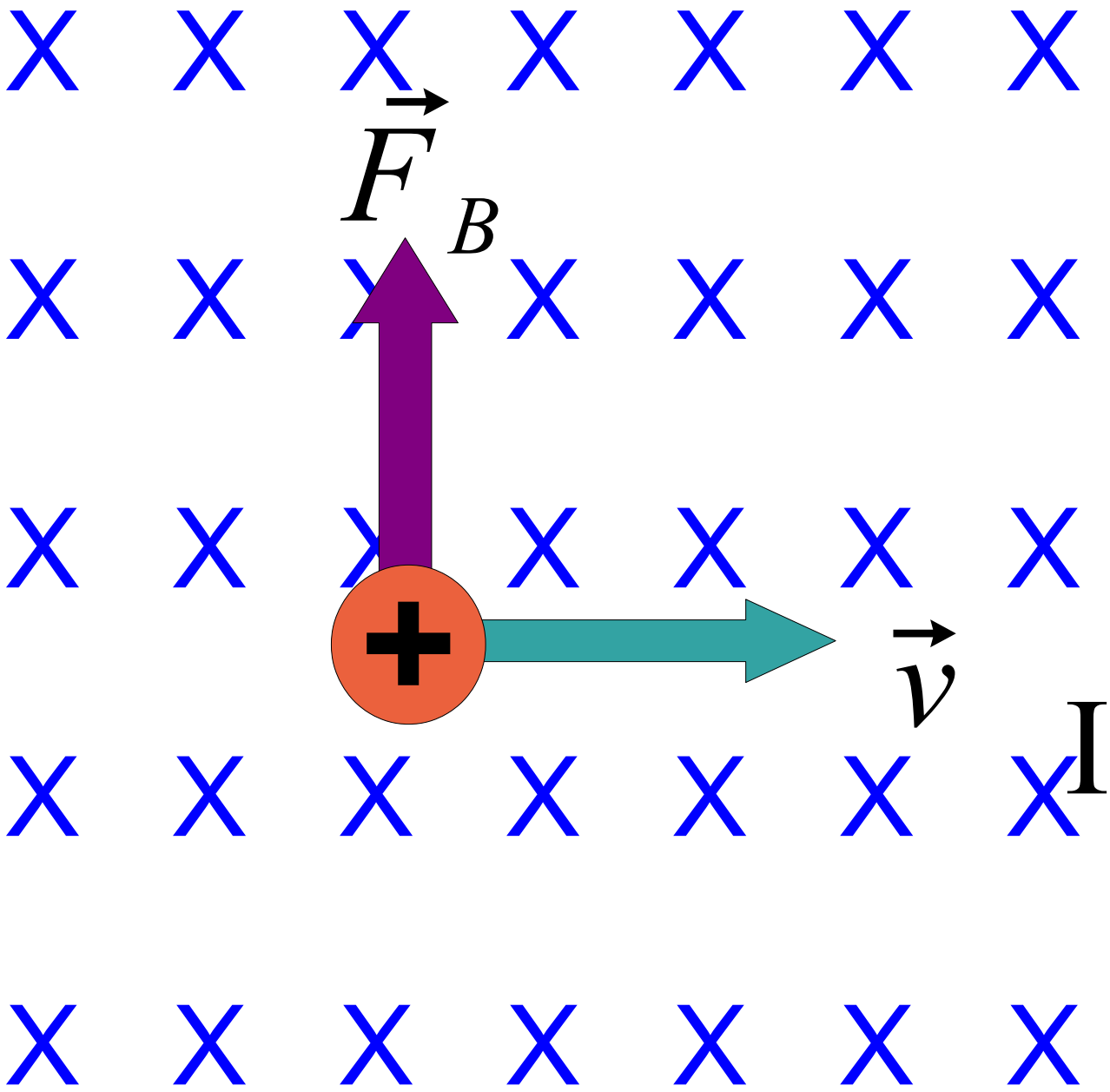
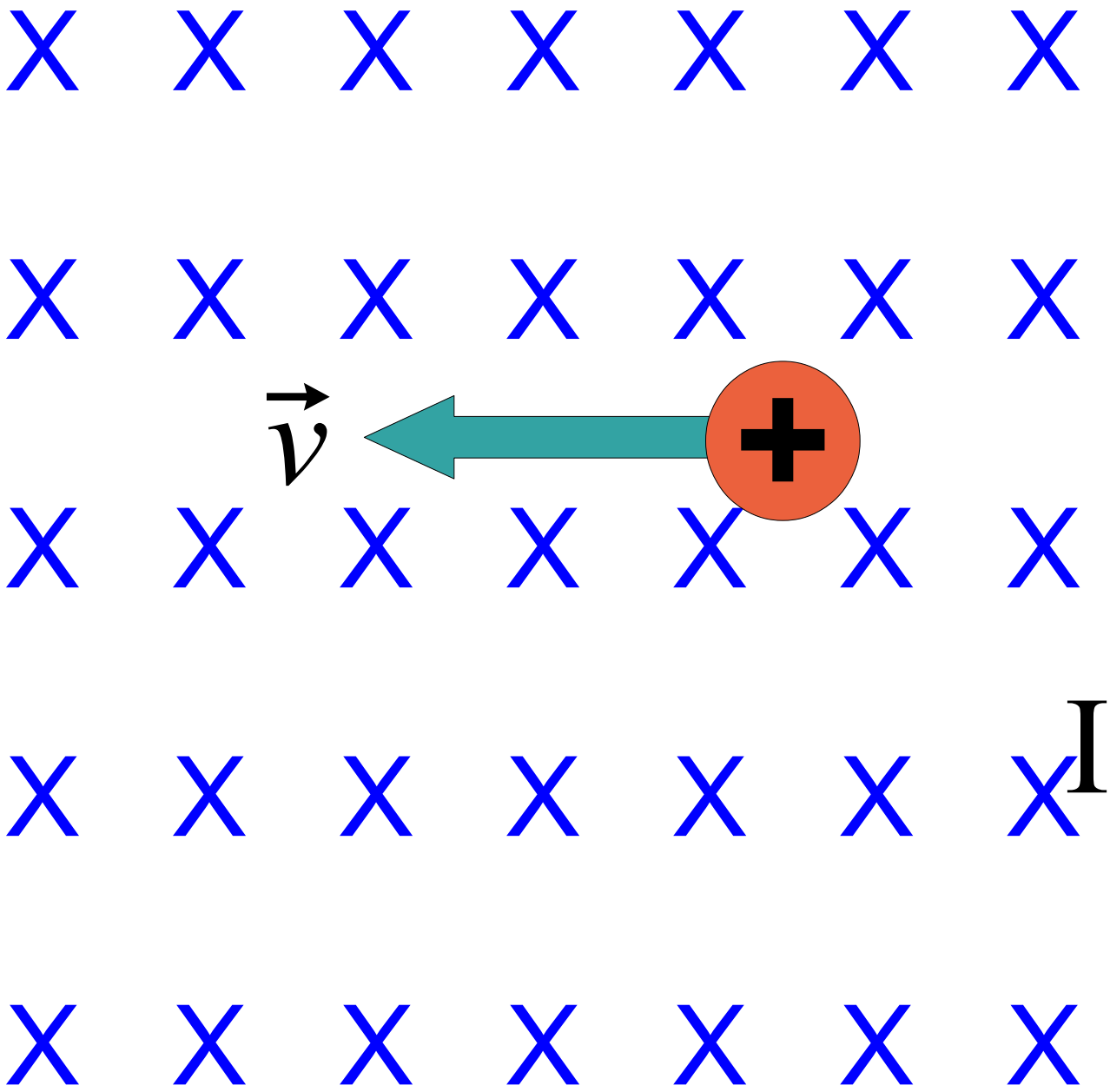
$$\vec{F}_B = 5\text{C}\left[0\,\hat{i} + 0\,\hat{j} - 15\,T\,m/s\,\hat{k} - 20\,T\,m/s\,\hat{k} - 0\,\hat{i} - 0\,\hat{j}\right]N$$



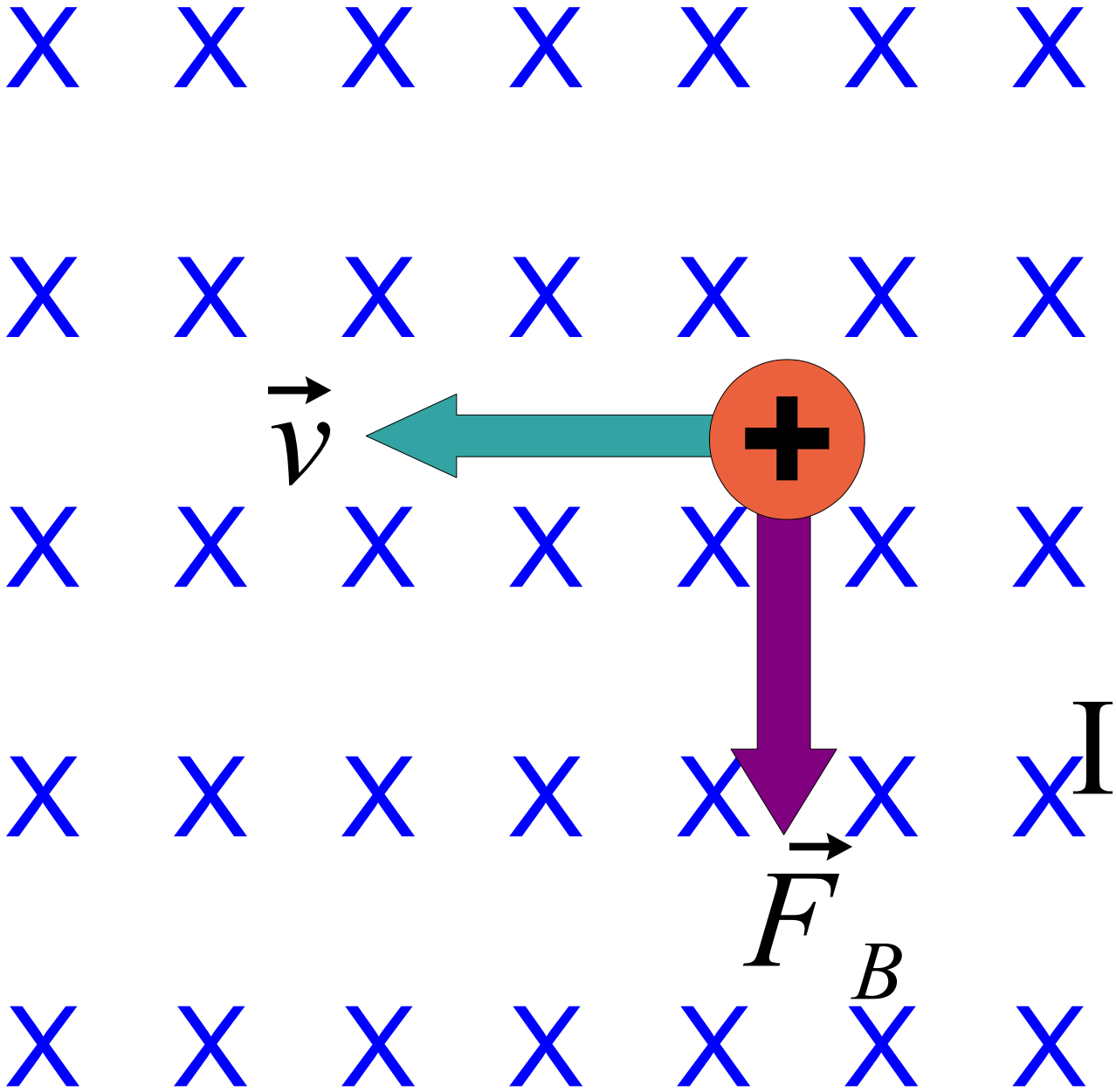
$\vec{B}$

Into Page.



$\vec{B}$

Into Page.



$\vec{B}$

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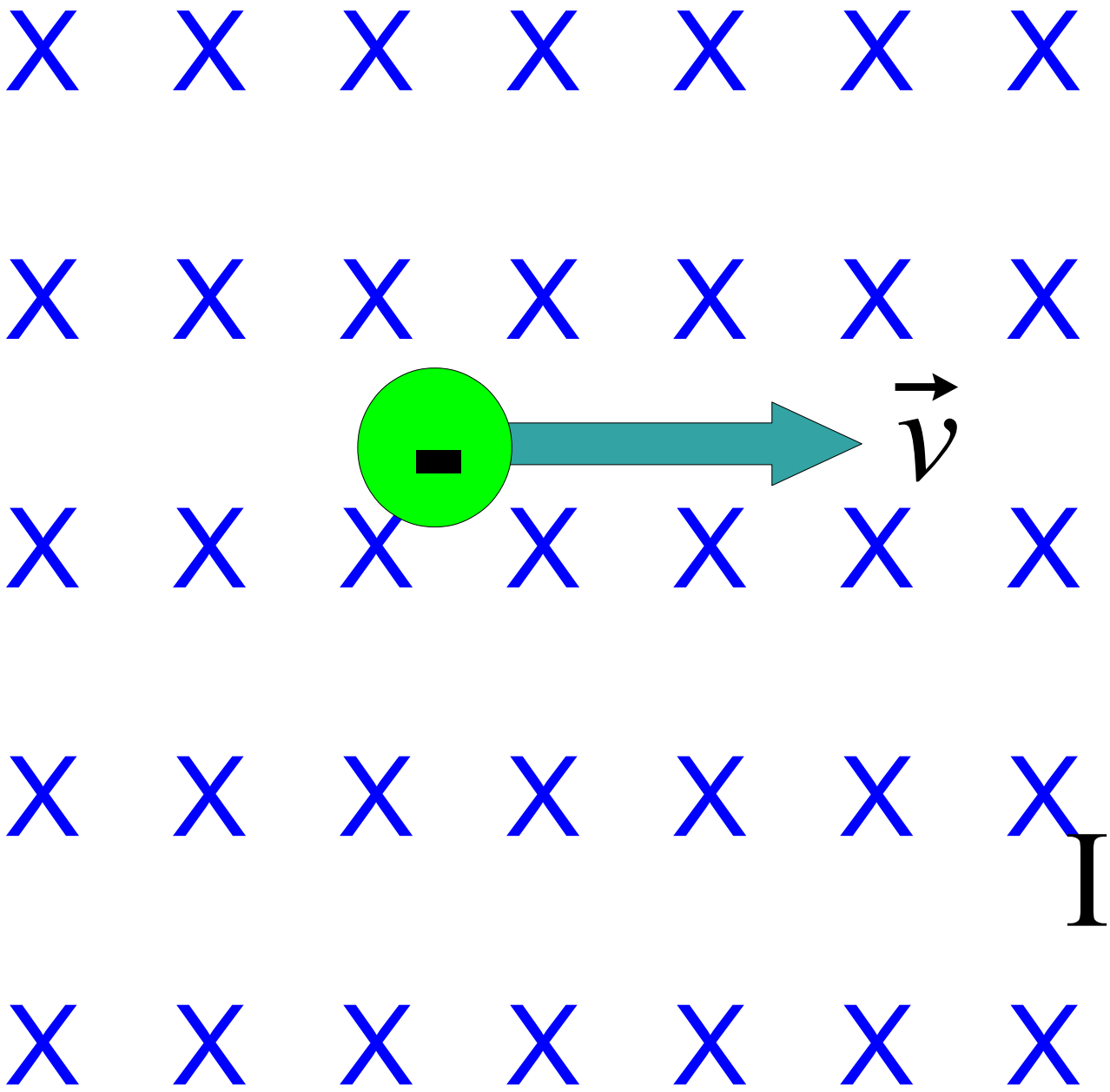
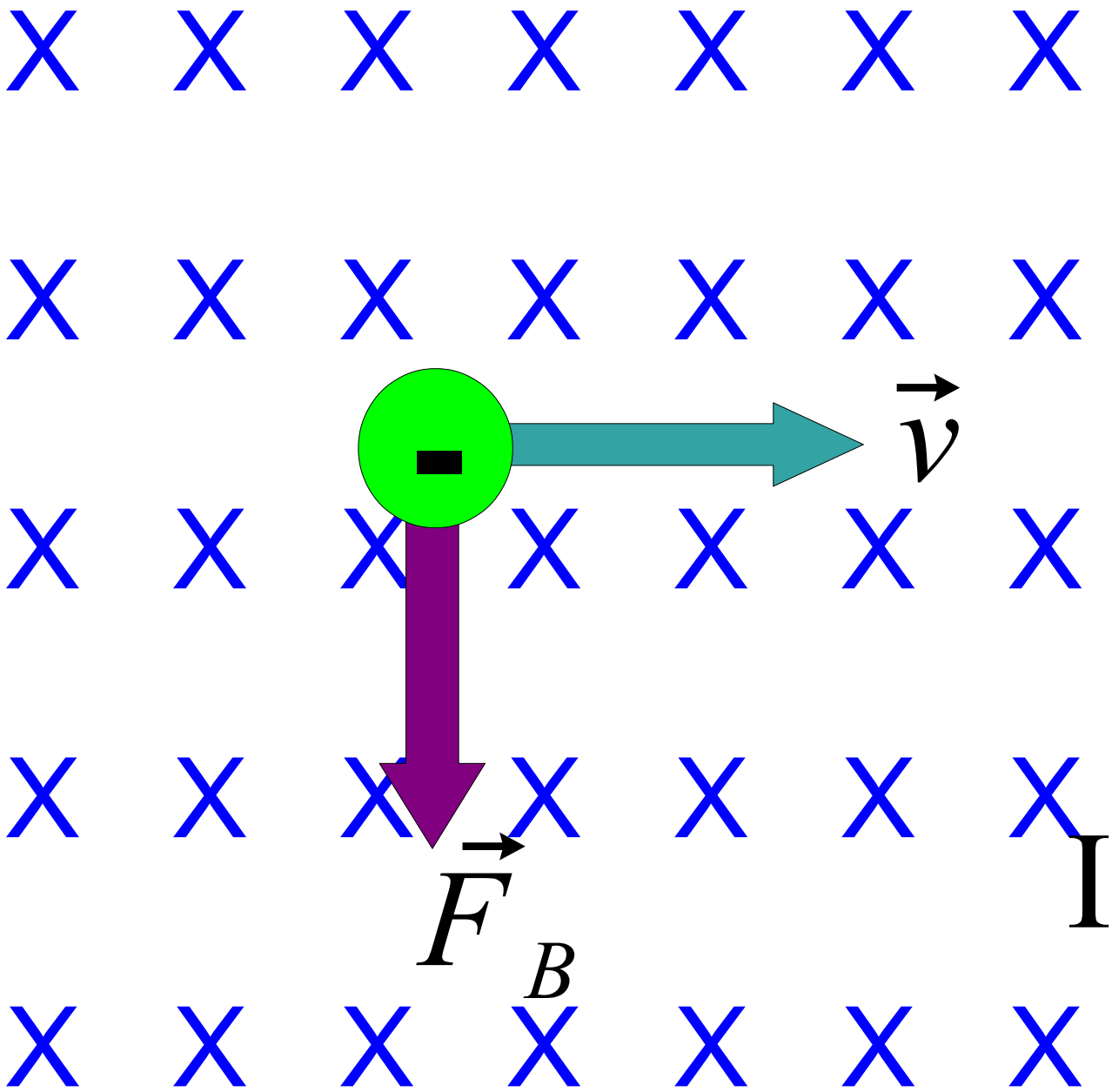

$\vec{v}$
$\vec{B}$
Into Page.



$\vec{B}$

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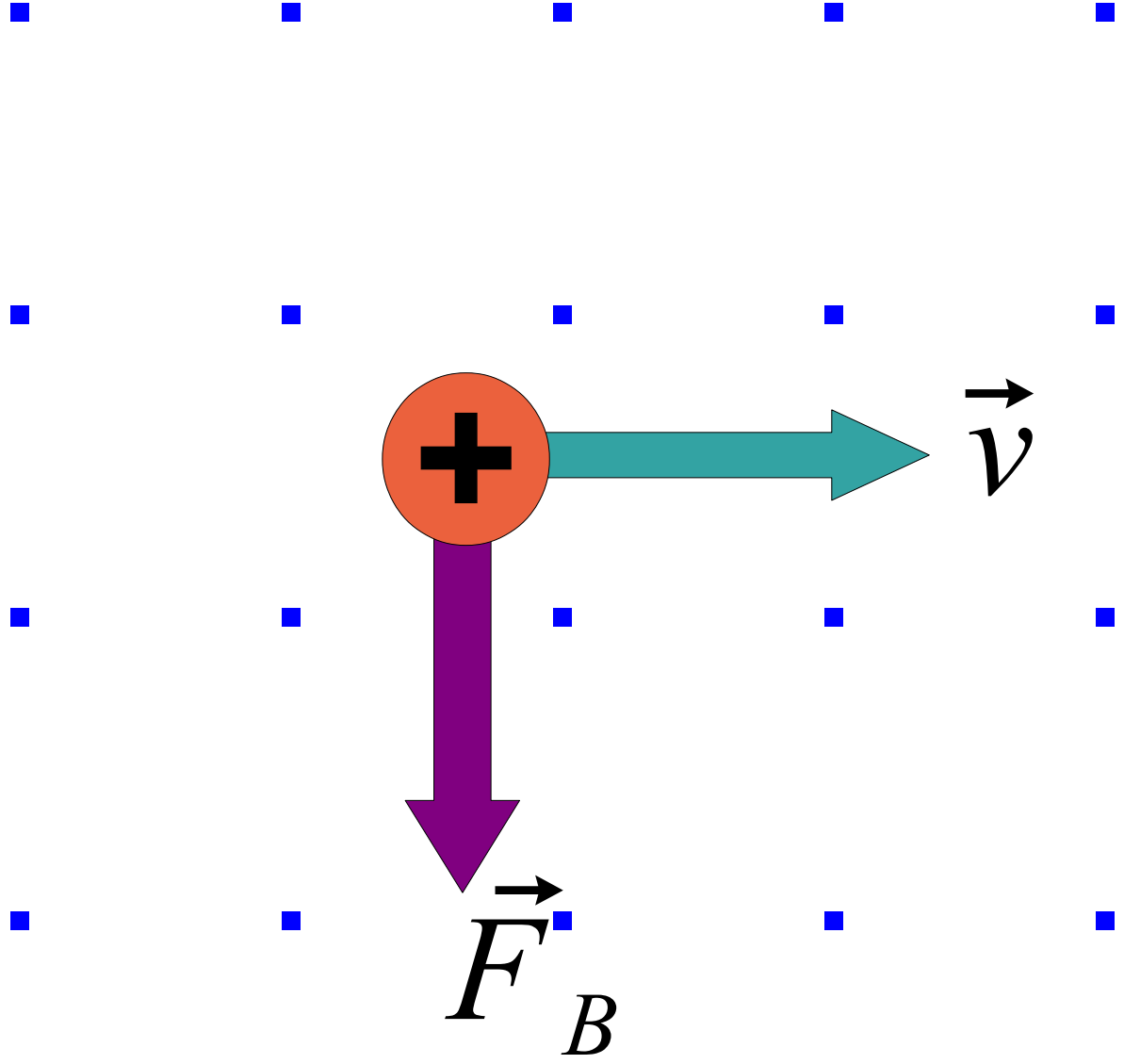
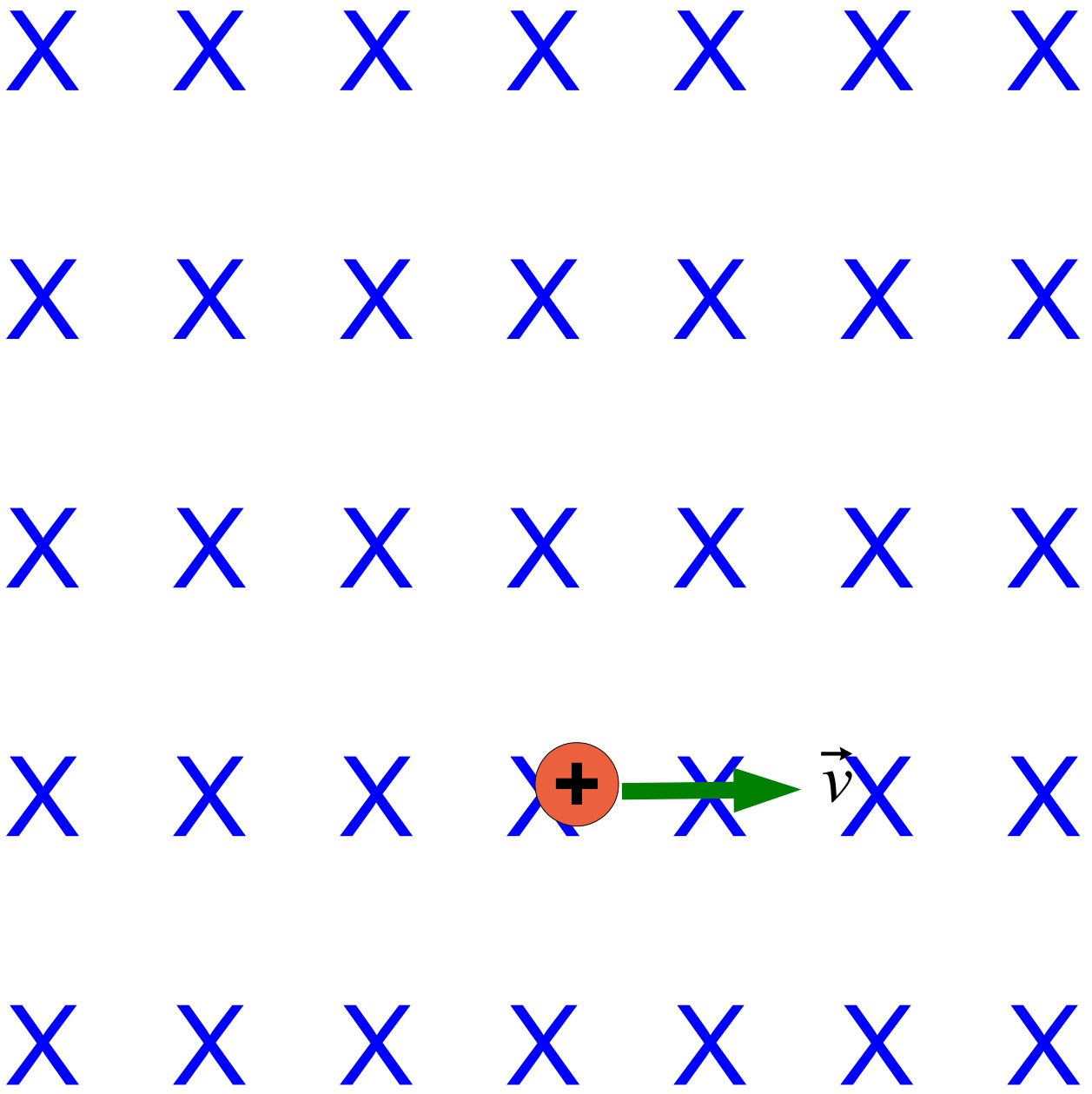


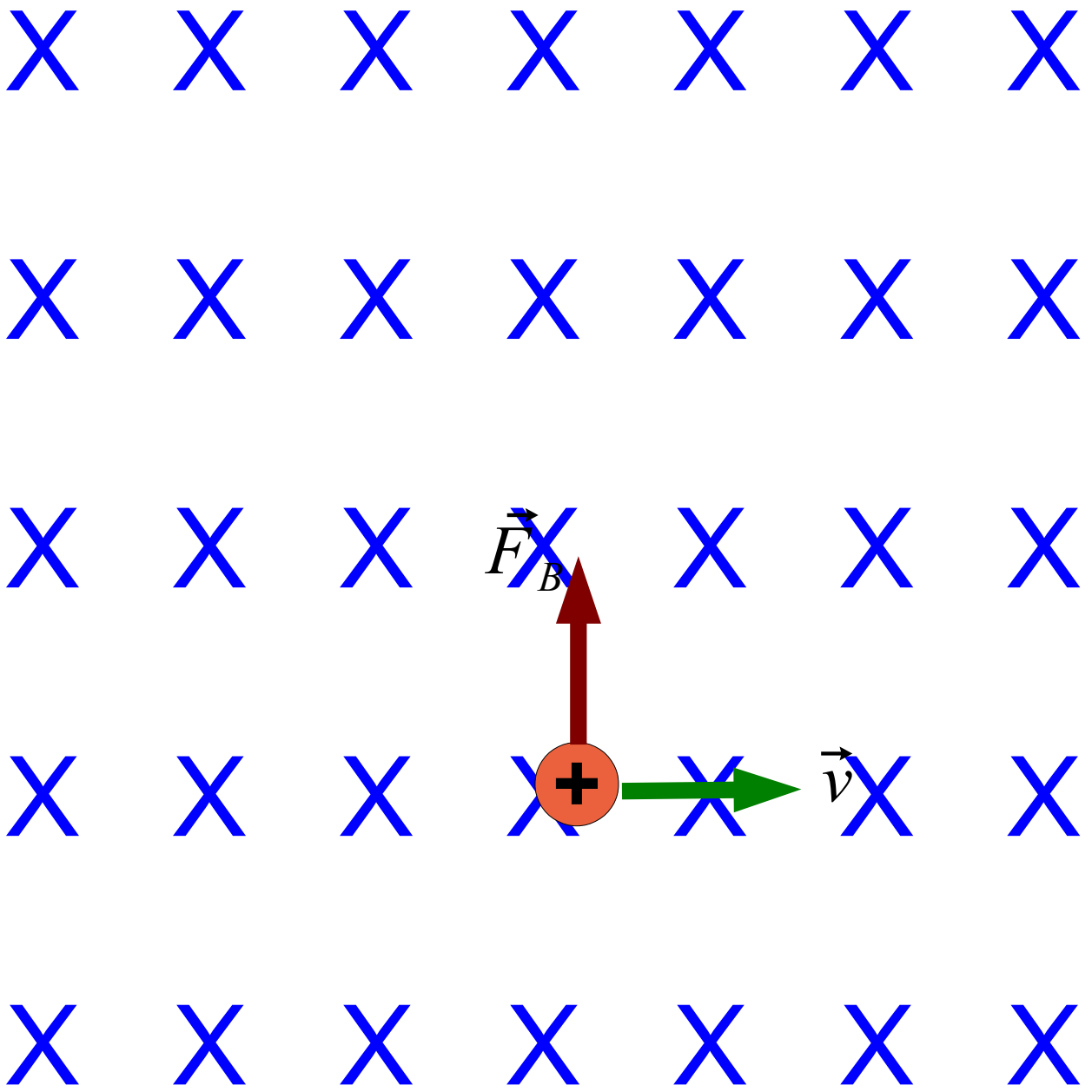
$\vec{B}$

Out of Page.


$\vec{B}$
Into Page.
$\vec{v}$

$\vec{B}$

Into Page.



$\vec{B}$

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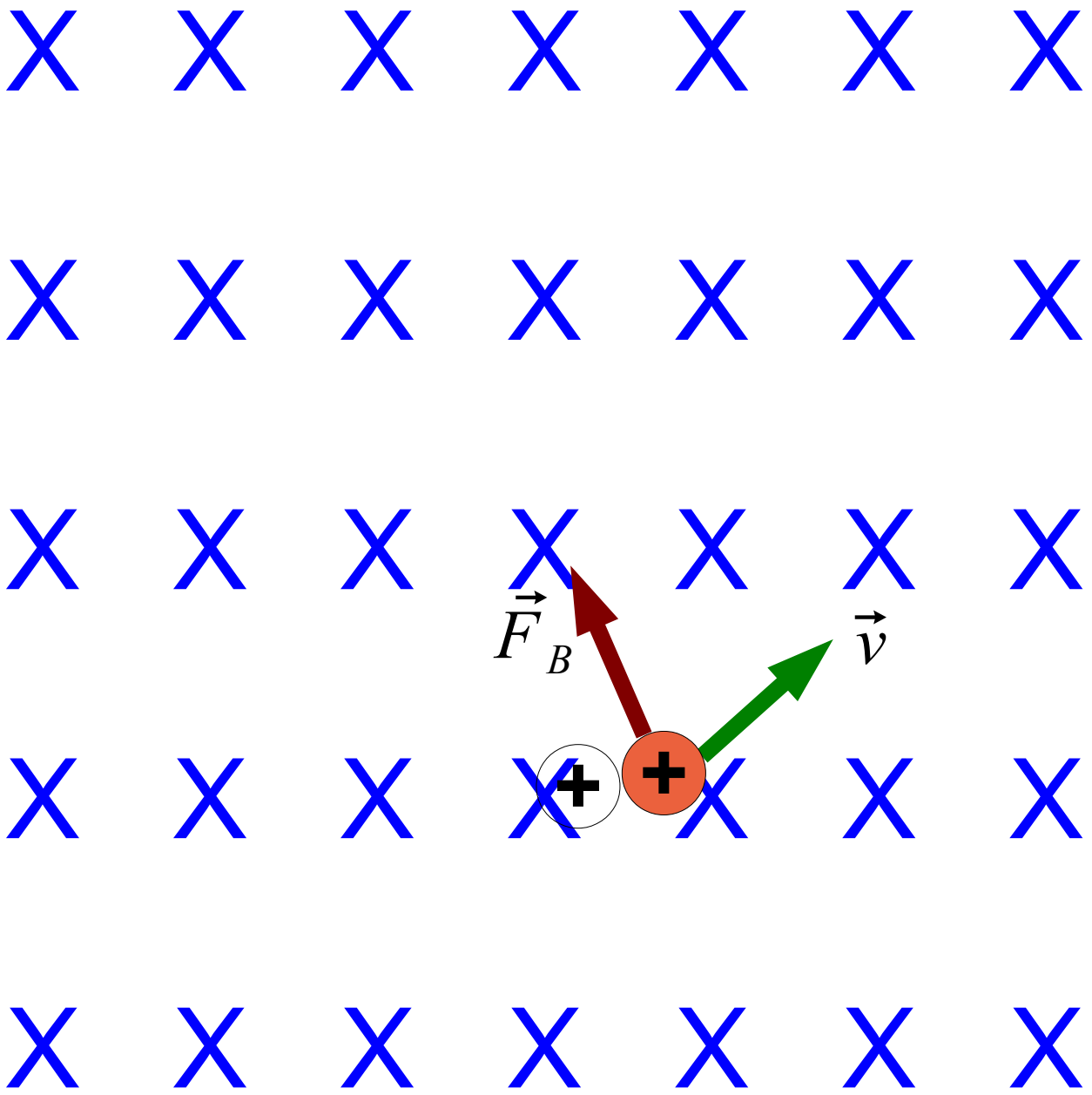

$\vec{B}$

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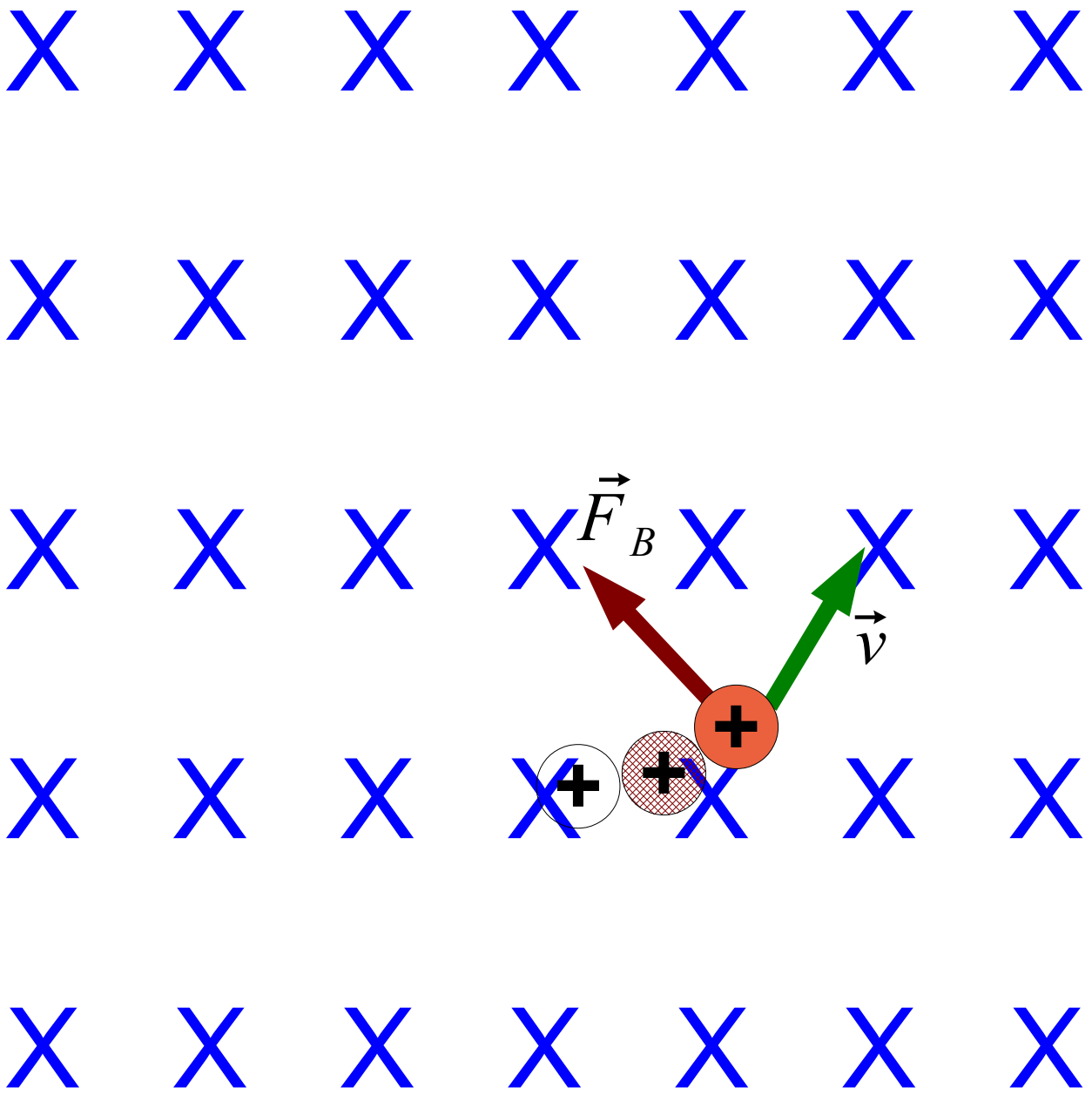
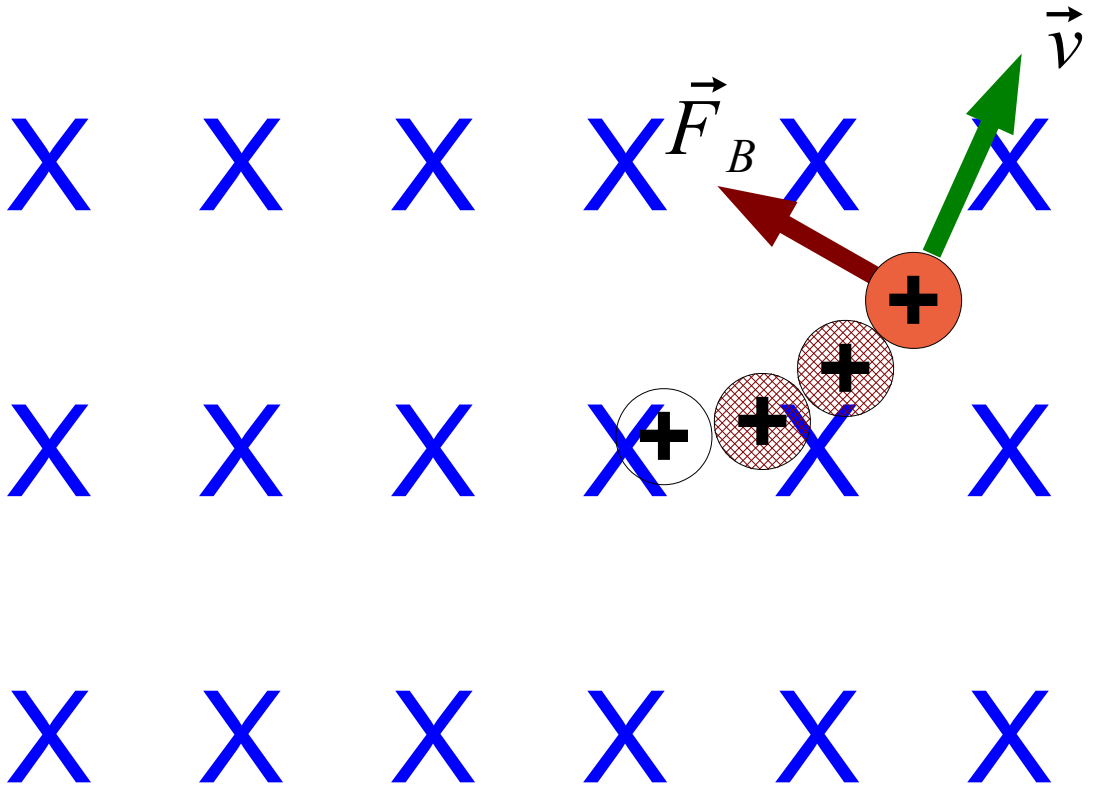


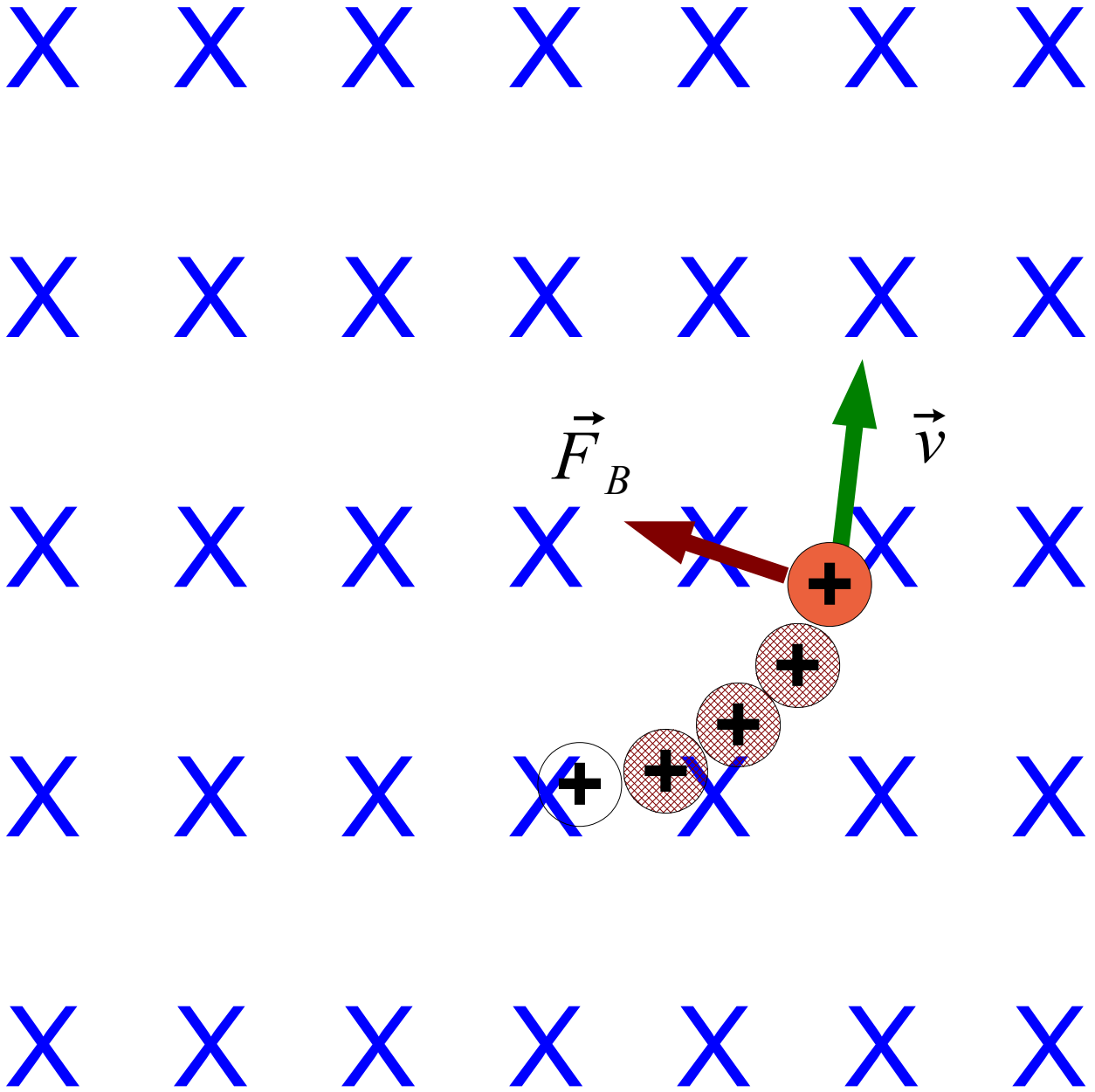
$\vec{B}$

Into Page.



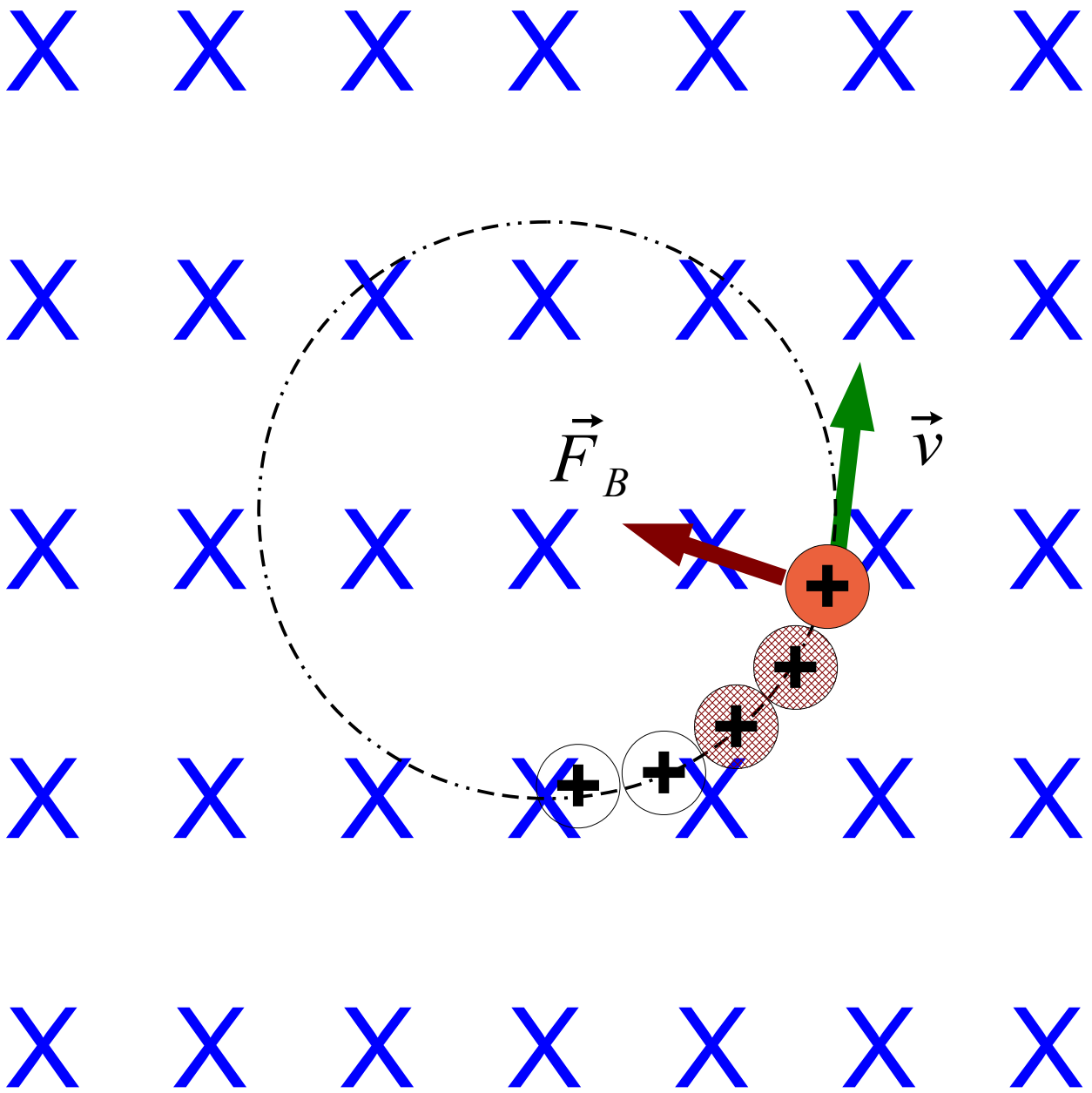
$\vec{B}$

Into Page.



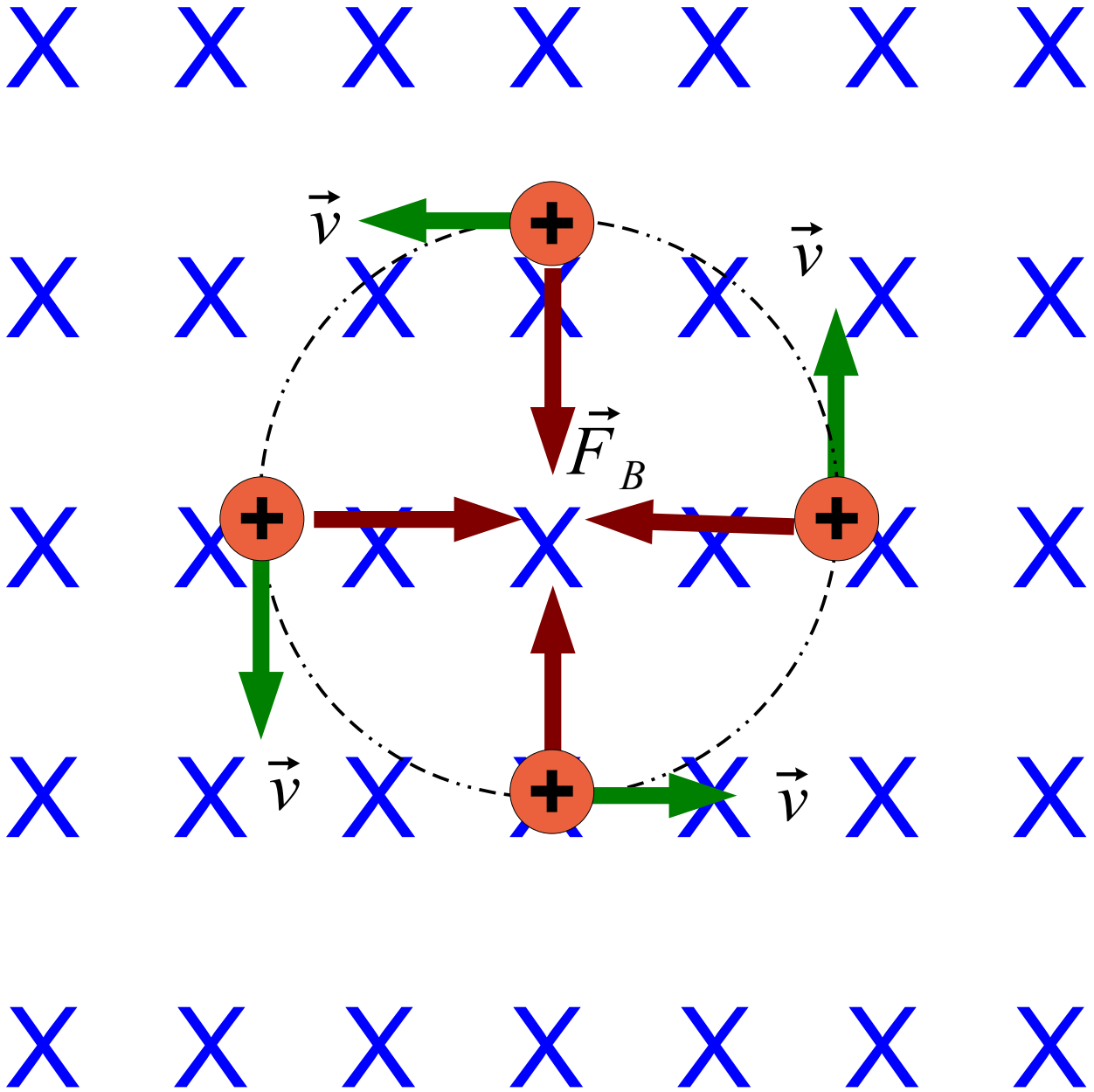
$\vec{B}$

Into Page.



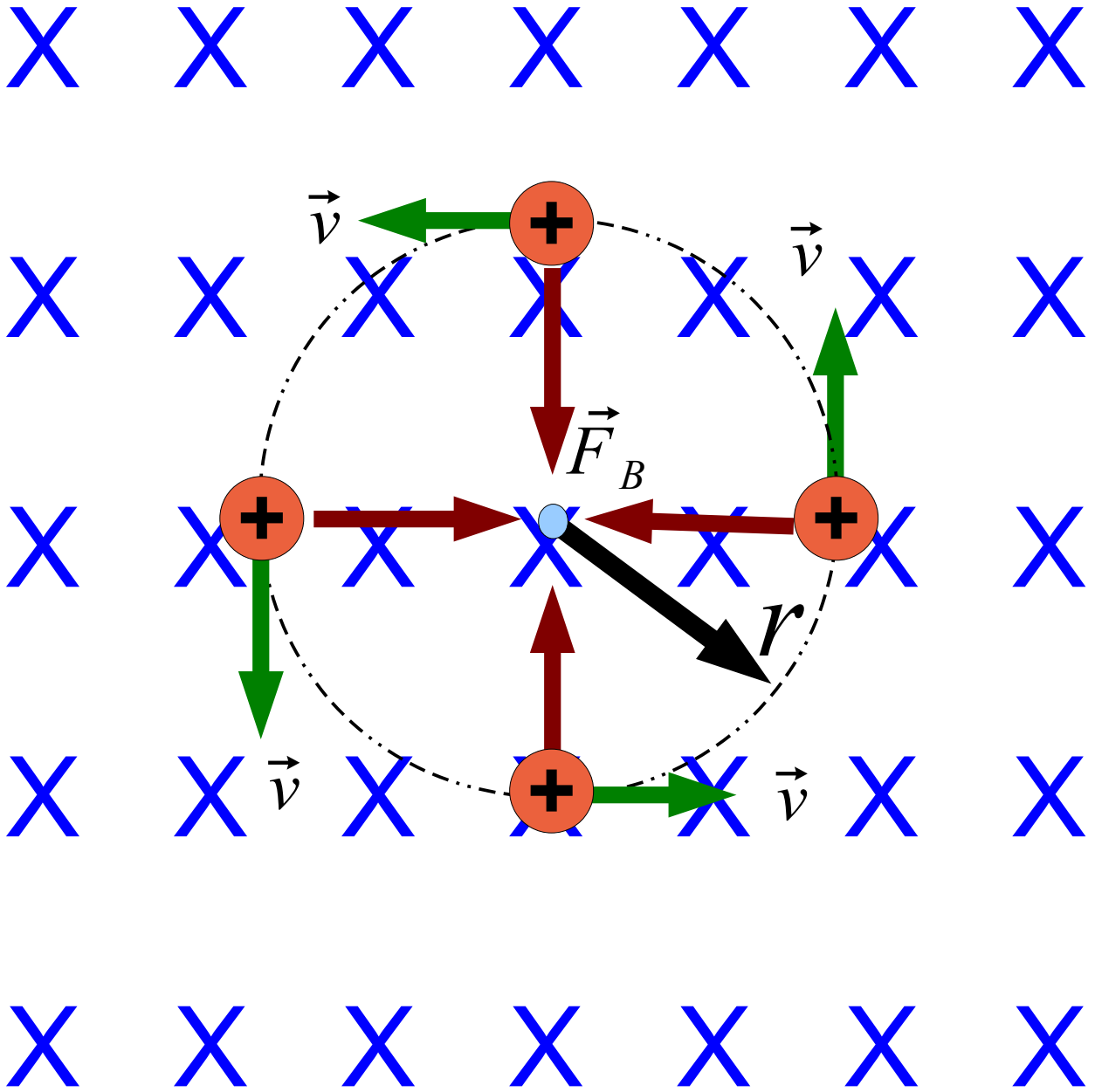
$\vec{B}$

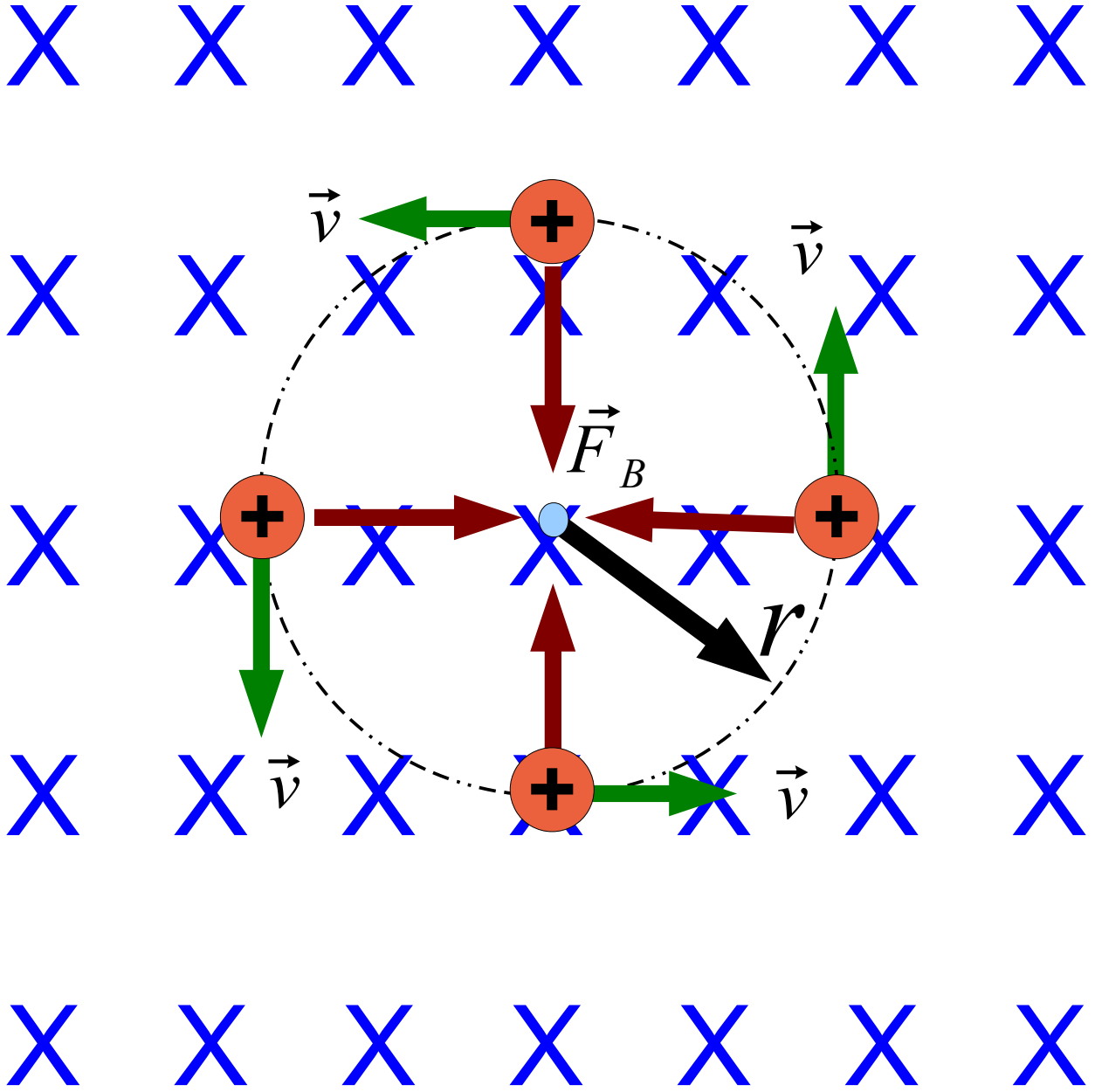
Into Page.



$\vec{B}$

Into Page.





$\vec{B}$

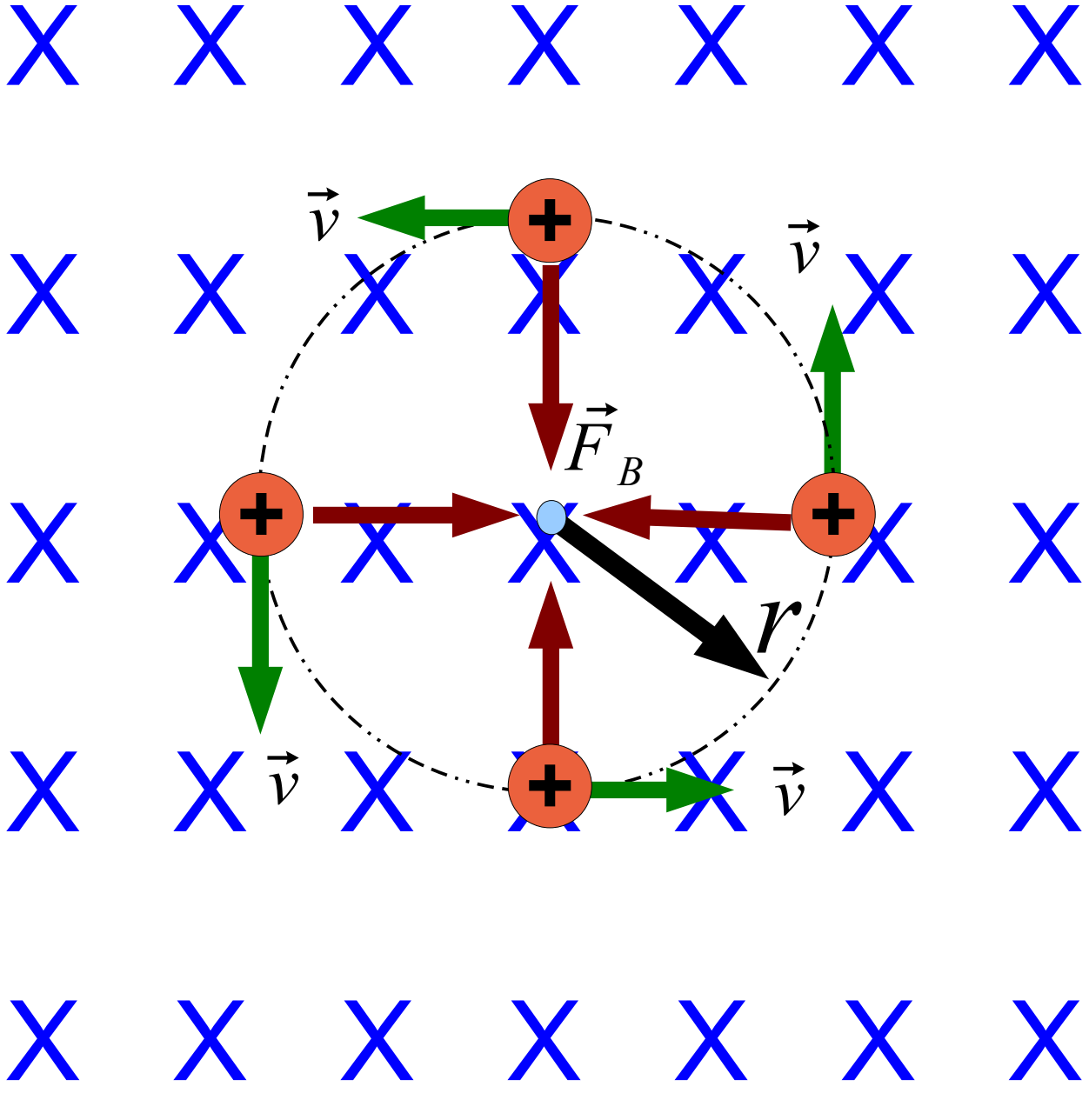
Into Page.

$$F_C = F_B$$

$$m a_C = qvB \sin\theta$$

$$ma_C = qvB \sin 90^o$$

$$m\frac{v^2}{r} = qvB$$



$\vec{B}$

Into Page.

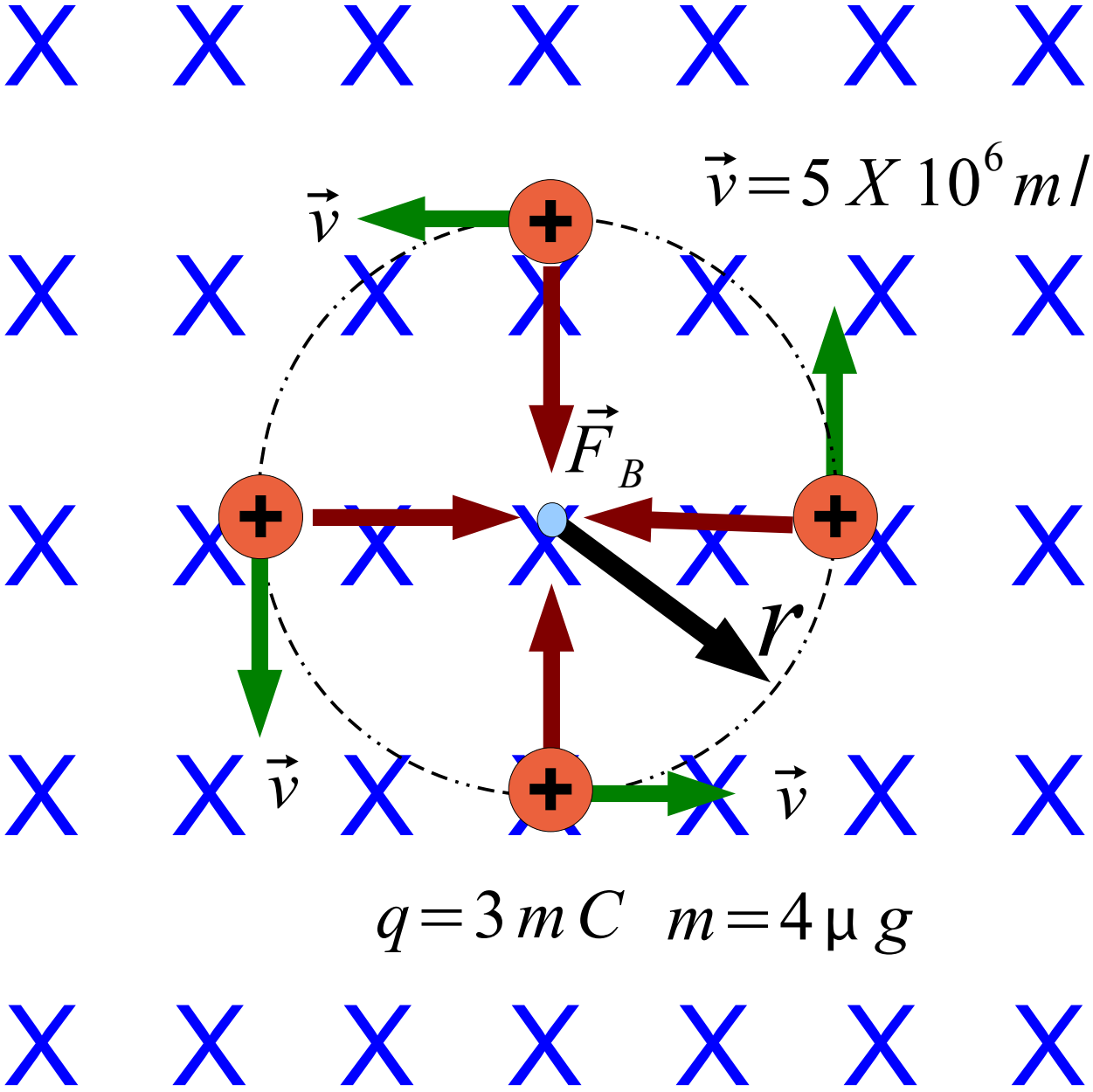
$$F_C = F_B$$

$$m\,a_C = qvB\sin\theta$$

$$ma_C = qvB\sin 90^o$$

$$m\frac{v^2}{r} = qvB$$

$$r = \frac{mv}{qB}$$



$\vec{v} = 5\ X\ 10^{6}\ m/s$

$\vec{B} = 3\ T$

Into Page.

$q = 3\ m\ C \quad m = 4\ \mu\ g$

$$r = \frac{mv}{qB}$$

$$r = \frac{4\ X\ 10^{-9}\ kg\left(5\ X\ 10^{6}\ m/s\right)}{3\ X\ 10^{-3}\ C\left(3\mathrm{T}\right)}$$

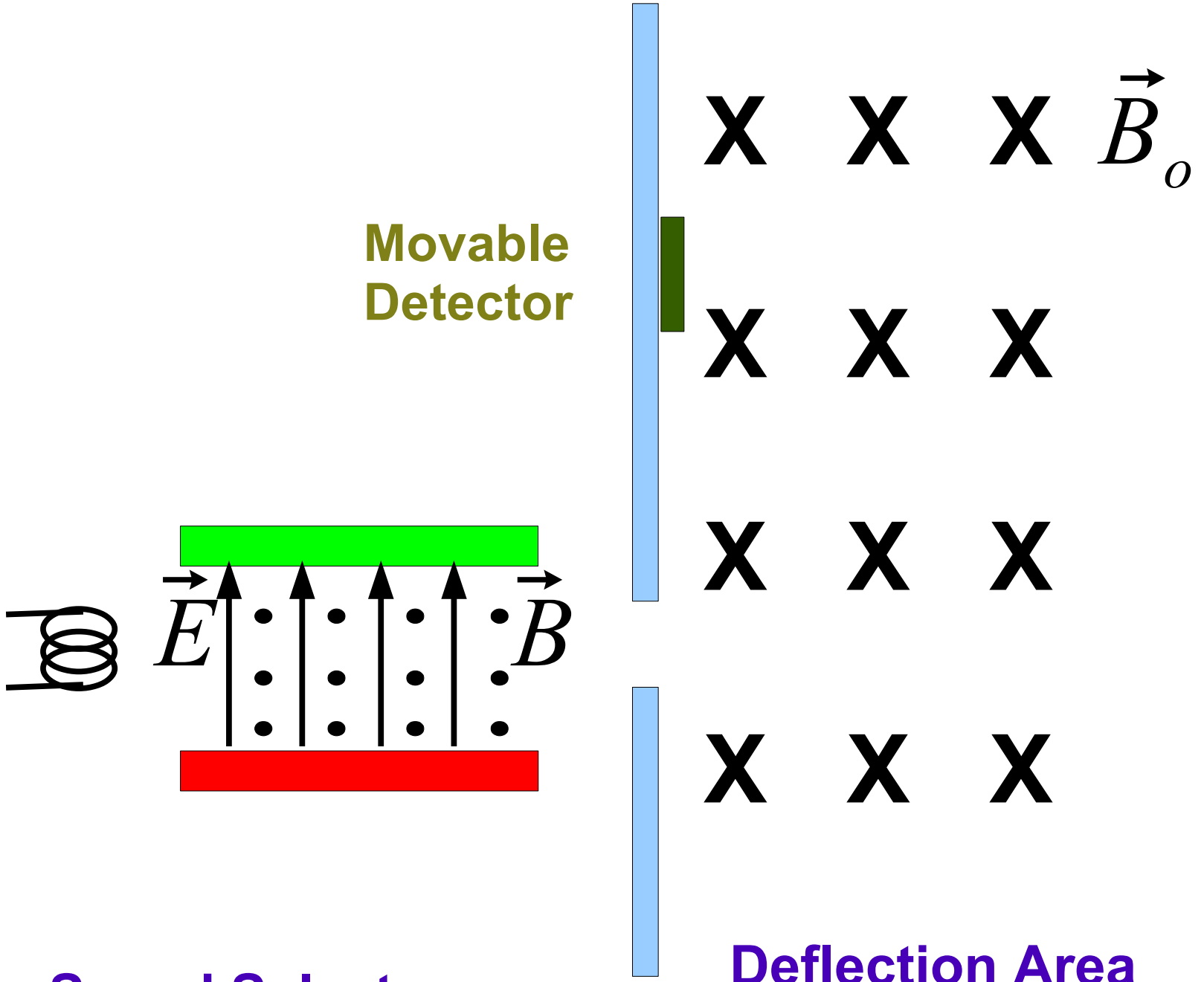
$$r = 2.2\ m$$

Lorentz Force

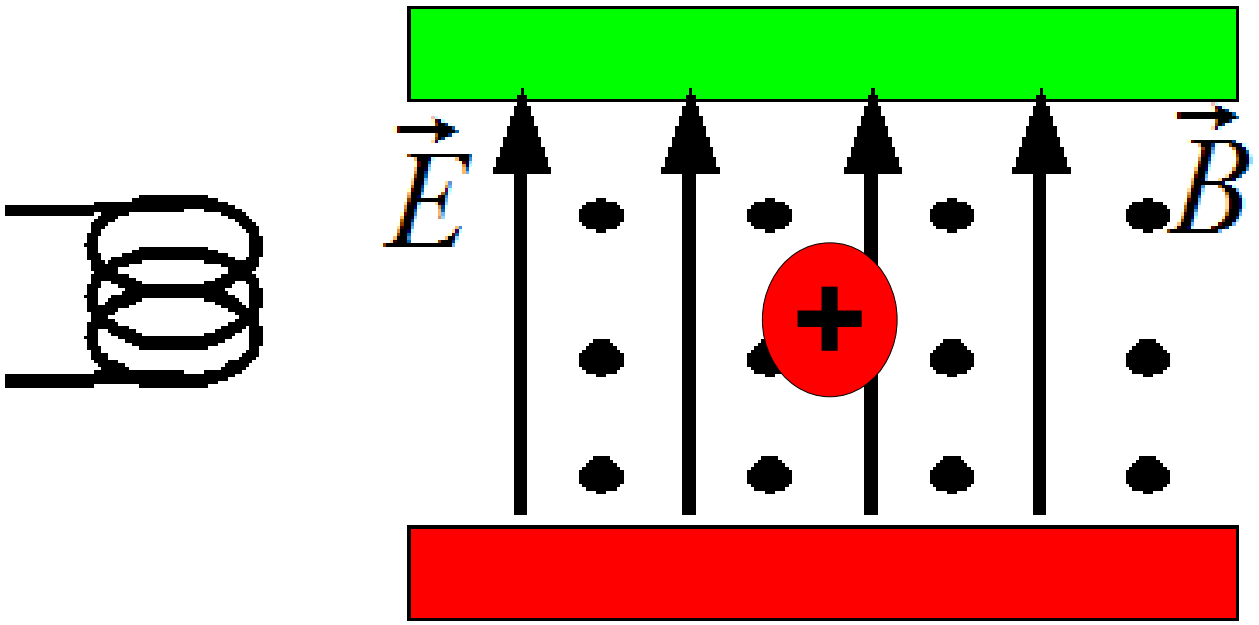
$$\vec{F} = q\vec{E} + q\vec{v}\ X\ \vec{B}$$

Mass Spectrometer

Different Orientation than Author's.

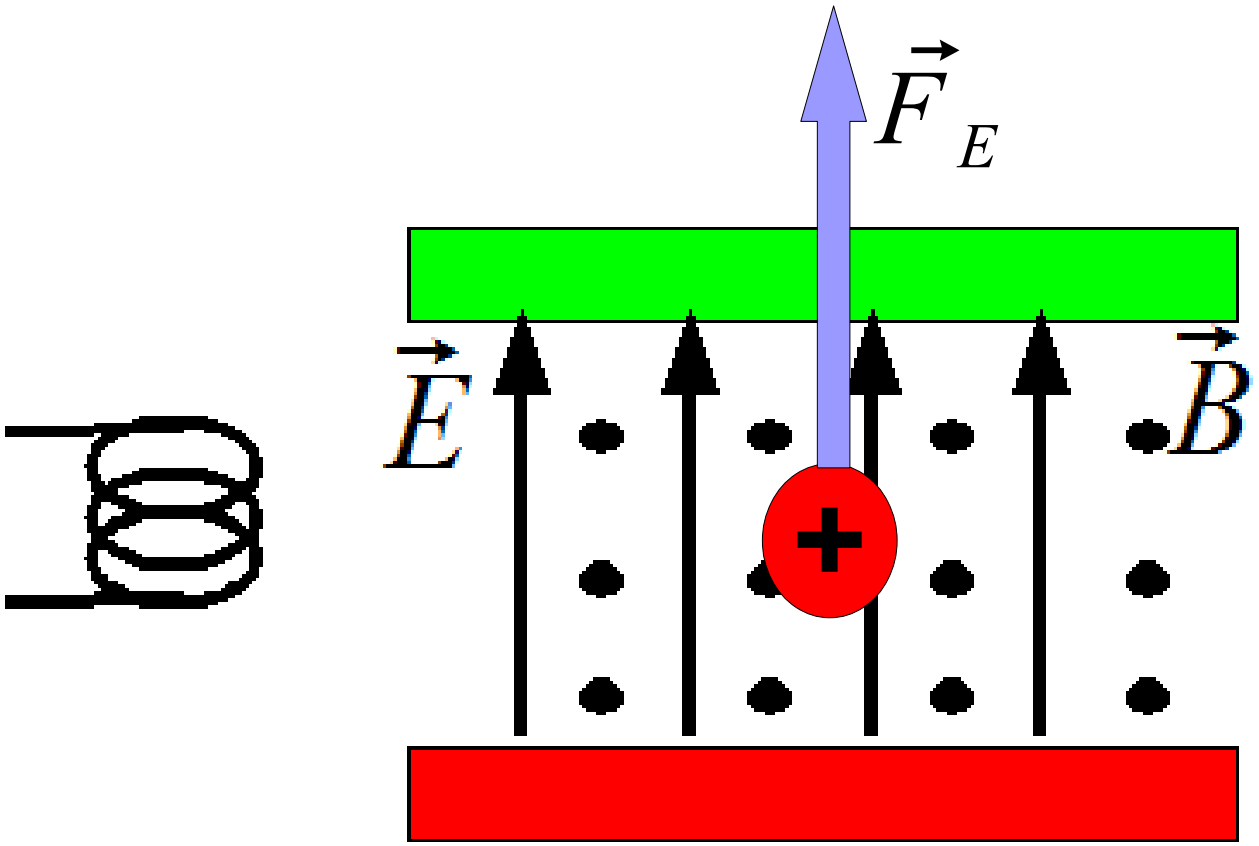


Different Orientation than Author's.



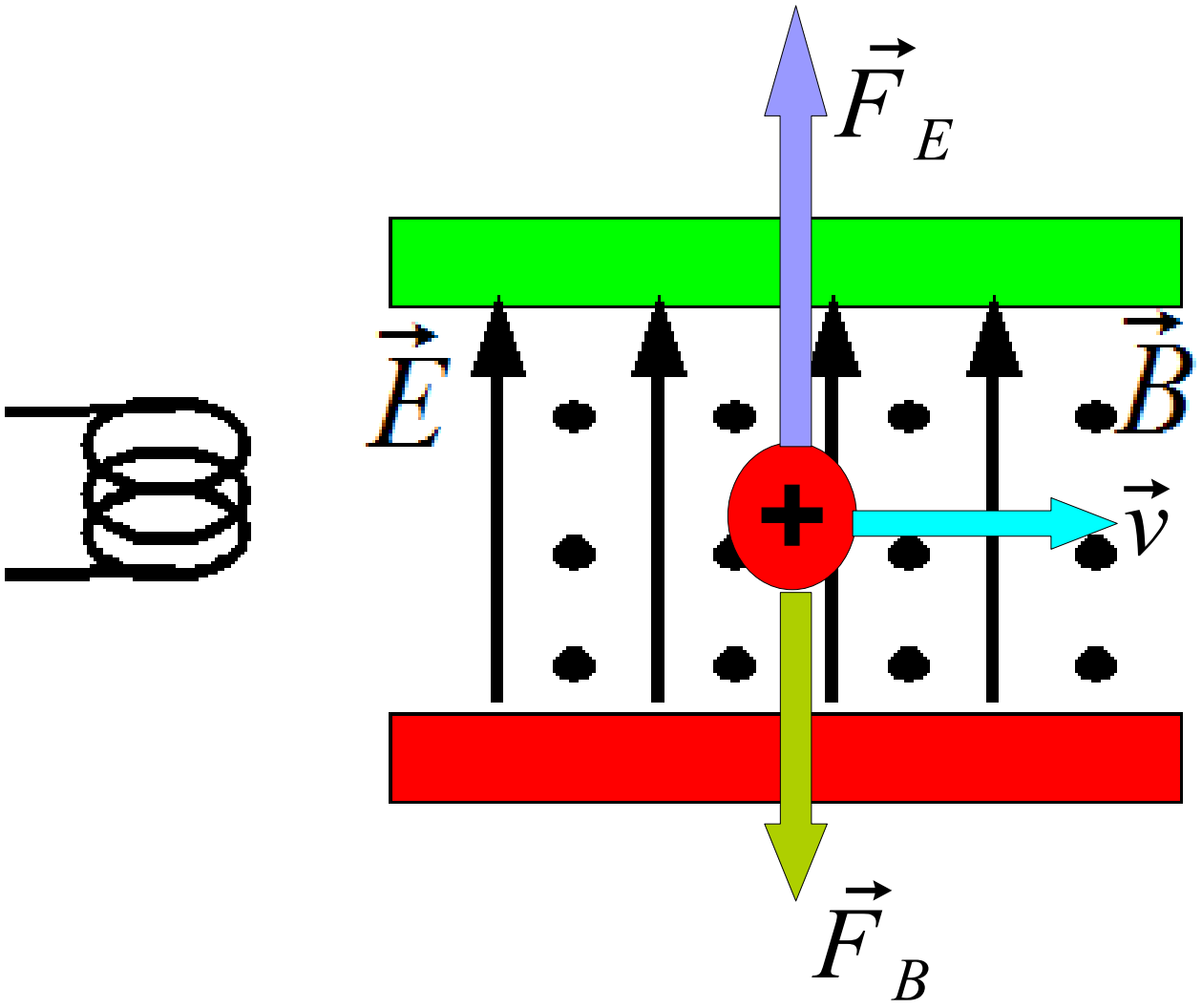
Speed Selector

Different Orientation than Author's.



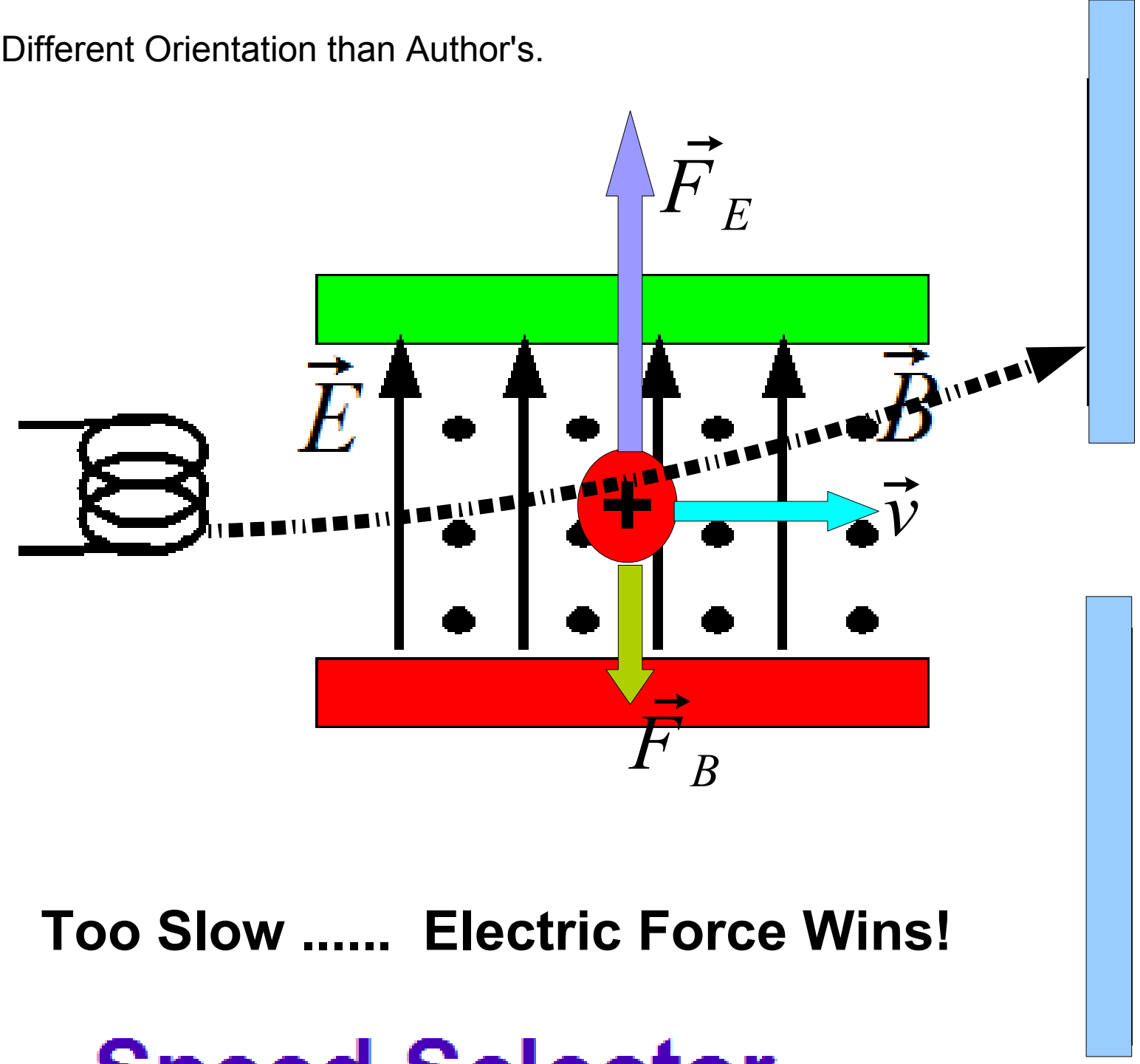
Speed Selector

Different Orientation than Author's.



Speed Selector

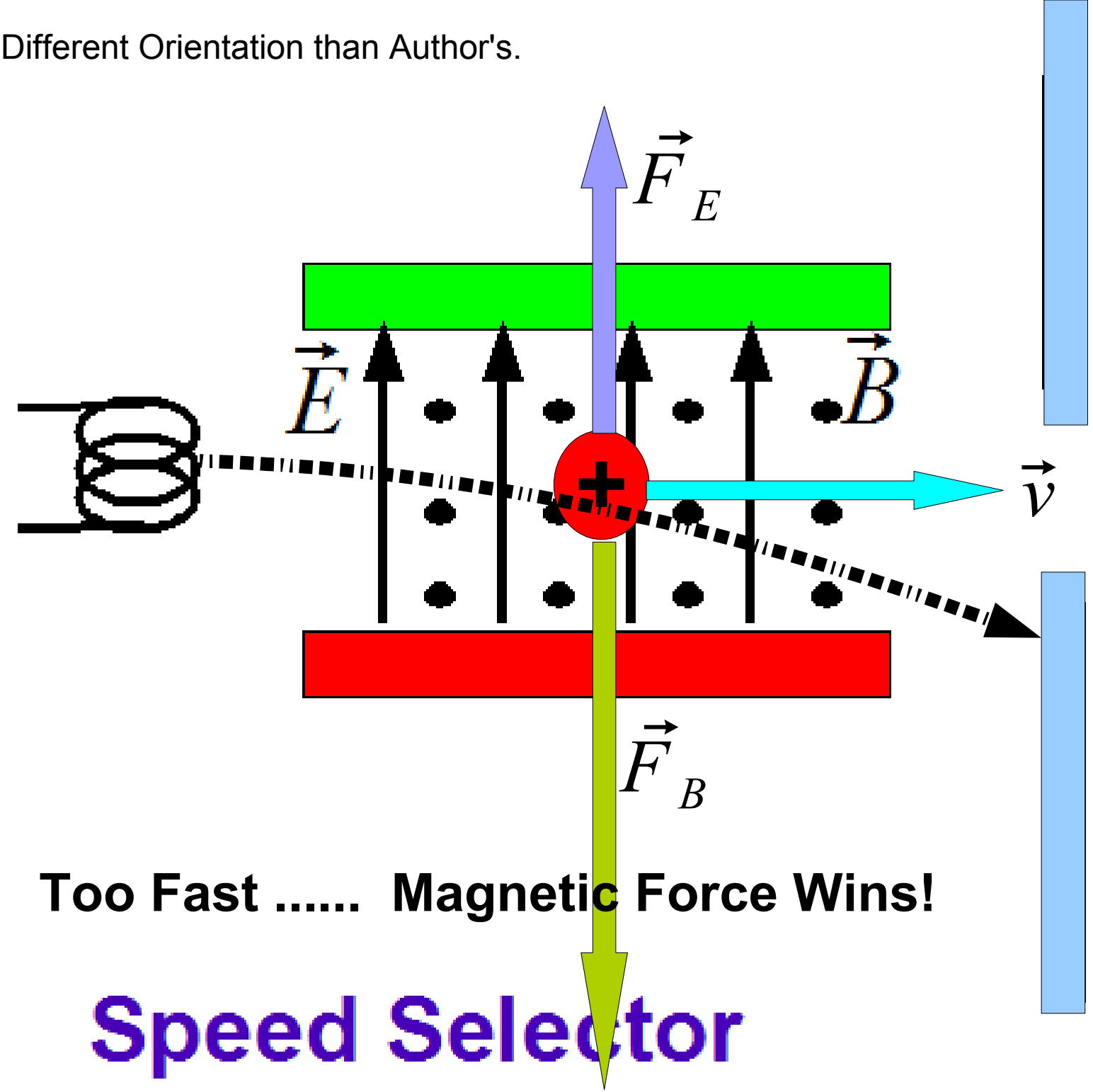
Different Orientation than Author's.



Too Slow ..... Electric Force Wins!

Speed Selector

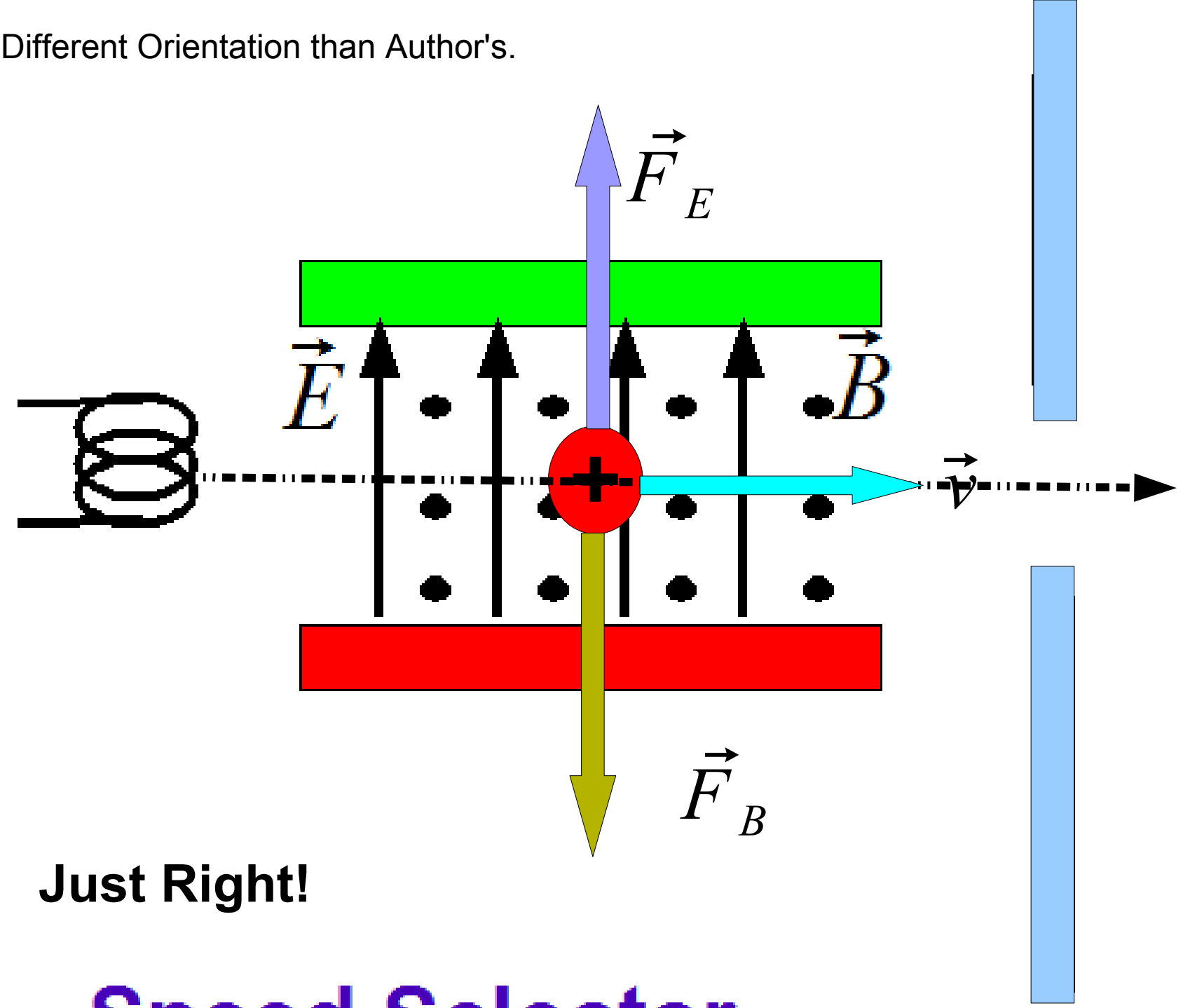
Different Orientation than Author's.



Too Fast ..... Magnetic Force Wins!

Speed Selector

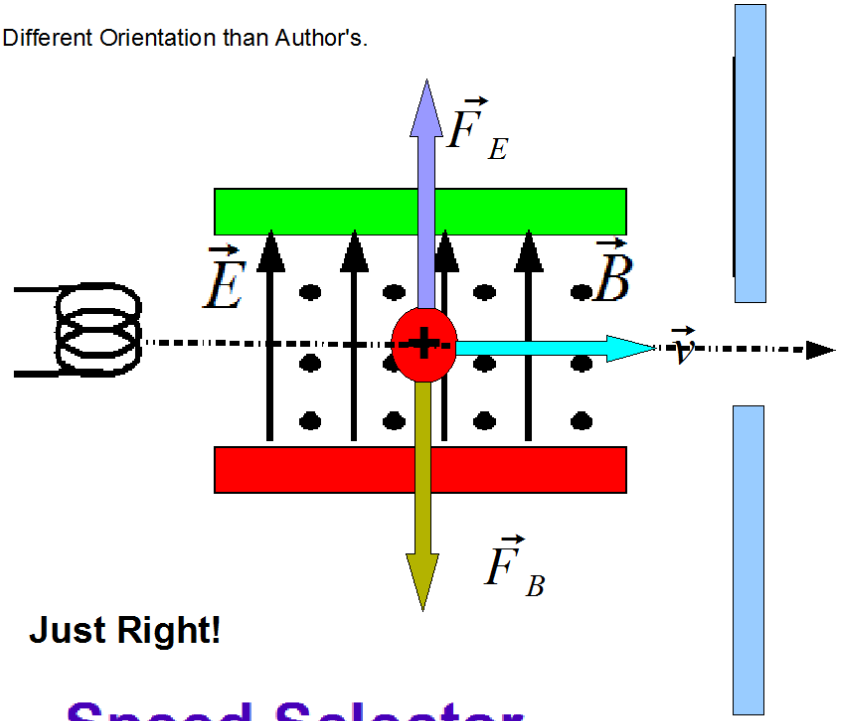
Different Orientation than Author's.



Just Right!

Speed Selector

Different Orientation than Author's.



Just Right!

Speed Selector

$$\vec{F}_E = \vec{F}_B$$

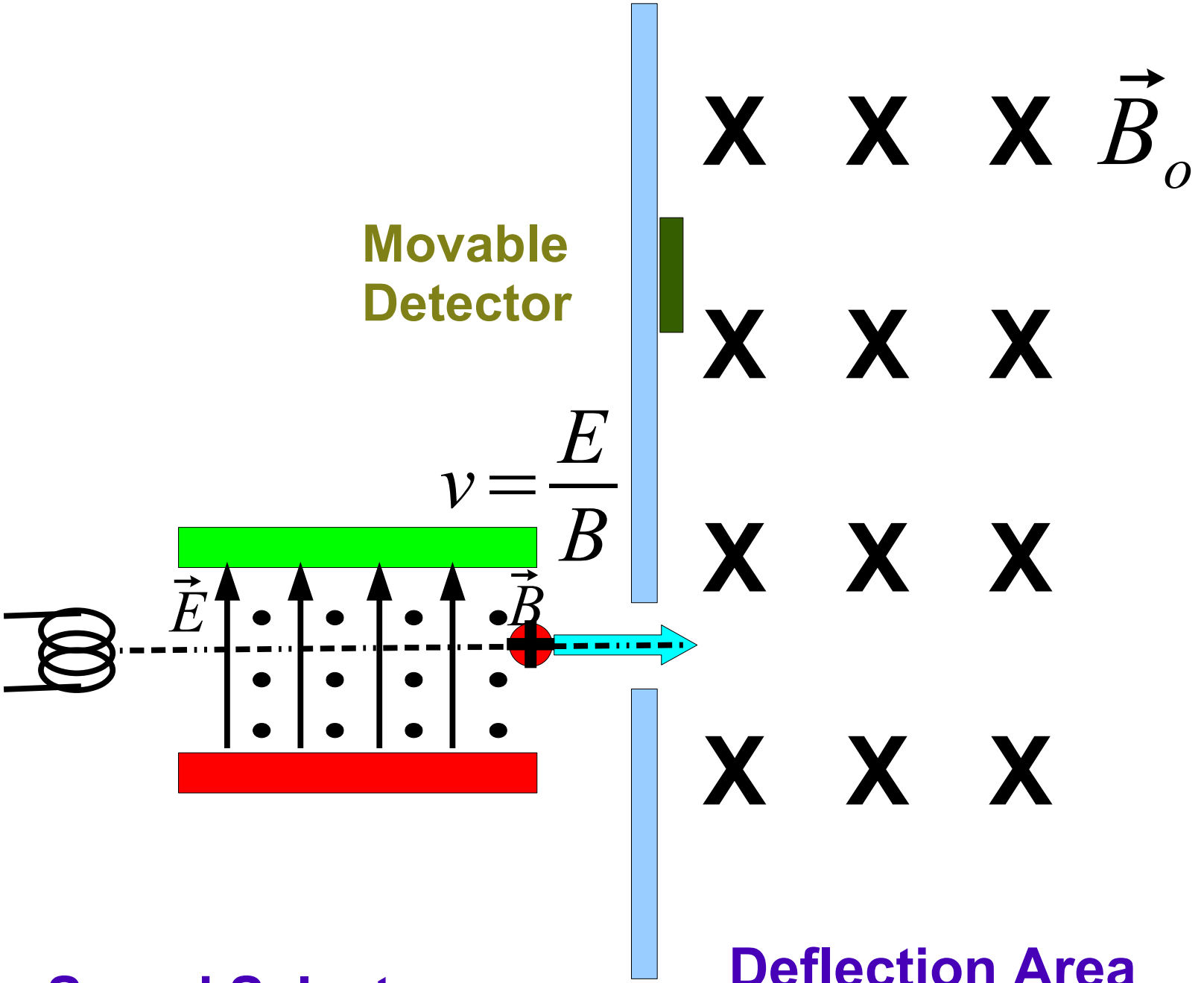
$$q\vec{E} = q\vec{v}\ X\ \vec{B}$$

$$qE = qvb\sin\theta$$

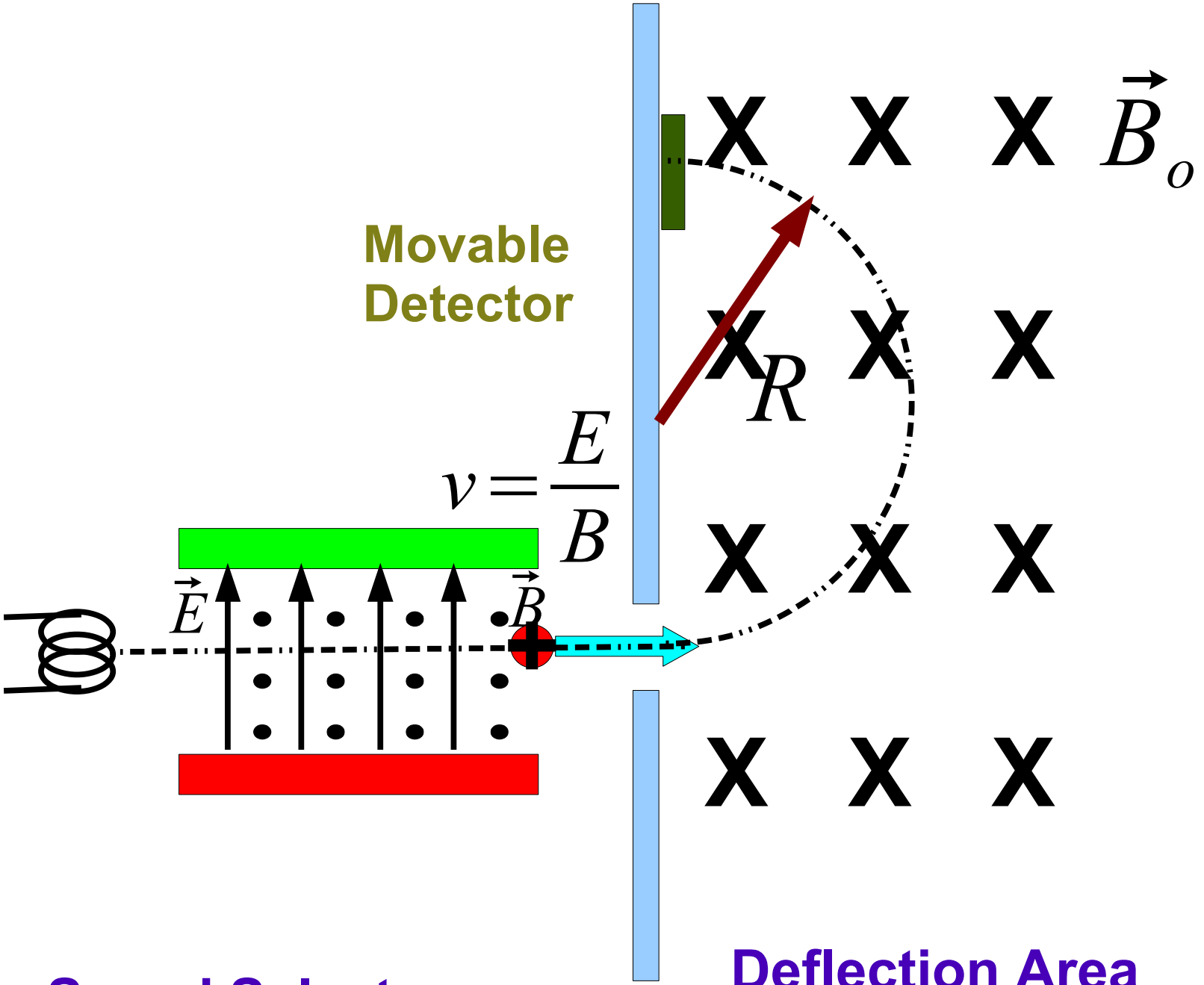
$$qE = qvB$$

$$v = v_{selected} = \frac{E}{B}$$

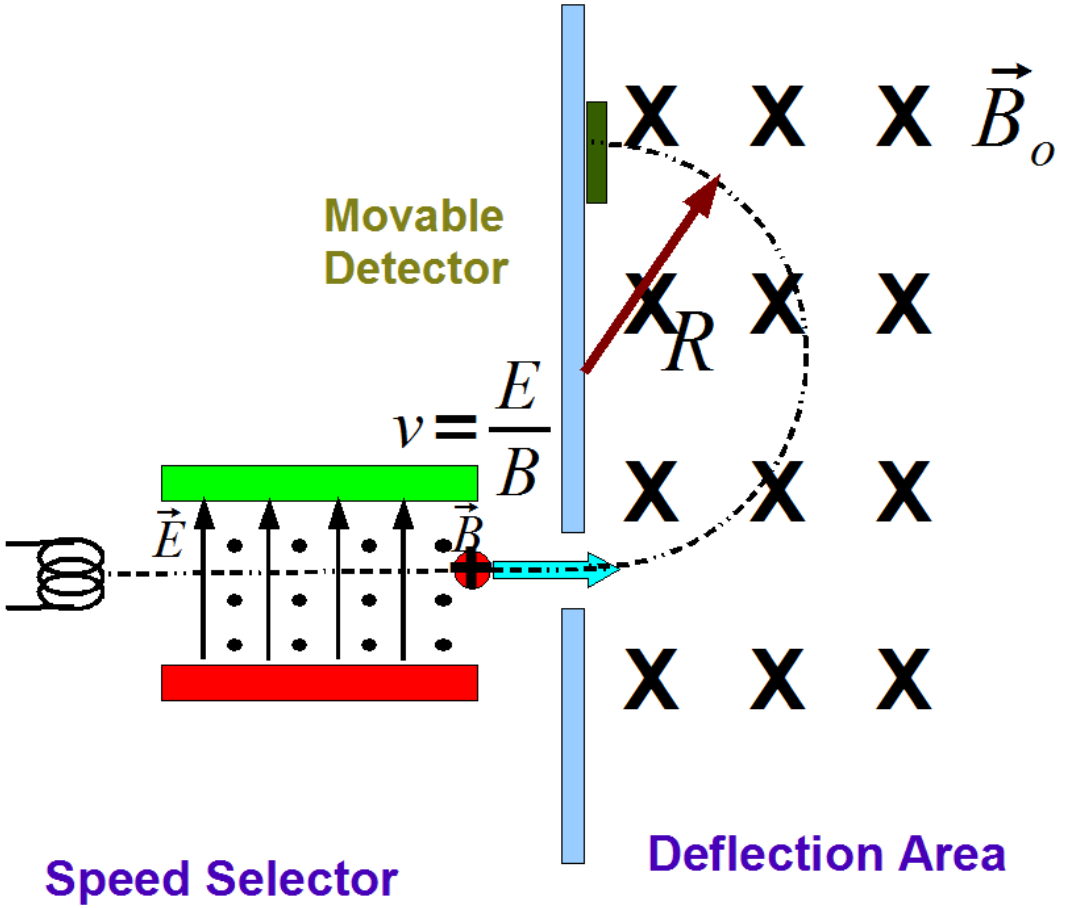
Different Orientation than Author's.



Different Orientation than Author's.



Different Orientation than Author's.



$$F_c = q\vec{v}\ X\ \vec{B}_o$$

$$m a_c = qvB_o$$

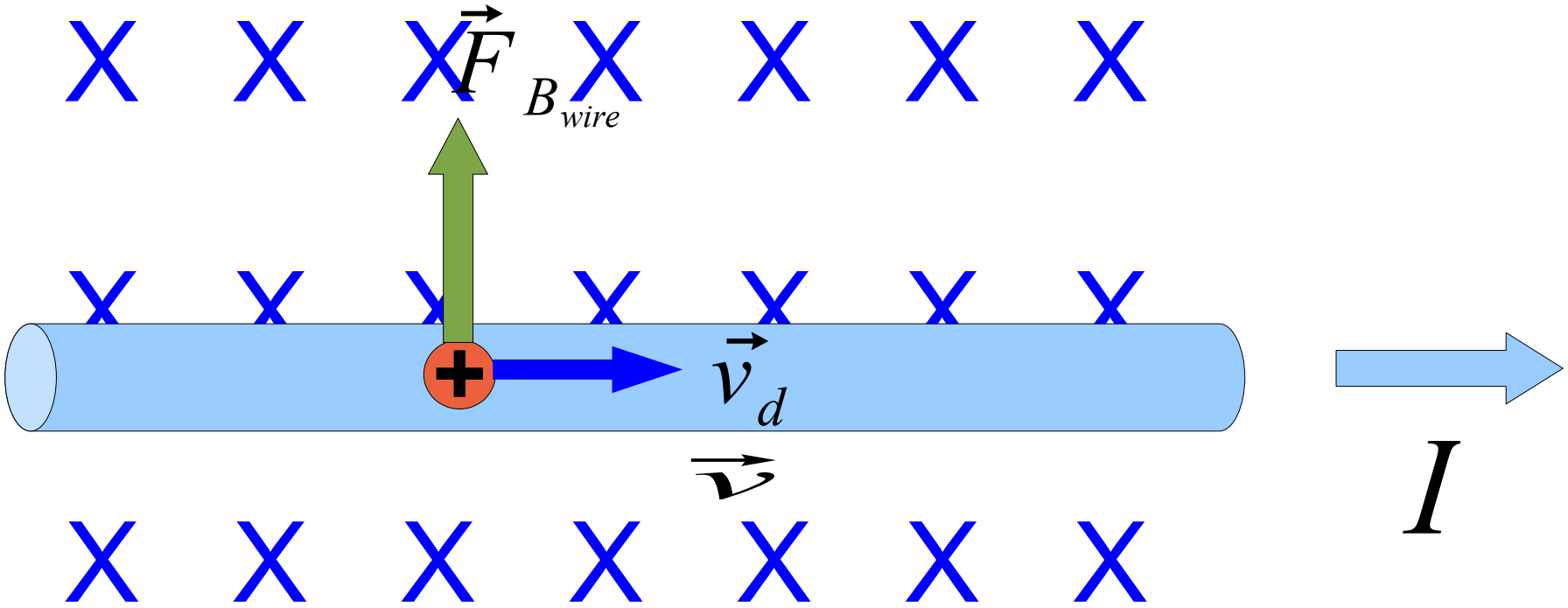
$$m\frac{v^2}{r} = qv\,B_o$$

$$\frac{m}{q} = \frac{r\,B_o}{v}$$

$$\frac{m}{q} = \frac{r\,B\,B_o}{E}$$

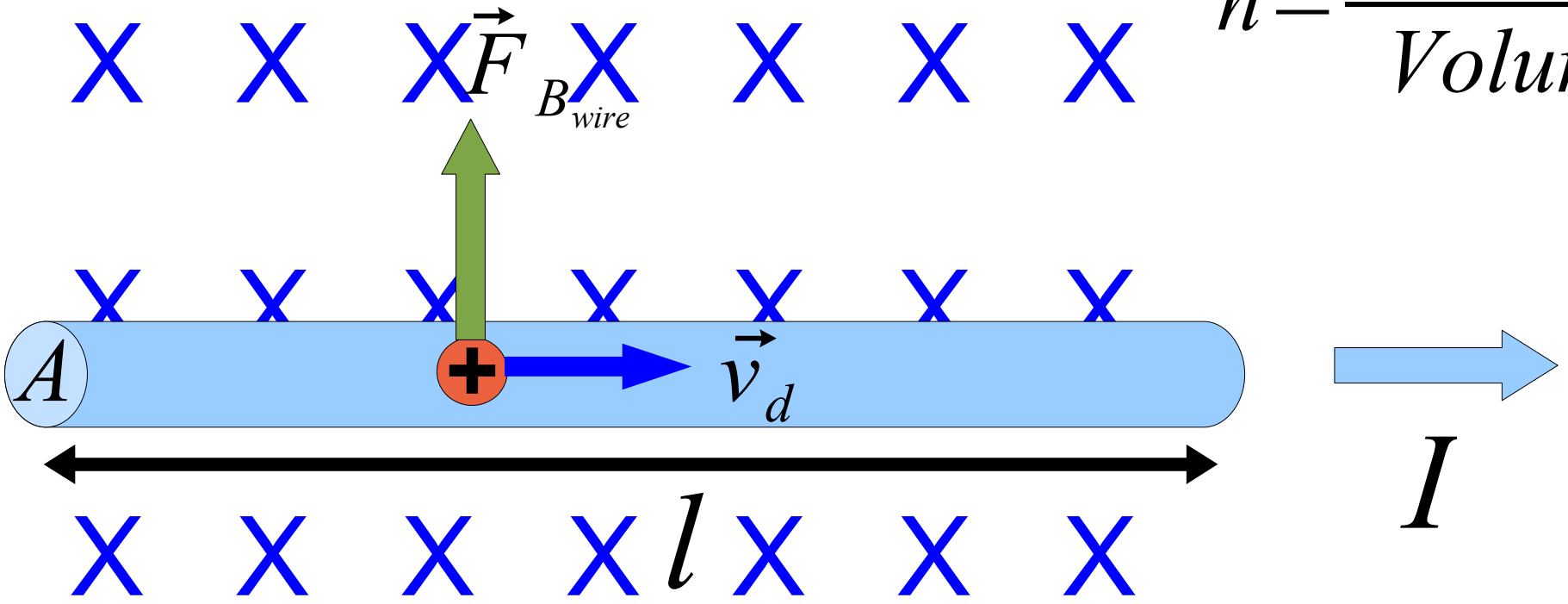
$$\frac{m}{q} = \frac{r\,B_o}{\frac{E}{B}}$$

Force on a Wire in a magnetic Field



Total Force = Force on each Charge Carrier *X* Total number of Charge Carriers

$$n = \frac{\#\ \text{charges}}{Volume}$$



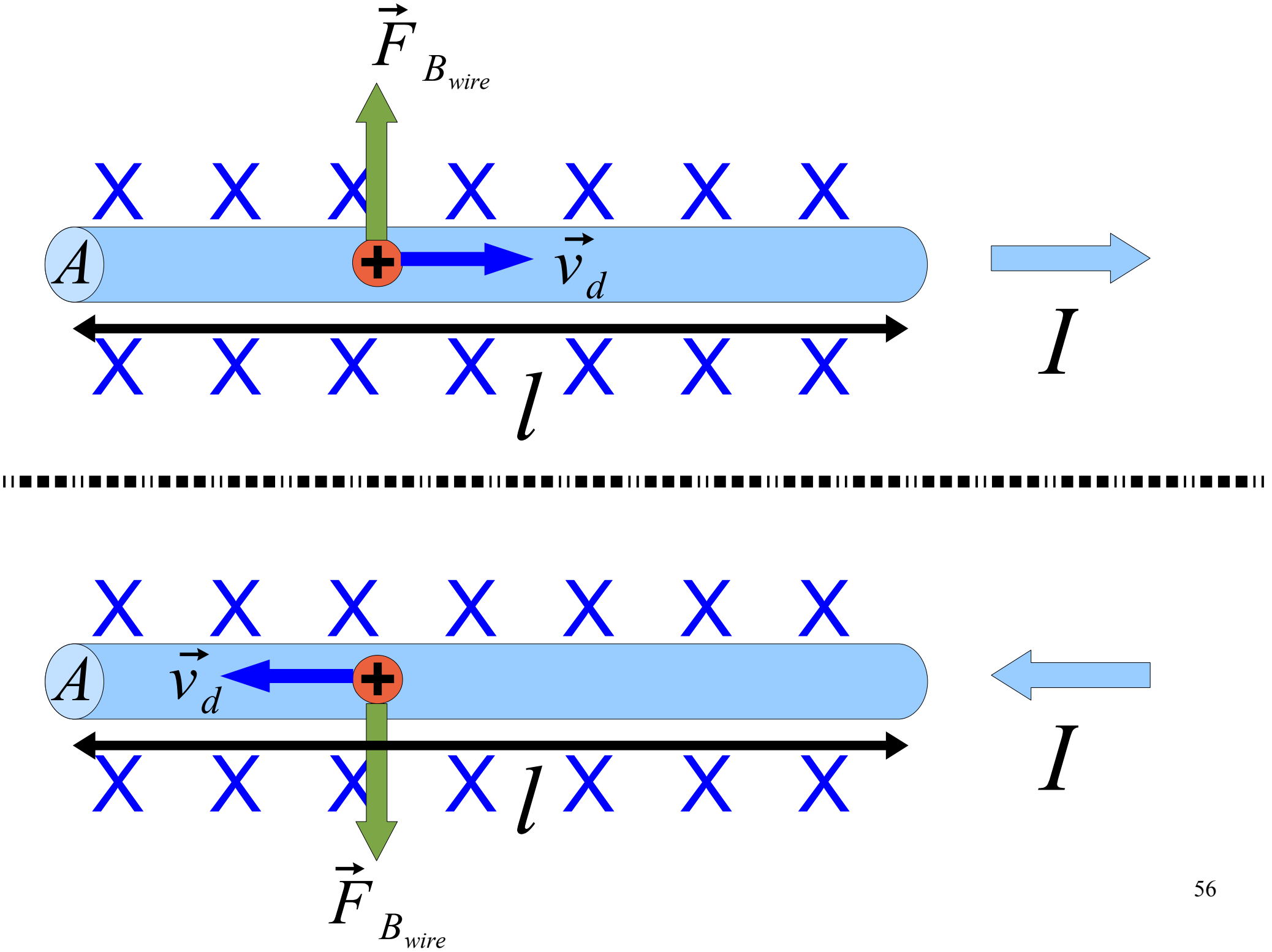
Total Force = Force on each Charge Carrier *X* Total number of Charge Carriers

$$F_{B_{wire}} = (q\, v_d\, B)(n\, V)$$

$$F_{B_{wire}} = (q\, v_d\, B)(n\, Al)$$

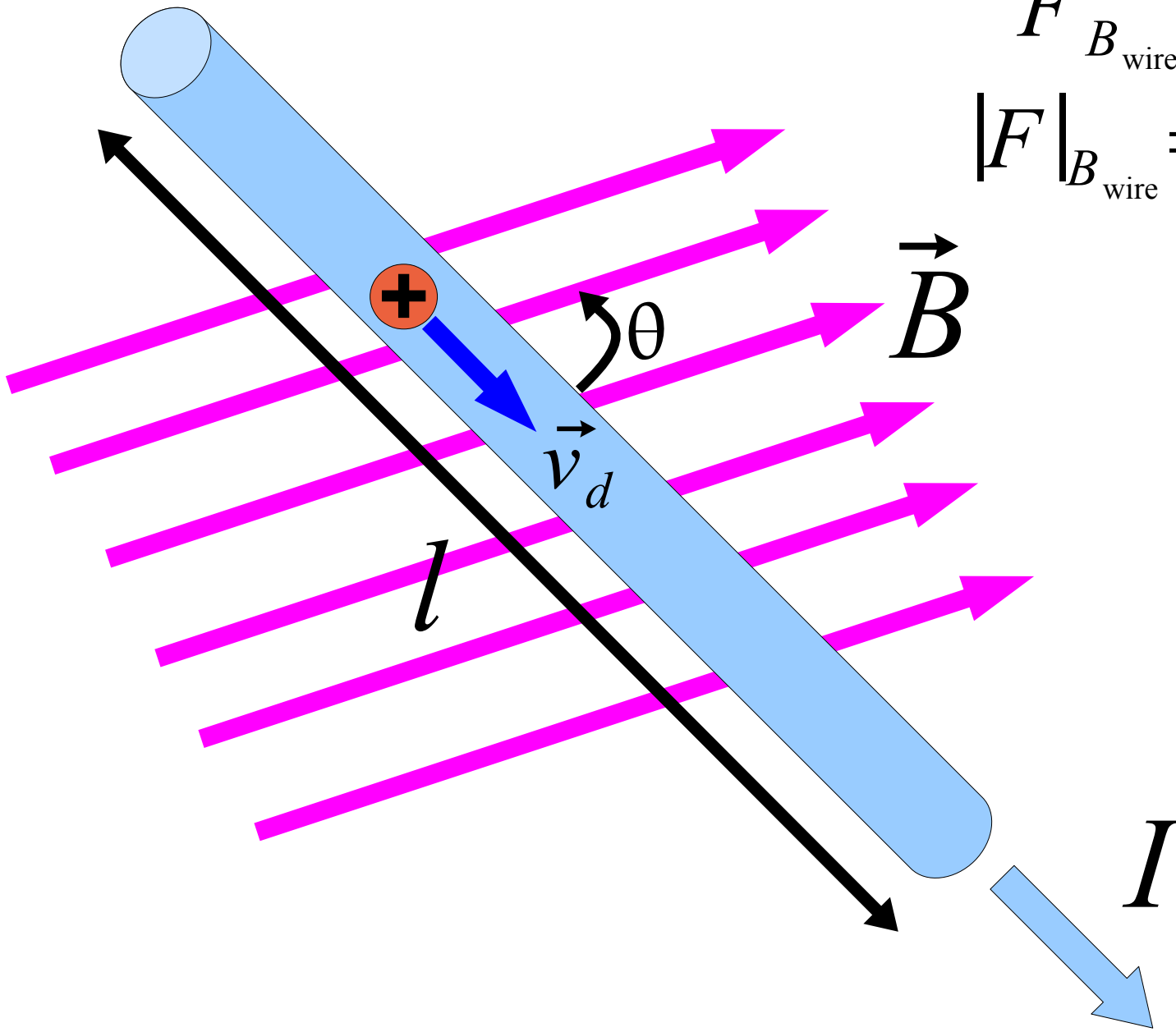
$$I = nqv_d A$$

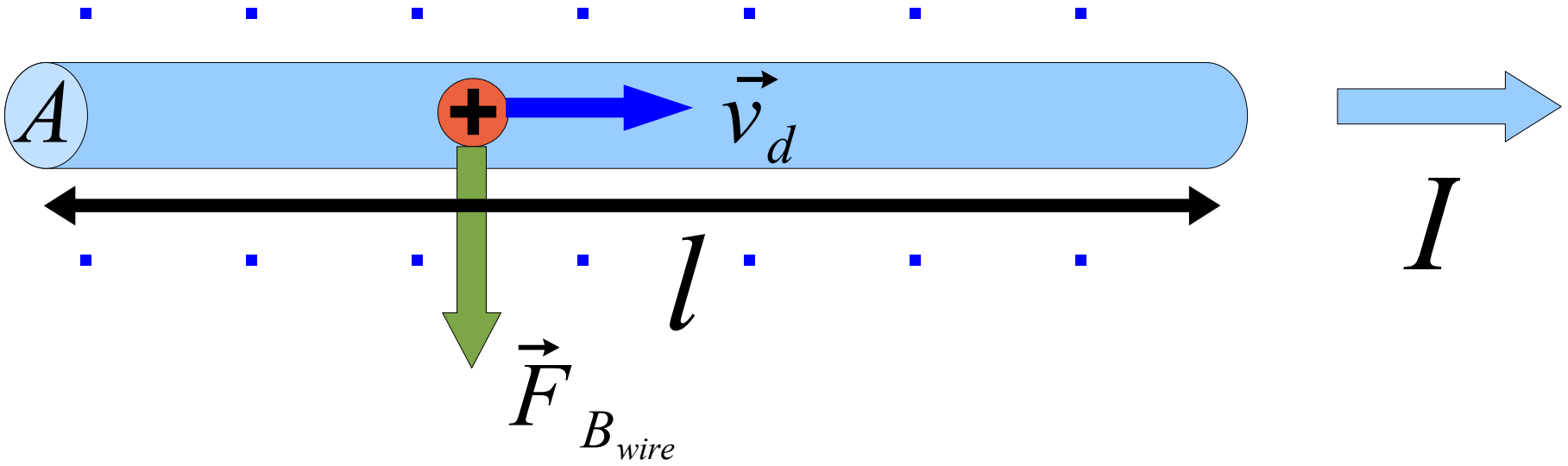
$$F_{B_{wire}} = IBl$$

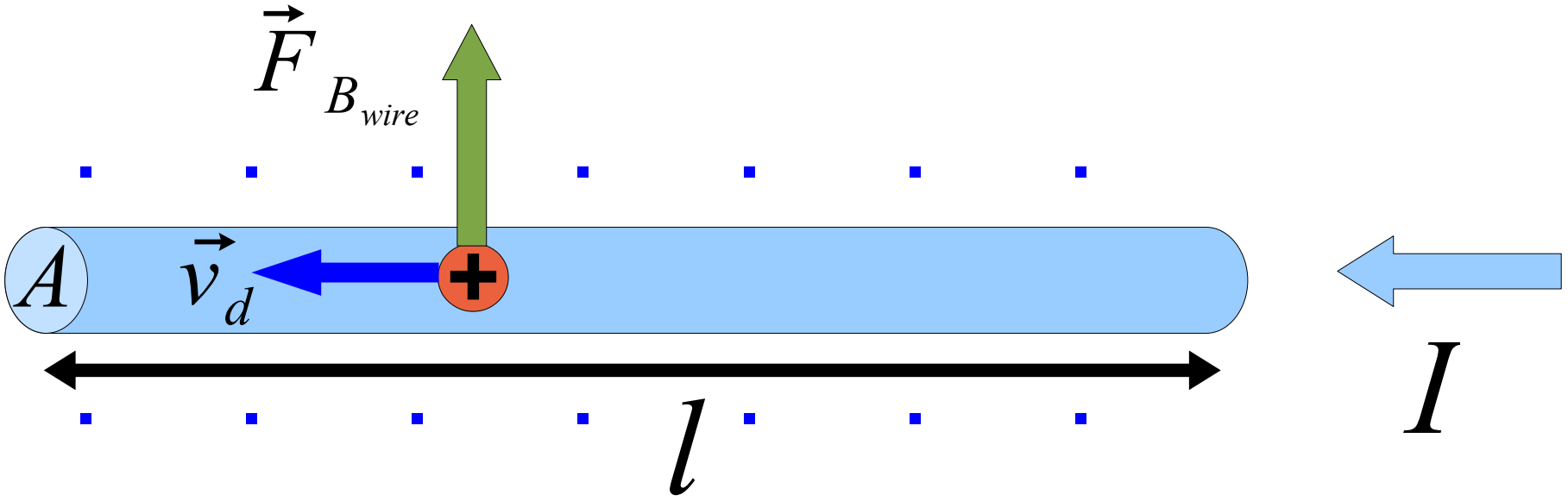

$\vec{F}_{B_{wire}}$
A
$\vec{v}_d$
l
I
A
$\vec{v}_d$
l
I
$\vec{F}_{B_{wire}}$

$$\vec{F}_{B_{\text{wire}}} = I\,\vec{l}\;X\;\vec{B}$$

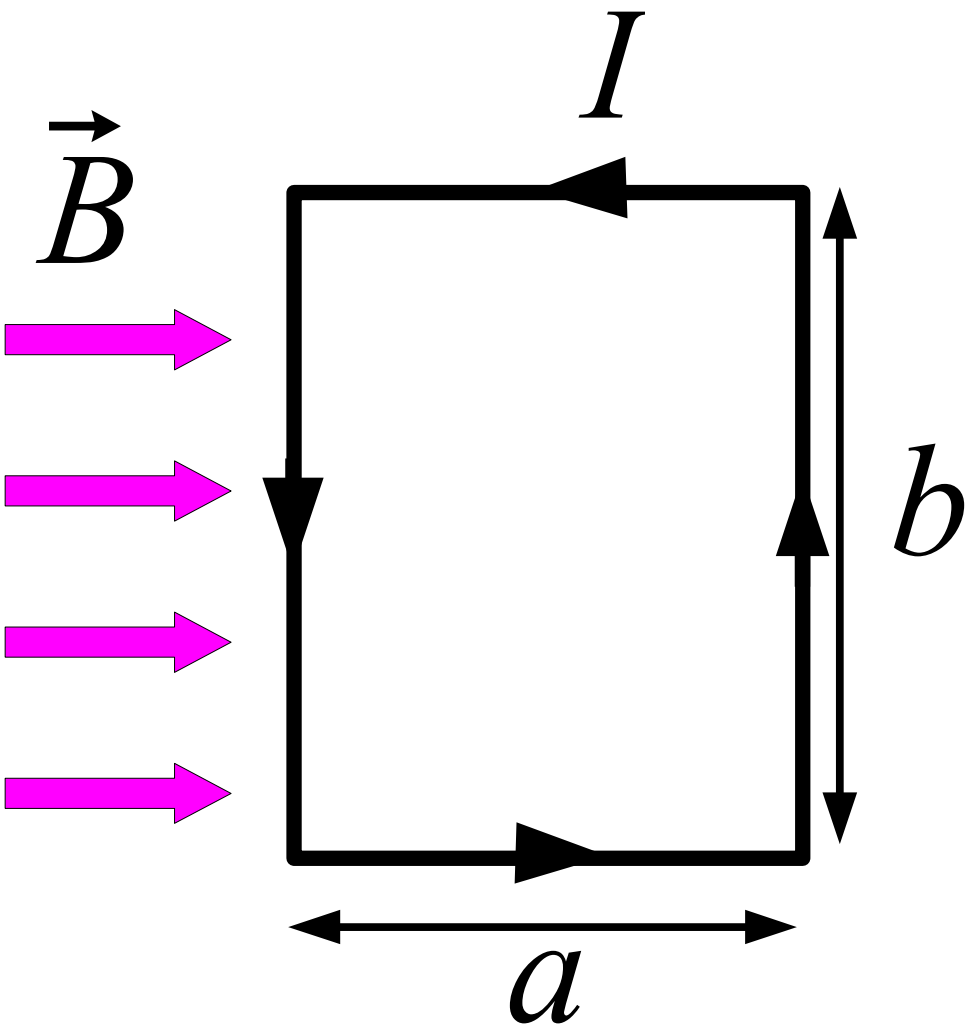
$$|F|_{B_{\text{wire}}} = I\,l\,B\sin\theta$$



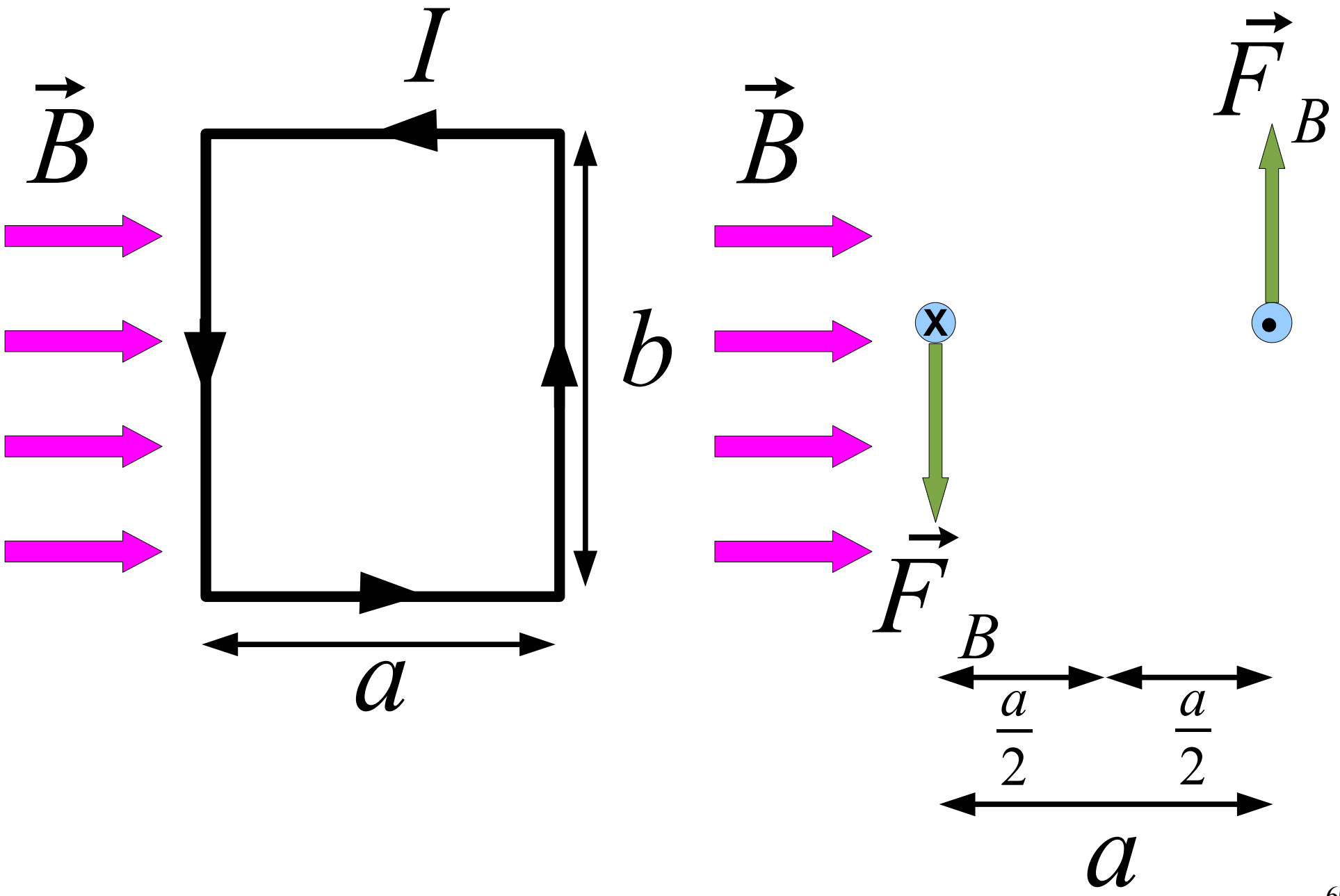

A
$\vec{v}_d$
l
I
$\vec{F}_{B_{wire}}$


$\vec{F}_{B_{wire}}$
A
$\vec{v}_d$
l
I

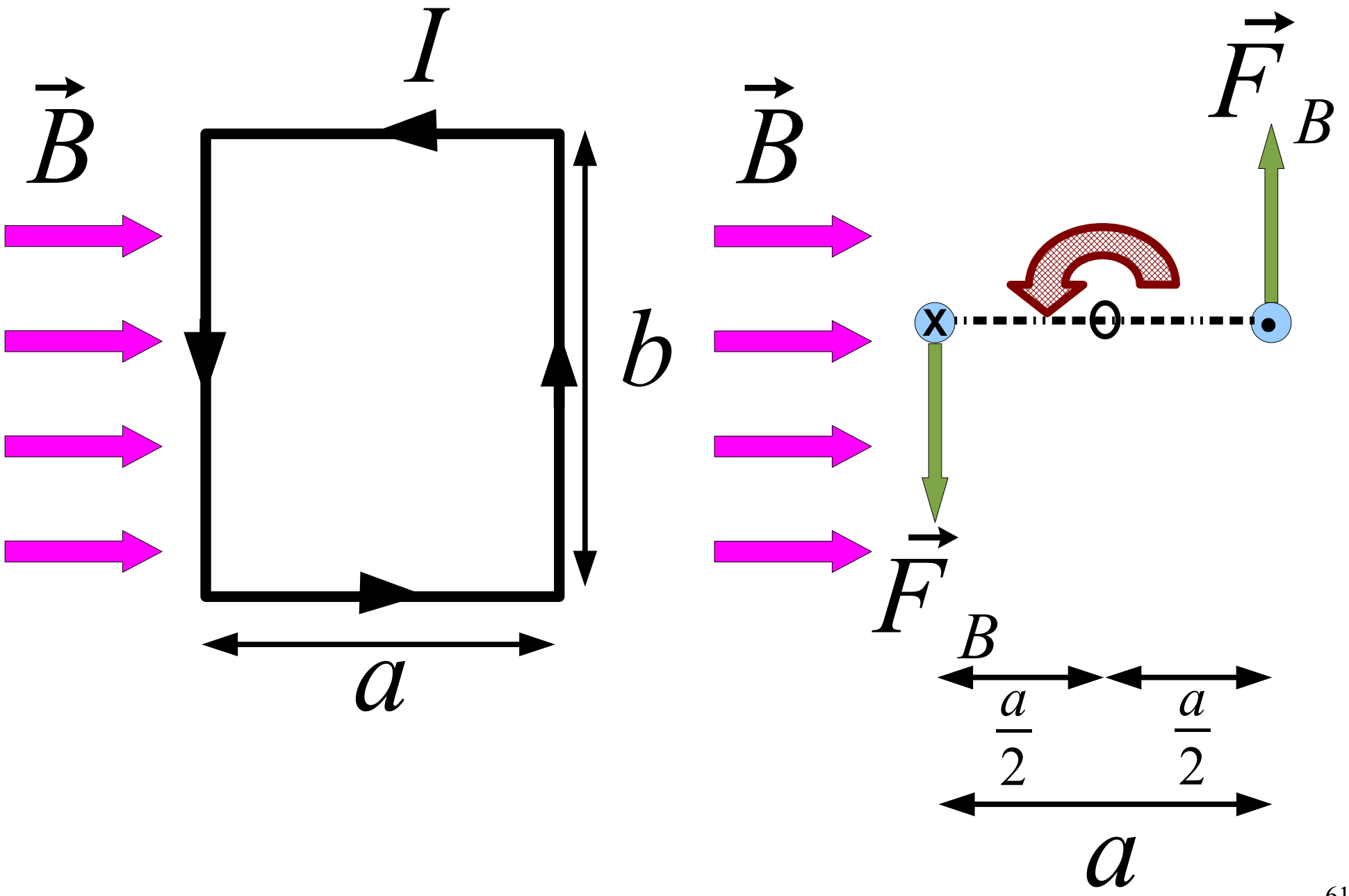
Torque on a Current Carrying Loop



Torque on a Current Carrying Loop

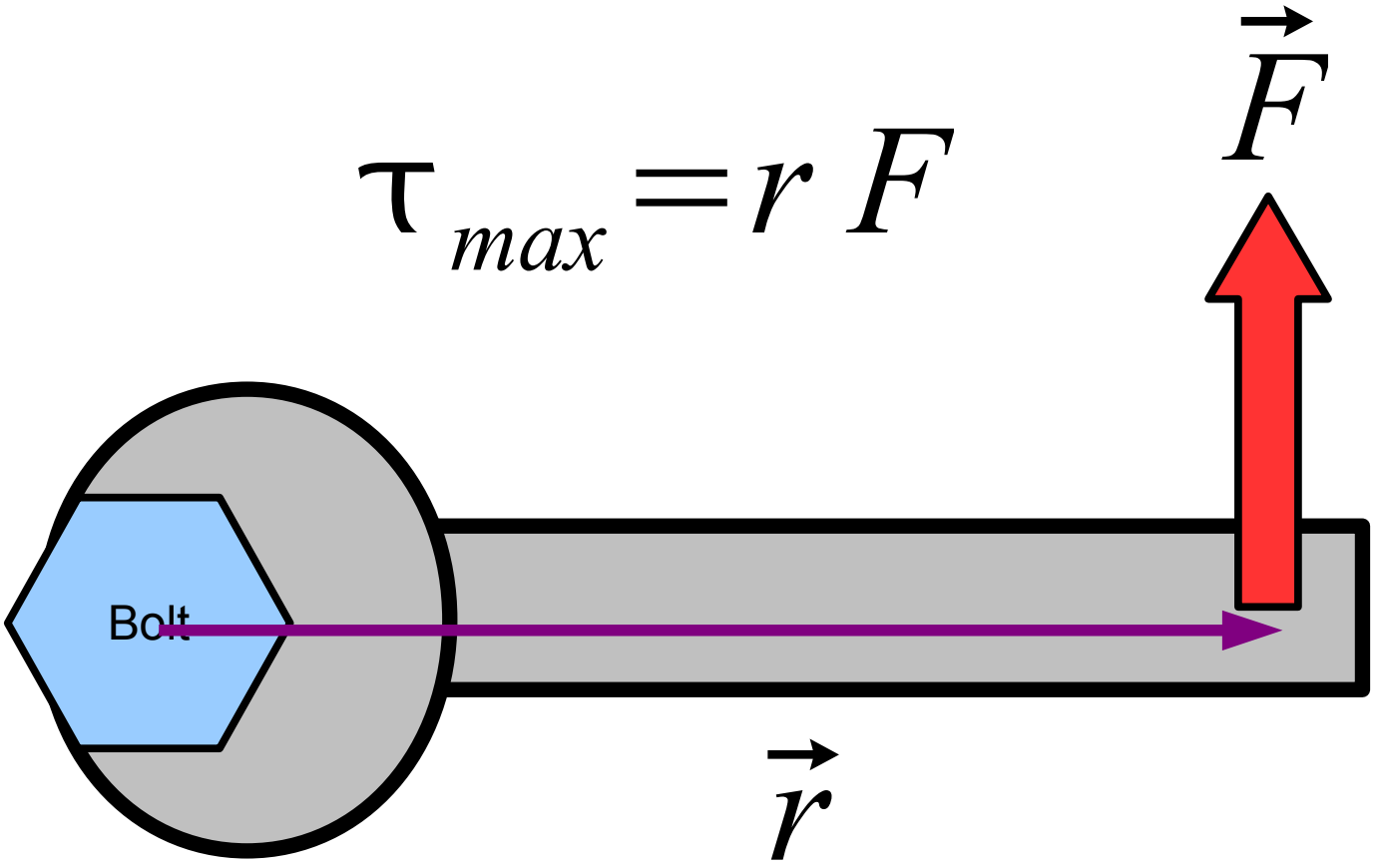


Torque on a Current Carrying Loop



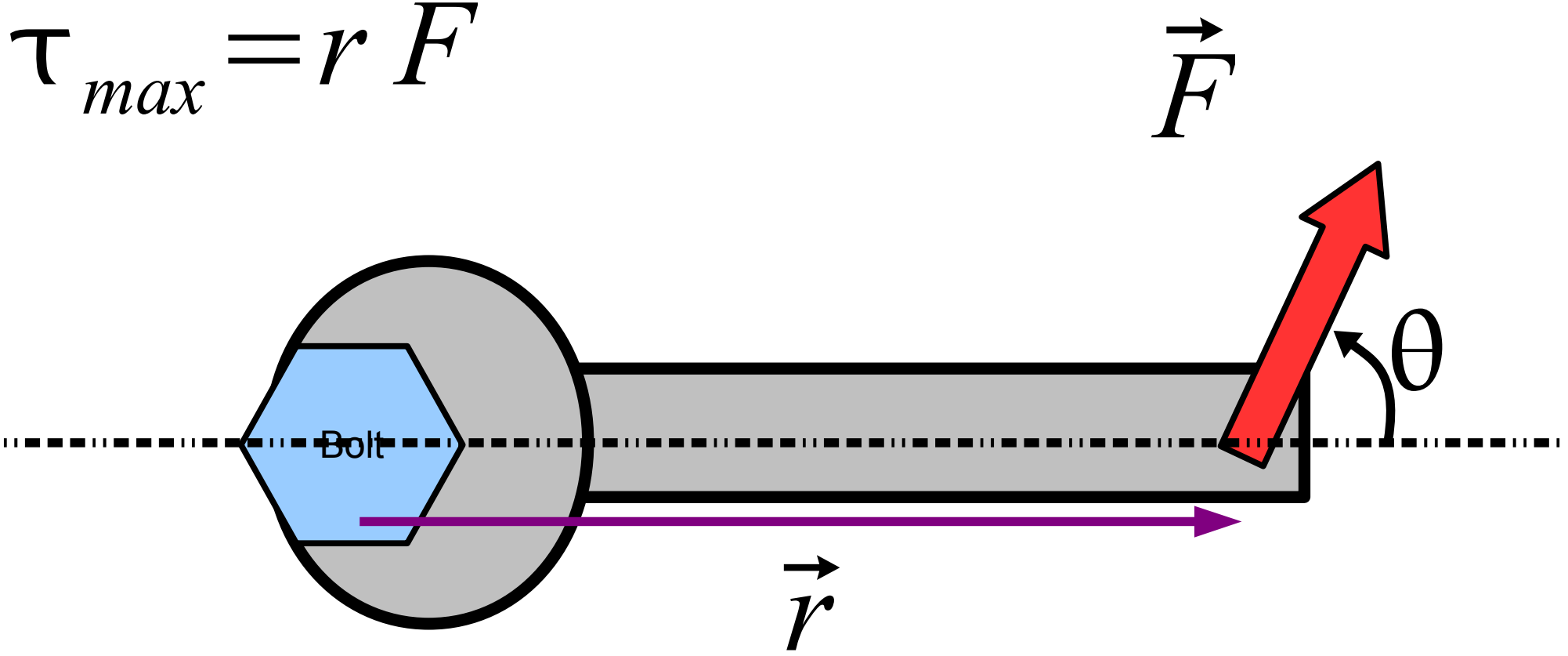
Recall .... Torque

$$\tau_{max} = r\,F$$



Recall .... Torque

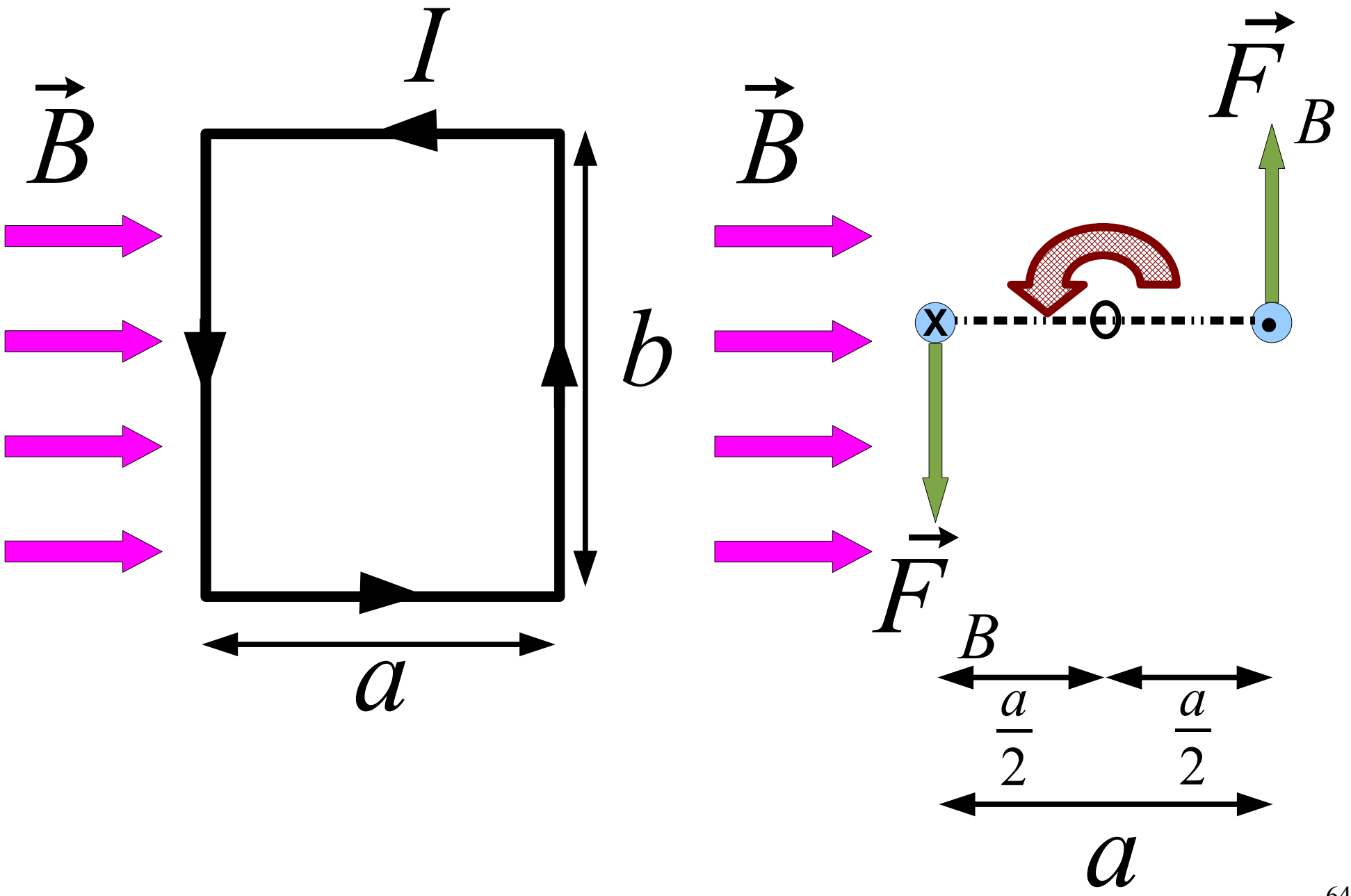
$$\tau_{max} = r\,F$$



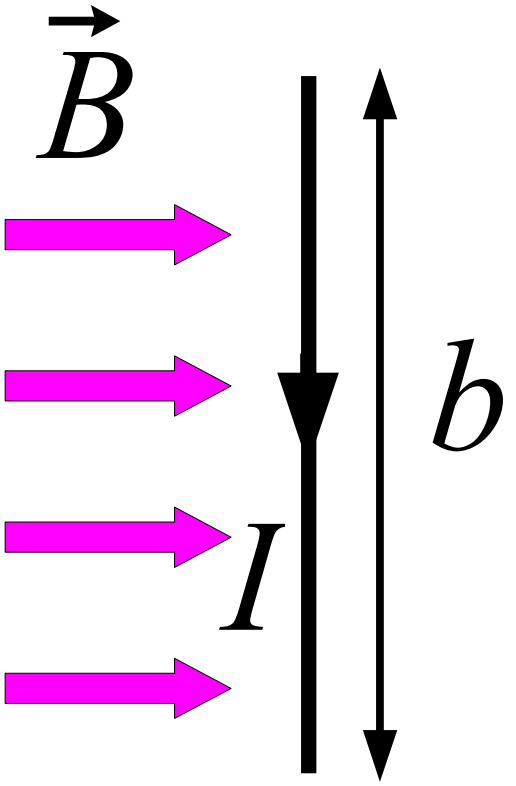
$$|\tau| = |r||F|\sin\theta$$

$$\vec{\tau} = \vec{r}\ X\ \vec{F}$$

Torque on a Current Carrying Loop



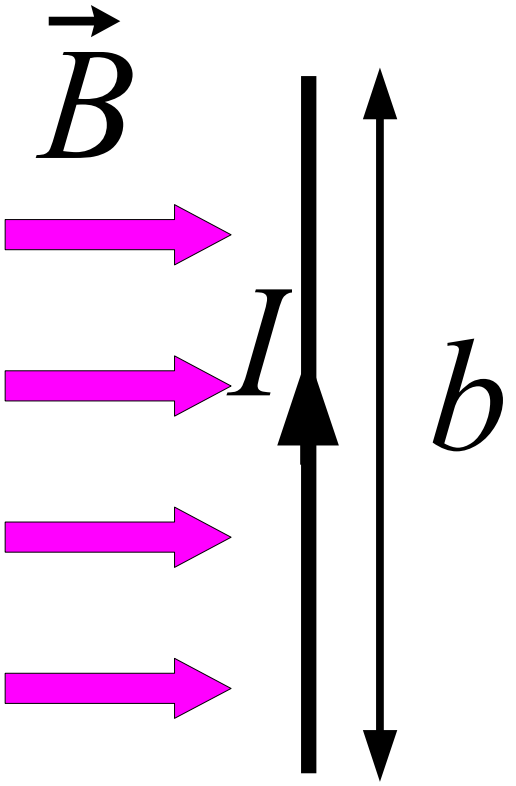
Torque on a Current Carrying Loop



$$F_{B_{wire}} = IlB = IbB$$

Force is out of page, towards you.

Torque on a Current Carrying Loop

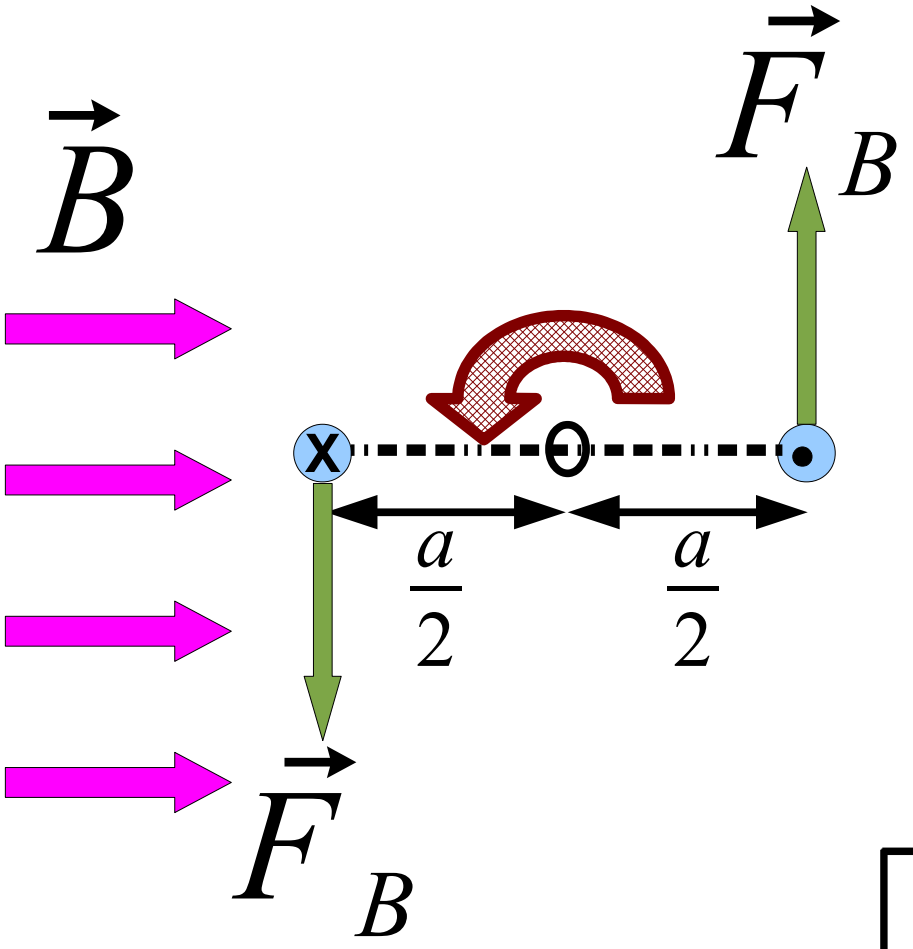


$$F_{B_{wire}} = IlB = IbB$$

Force is into page, away from you.

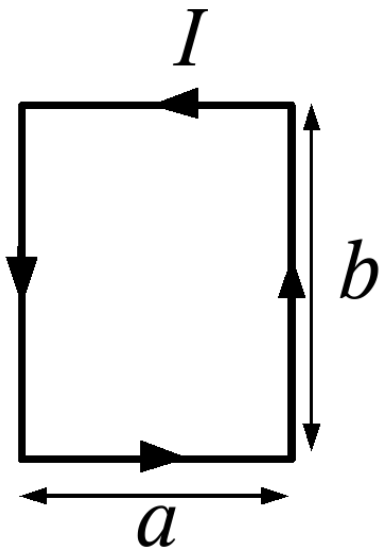
Torque on a Current Carrying Loop

$$\tau_{max} = F_B \frac{a}{2} + F_B \frac{a}{2}$$



$$\tau_{max} = (IbB)\frac{a}{2} + (IbB)\frac{a}{2}$$

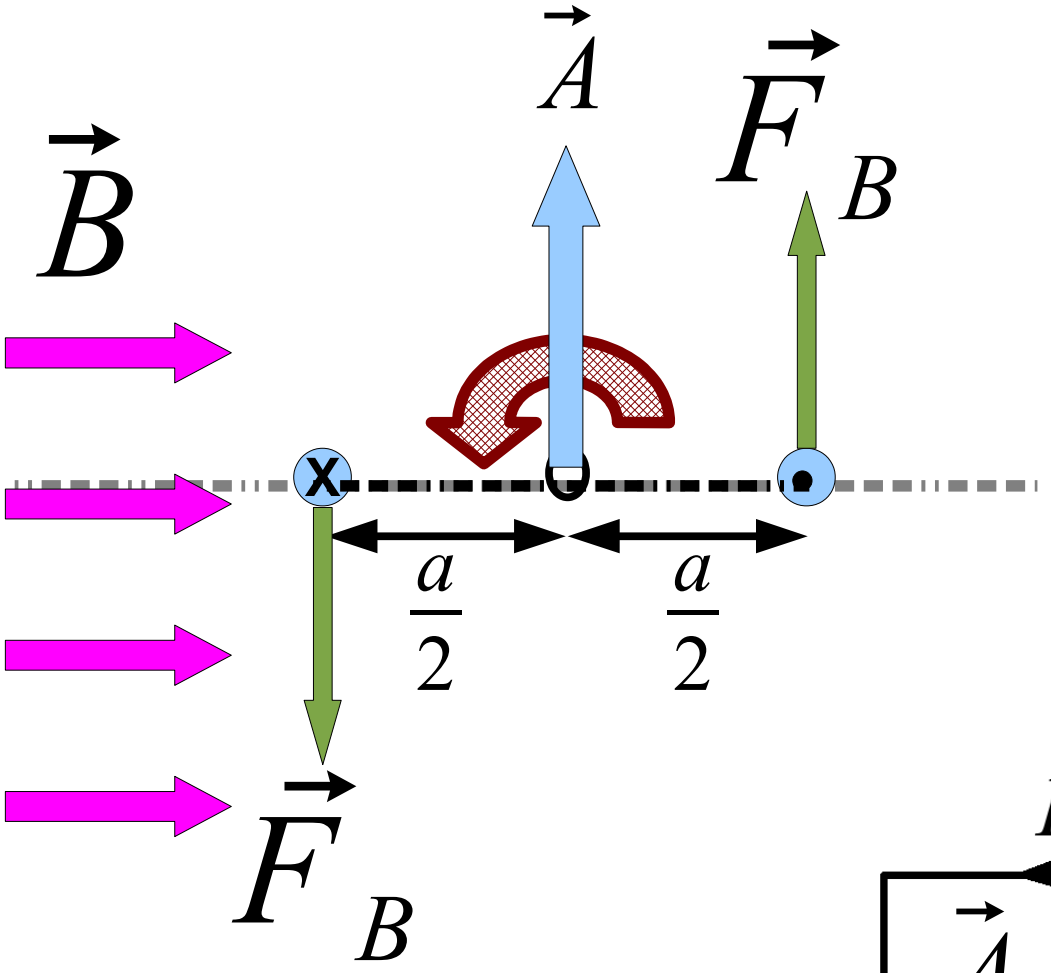
$$\tau_{max} = I(ab)B = IAB$$

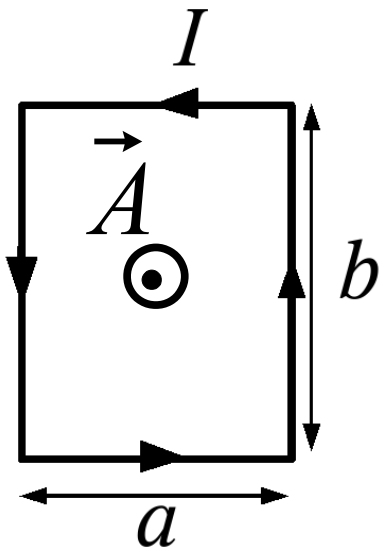


$$Area = A = ab$$

Torque on a Current Carrying Loop

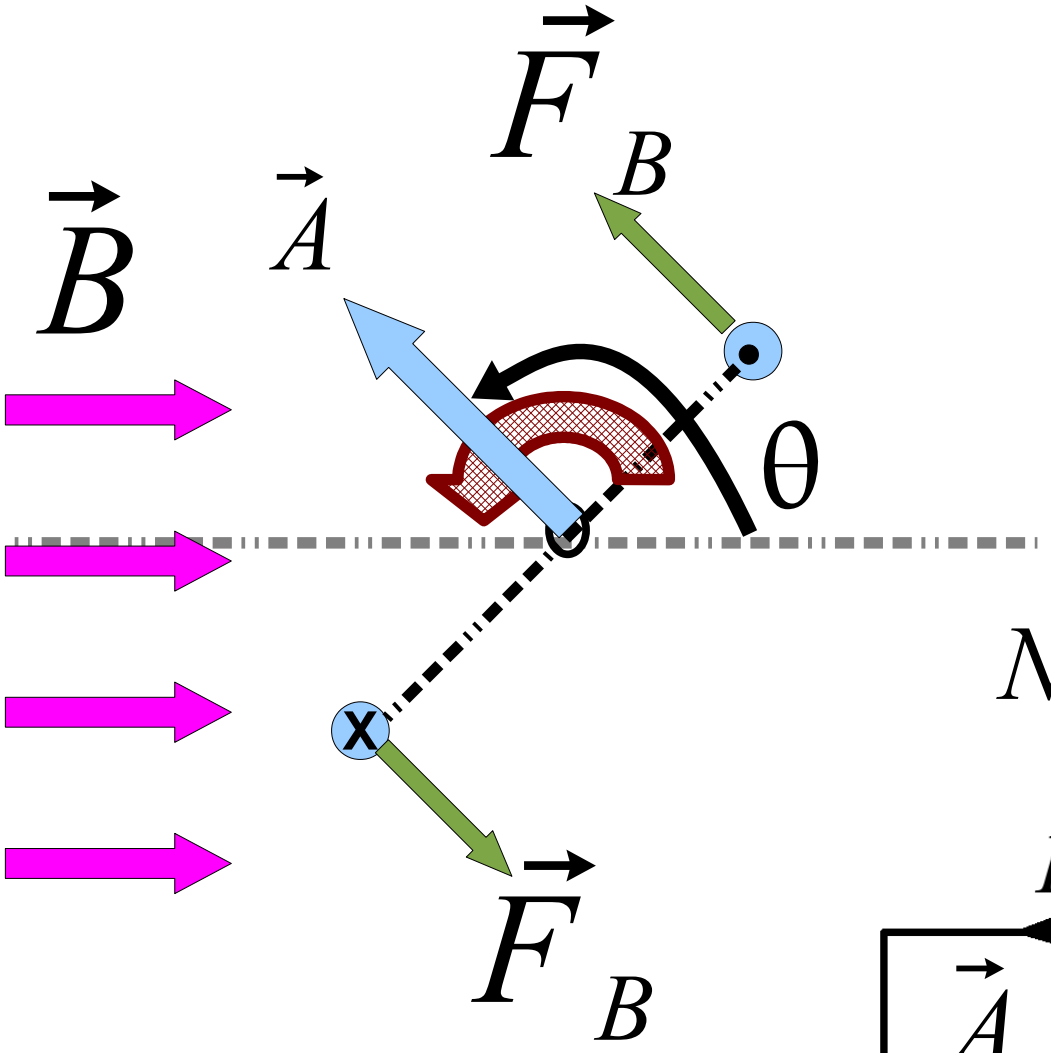
$$\tau_{max} = IAB$$





$$Area = A = ab$$

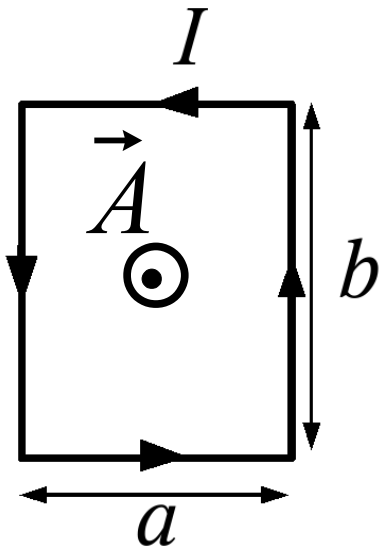
Torque on a Current Carrying Loop



$$\tau_{max} = N\ IAB$$

$$\tau = N\ IAB \sin\theta$$

$N =$ Number of Coils



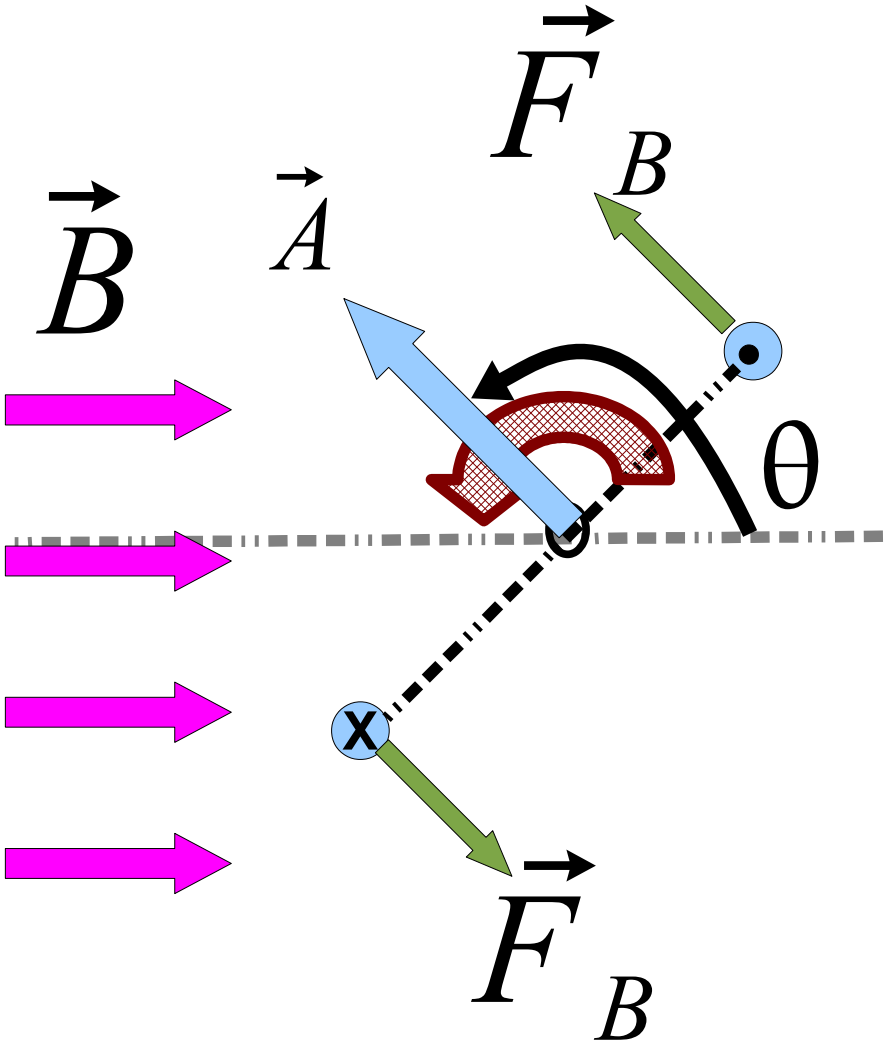
$$Area = A = ab$$

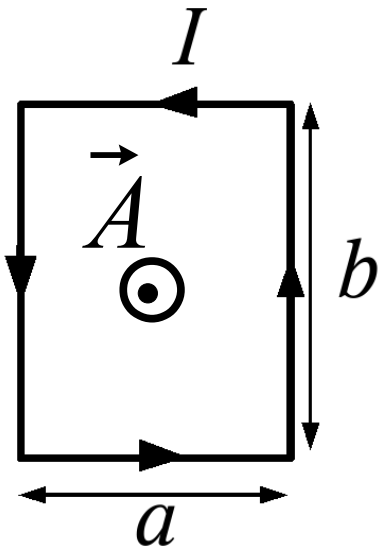
Torque on a Current Carrying Loop

$$\tau_{max} = N\,IAB$$

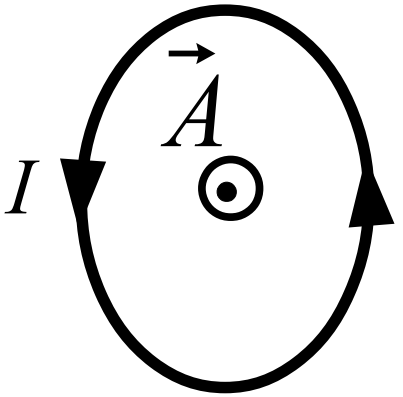
$$\tau = N\,IAB\sin\theta$$

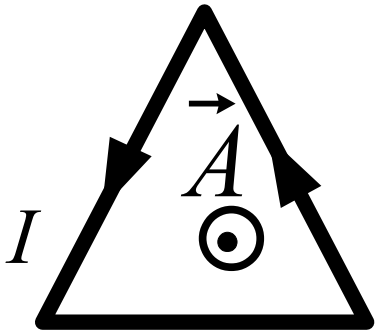
$N =$ Number of Coils



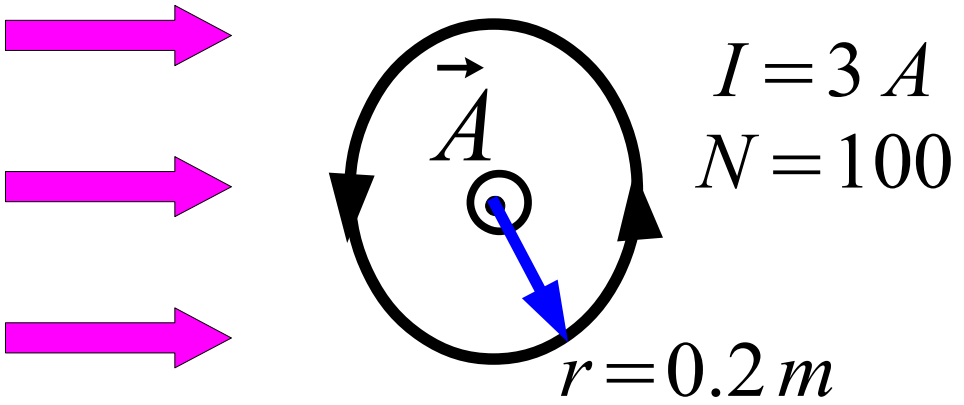


$$Area = A = ab$$





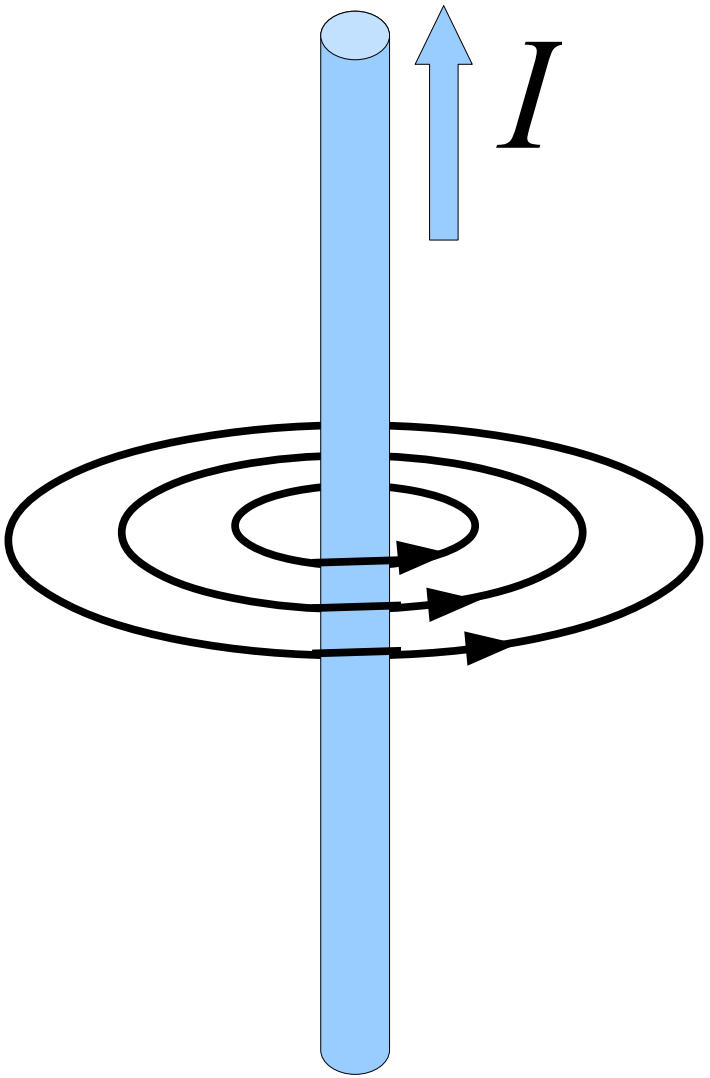
$$\vec{B} = 2.0\,T$$



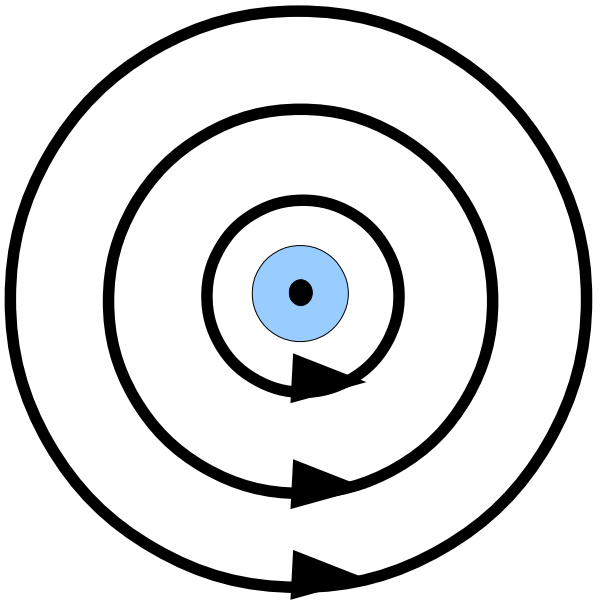
$$\tau_{max} = N\,IAB$$

$$100(3\ A)\left[3.14(0.2\,m)^2\right]2\,T = 75.36\ Nm$$

A Wire Carrying a Current Creates a Magnetic Field

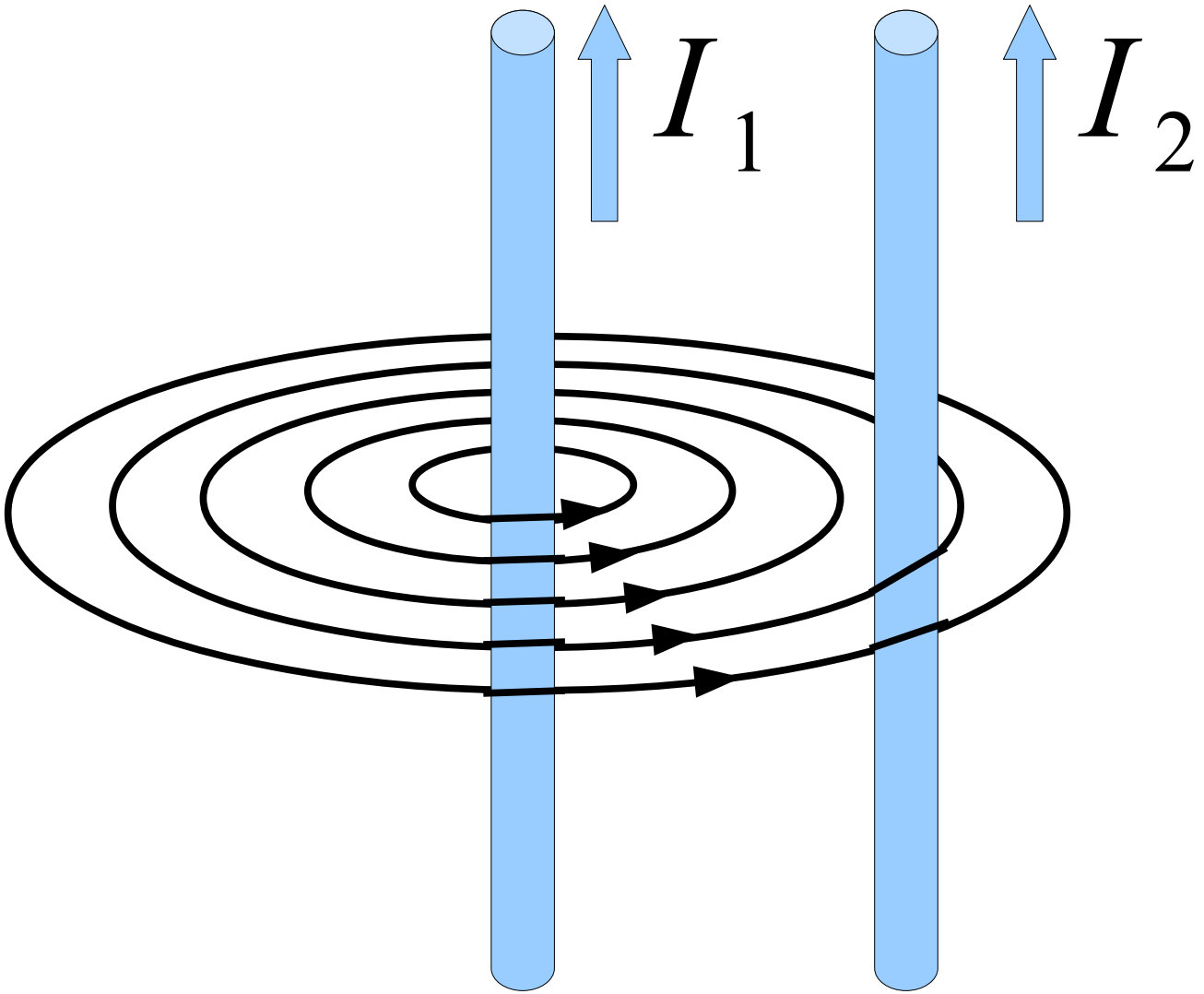


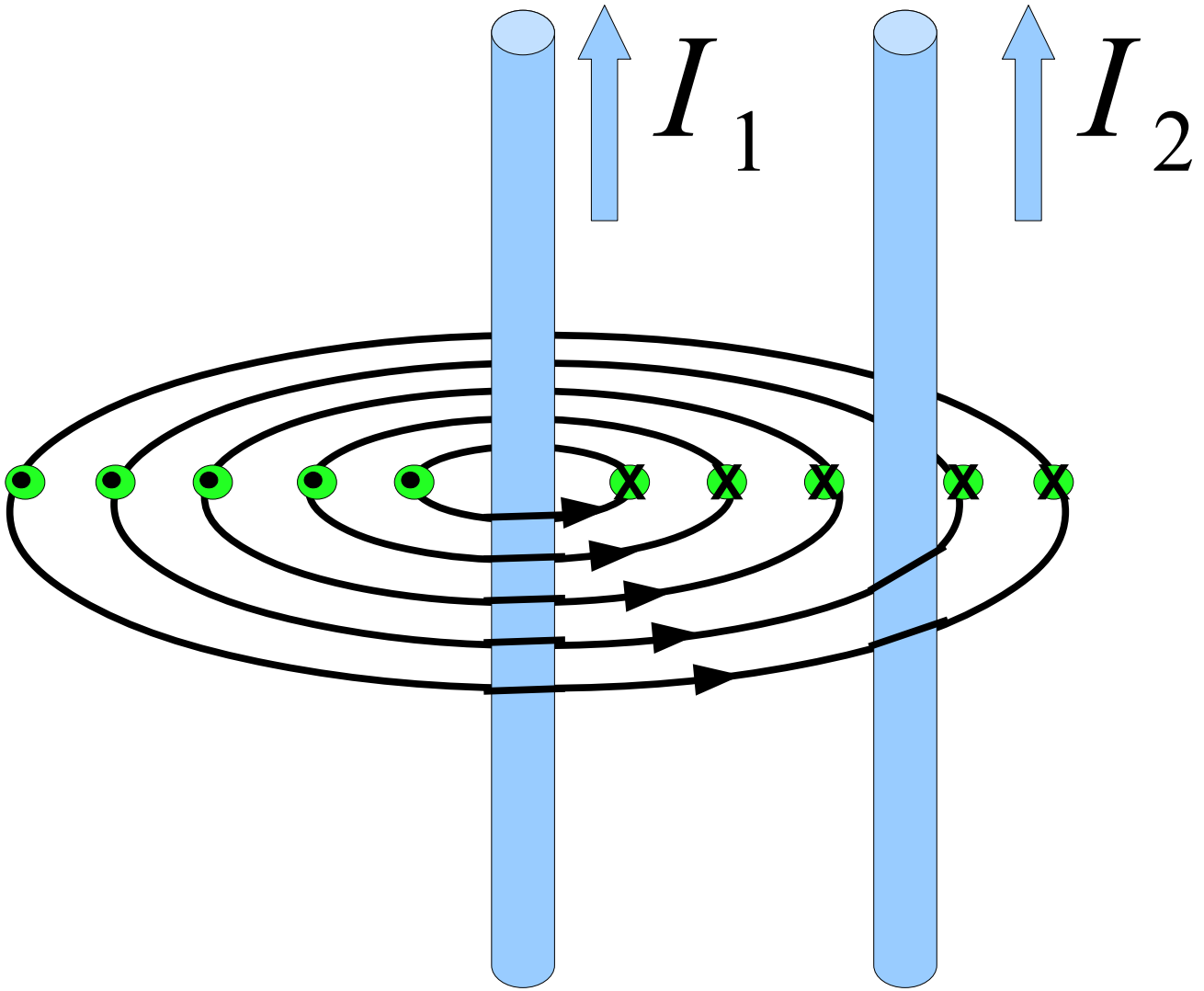
$$|B| = \frac{\mu_o I}{2\pi r}$$

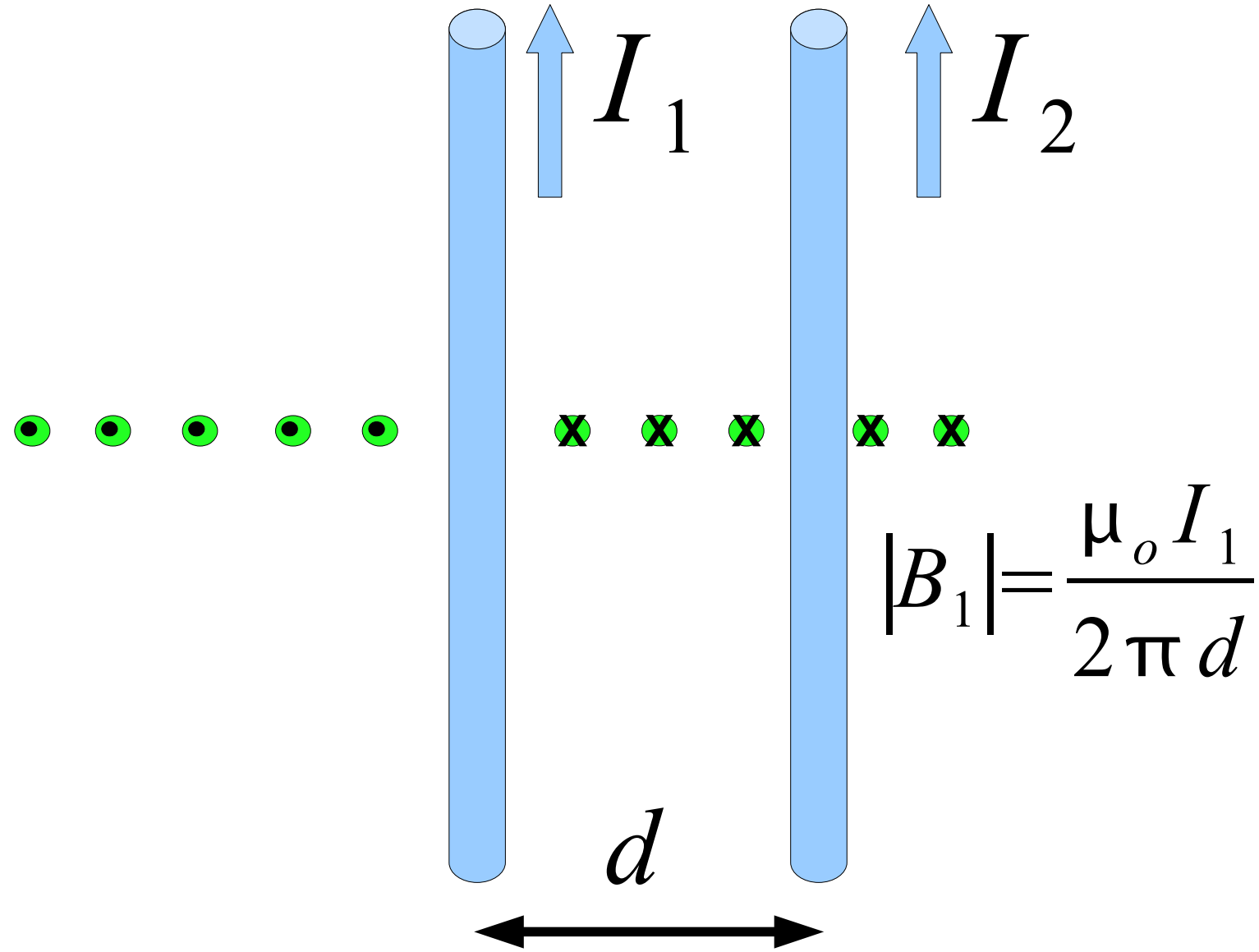


$$\mu_o = 4\pi X 10^{-7} \frac{Tm}{A}$$

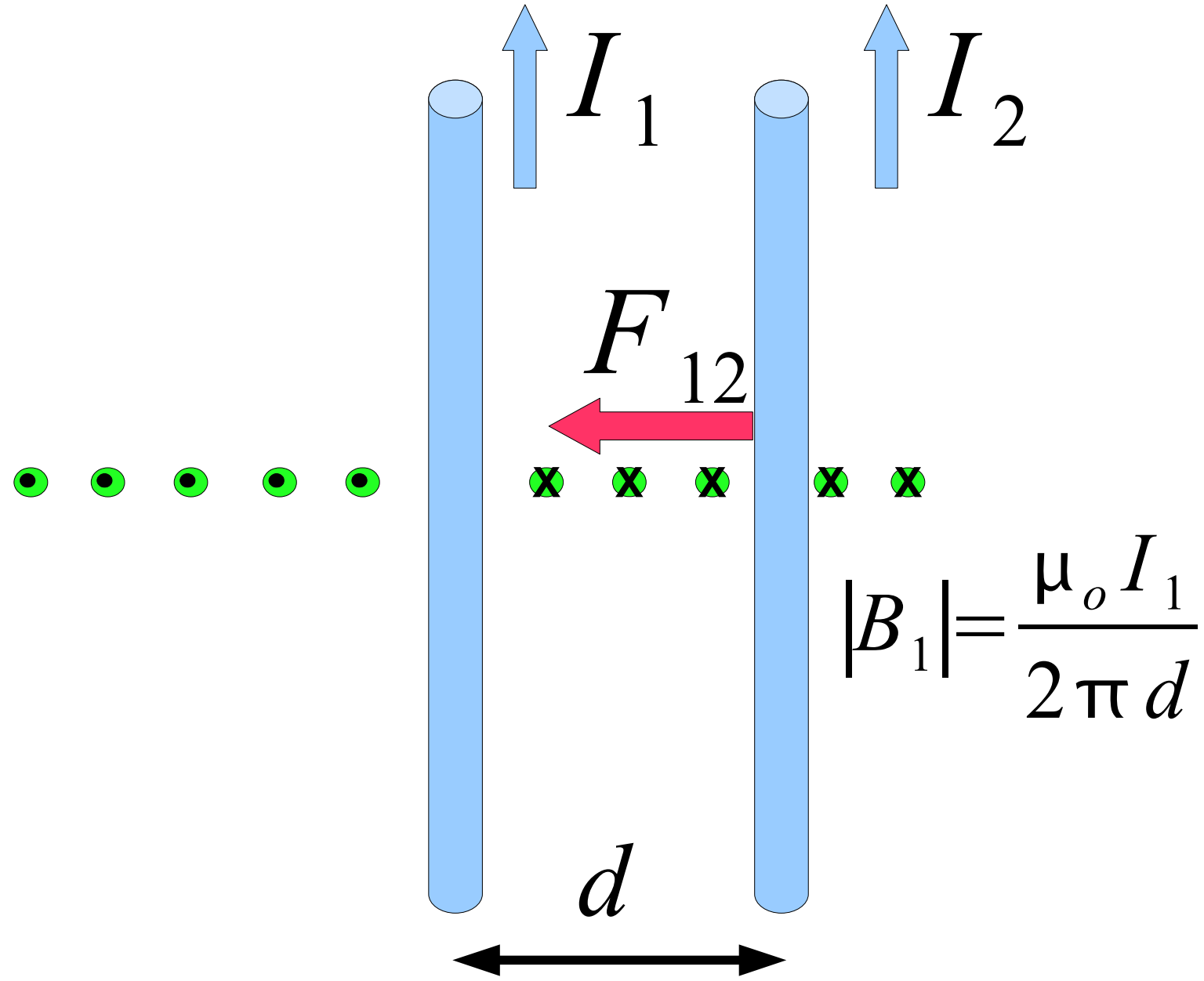
Making a motor ....



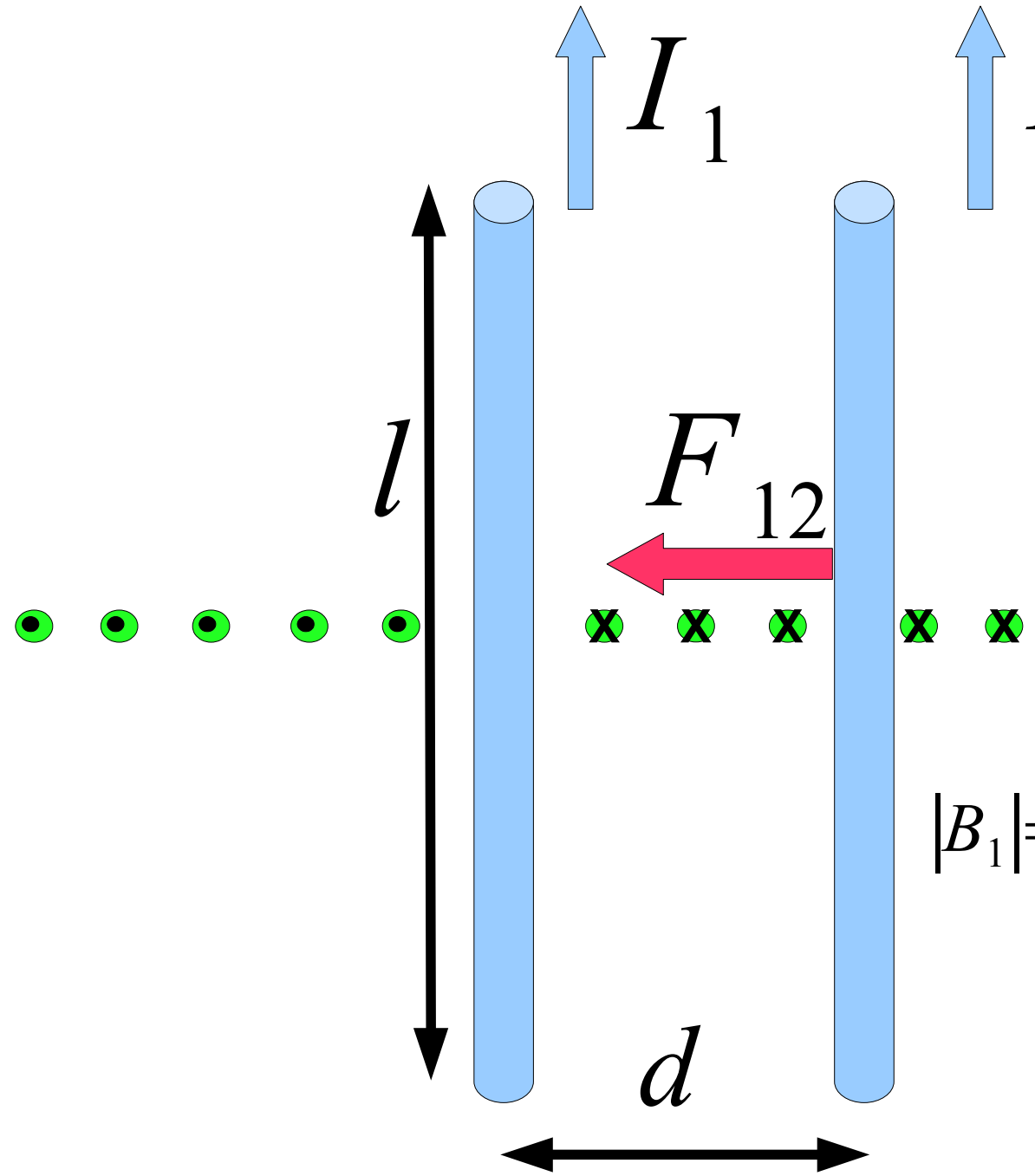

I_1
I_2



$$|B_1| = \frac{\mu_o I_1}{2\pi d}$$



$$|B_1| = \frac{\mu_o I_1}{2\pi d}$$

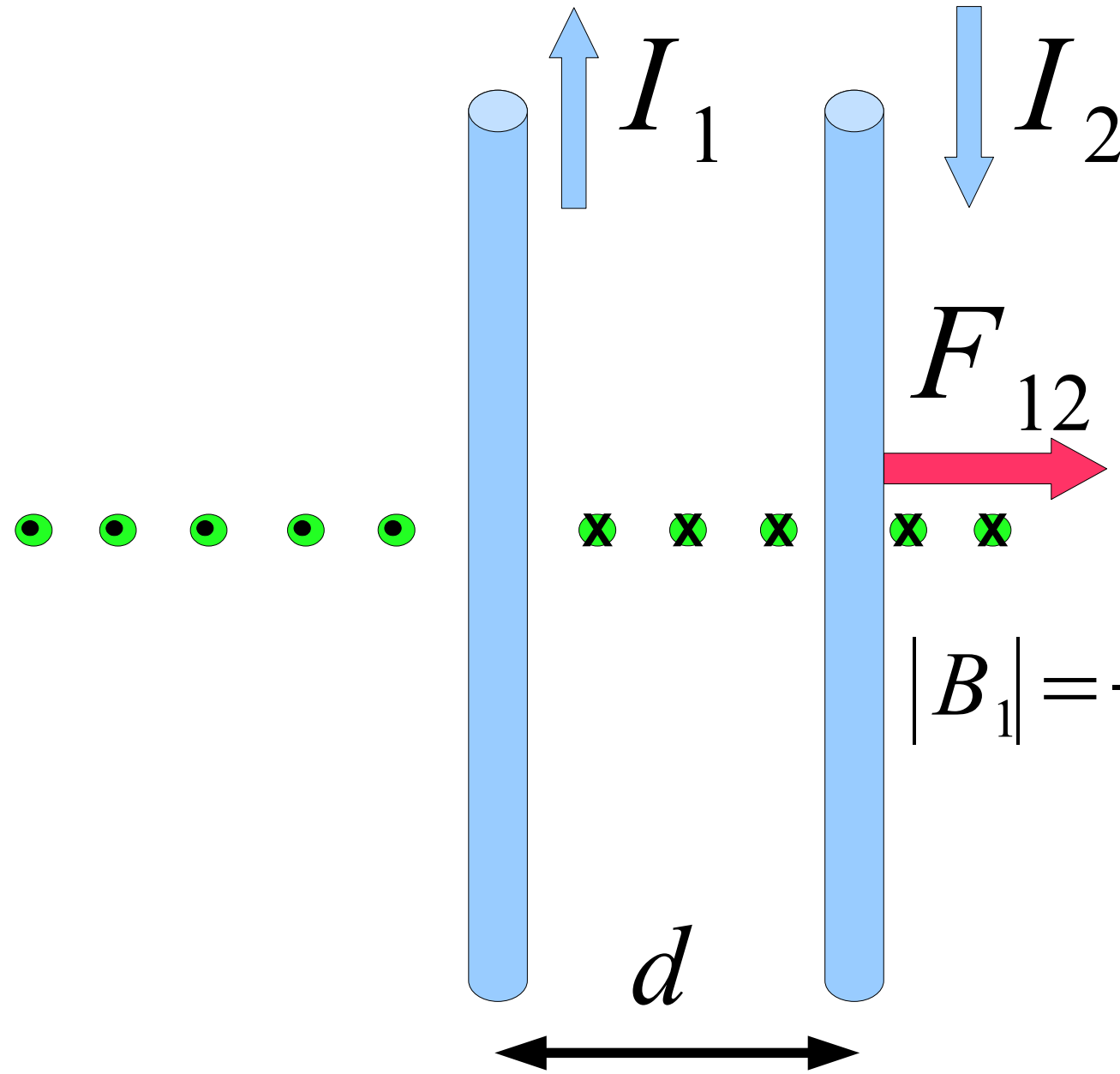


$$F_{12} = I_2 B_1 l$$

$$F_{12} = I_2 \left(\frac{\mu_o I_1}{2\pi d} \right) l$$

$$\frac{F_{12}}{l} = \frac{\mu_o I_1 I_2}{2\pi d}$$

$$|B_1| = \frac{\mu_o I_1}{2\pi d}$$

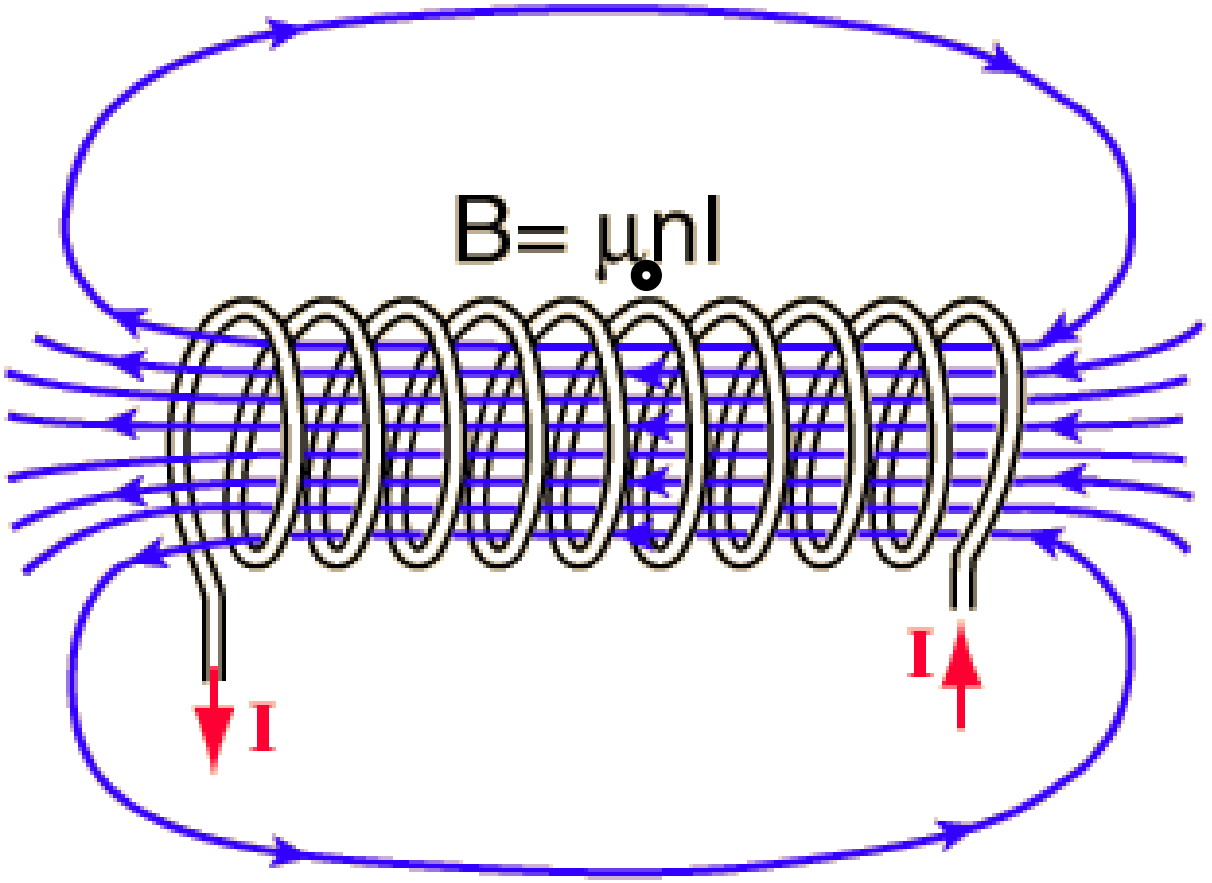


$$|B_1| = \frac{\mu_o I_1}{2\pi d}$$

Lorentz Force

$$\vec{F} = q\vec{E} + q\vec{v}\ X\ \vec{B}$$

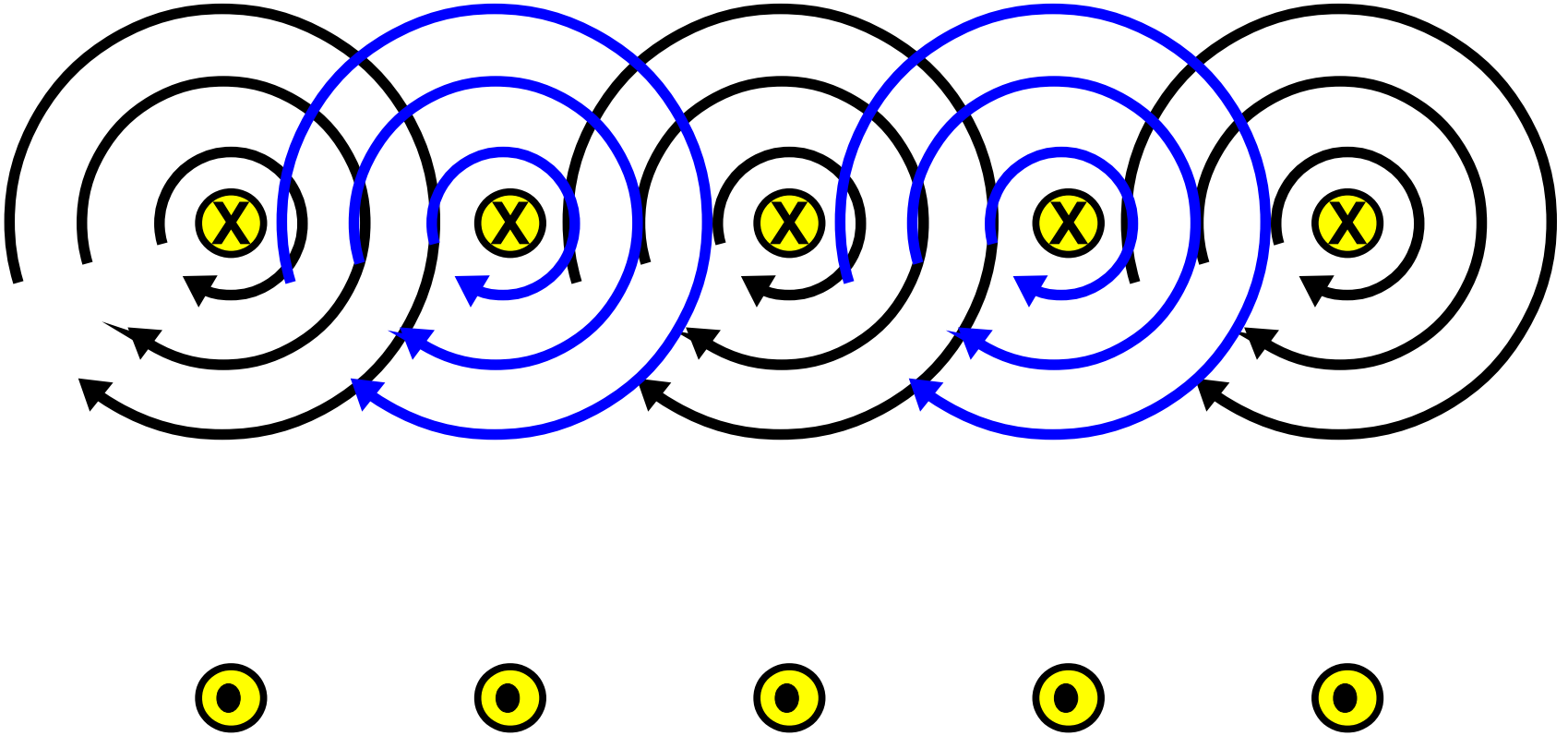
Coils and Solenoids



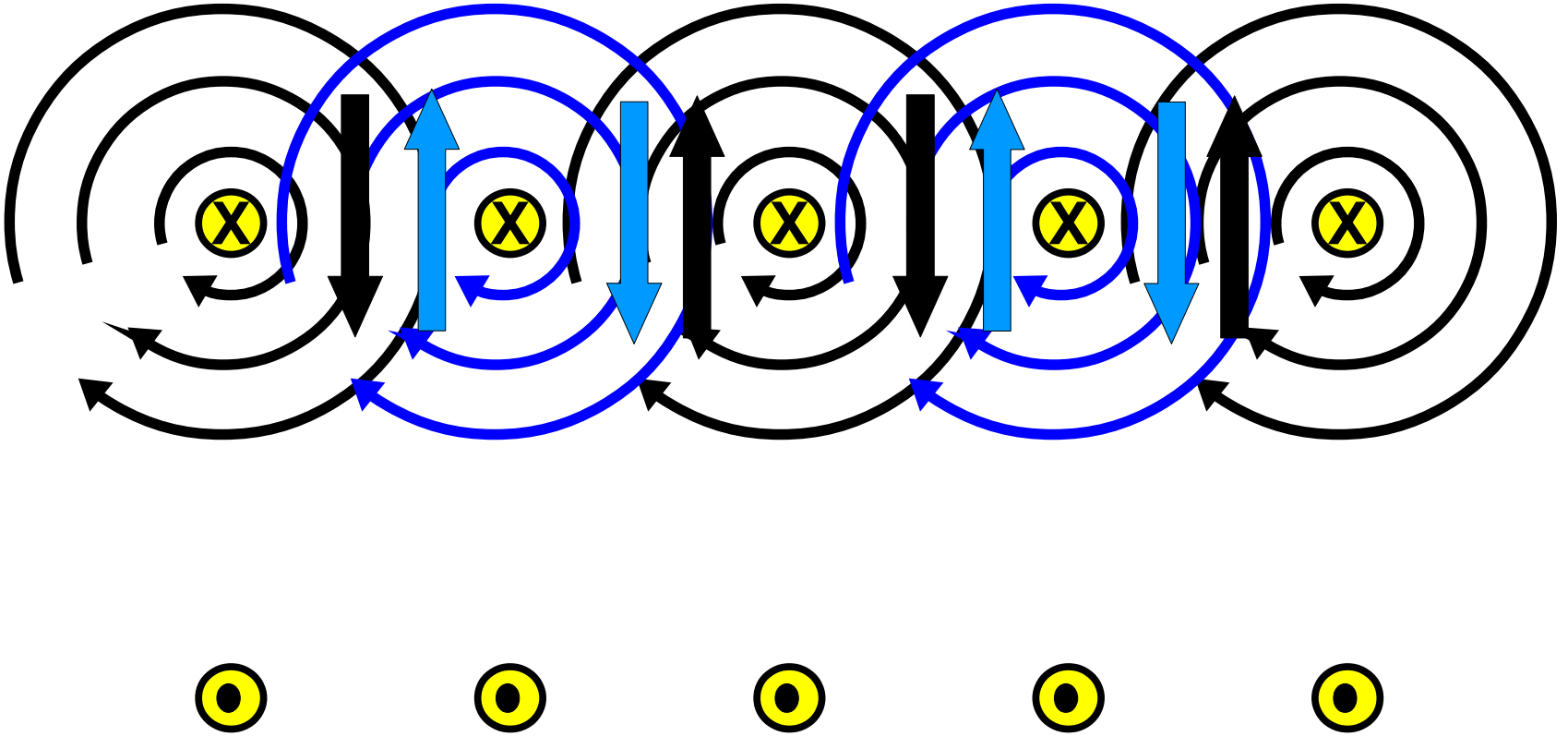
The magnetic field is concentrated into a nearly uniform field in the center of a long solenoid. The field outside is weak and divergent.

Coils and Solenoids

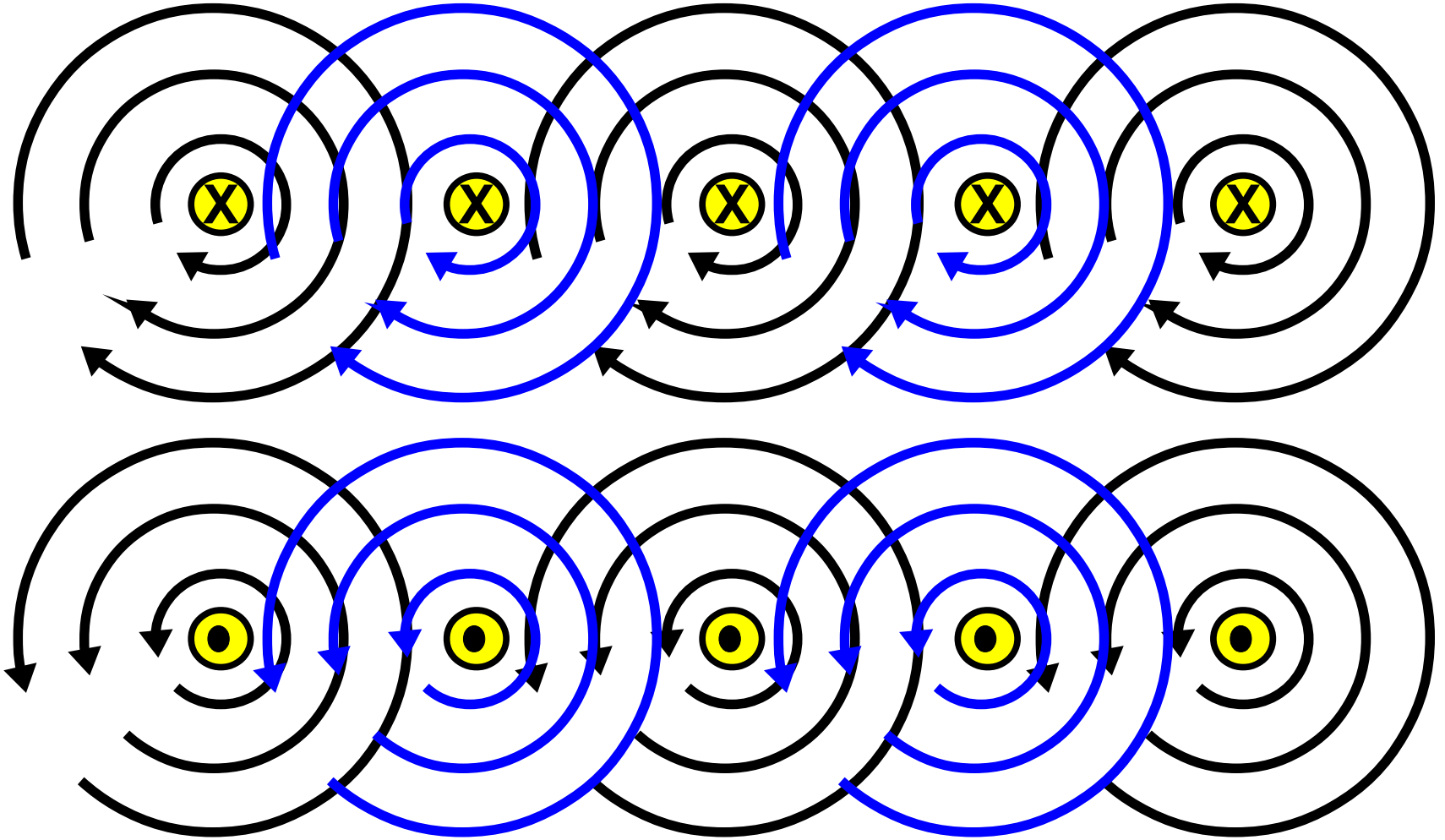
Coils and Solenoids



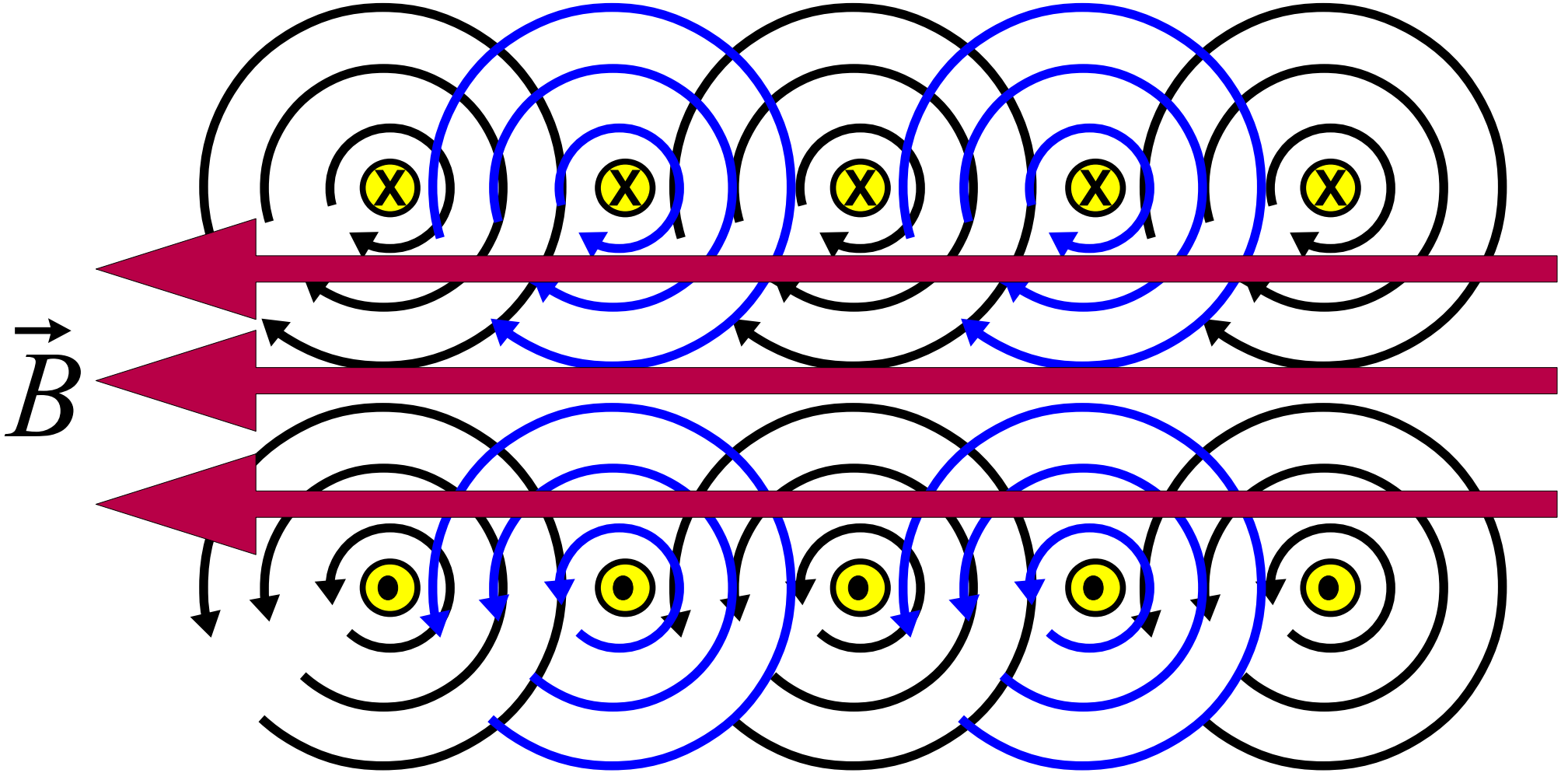
Coils and Solenoids



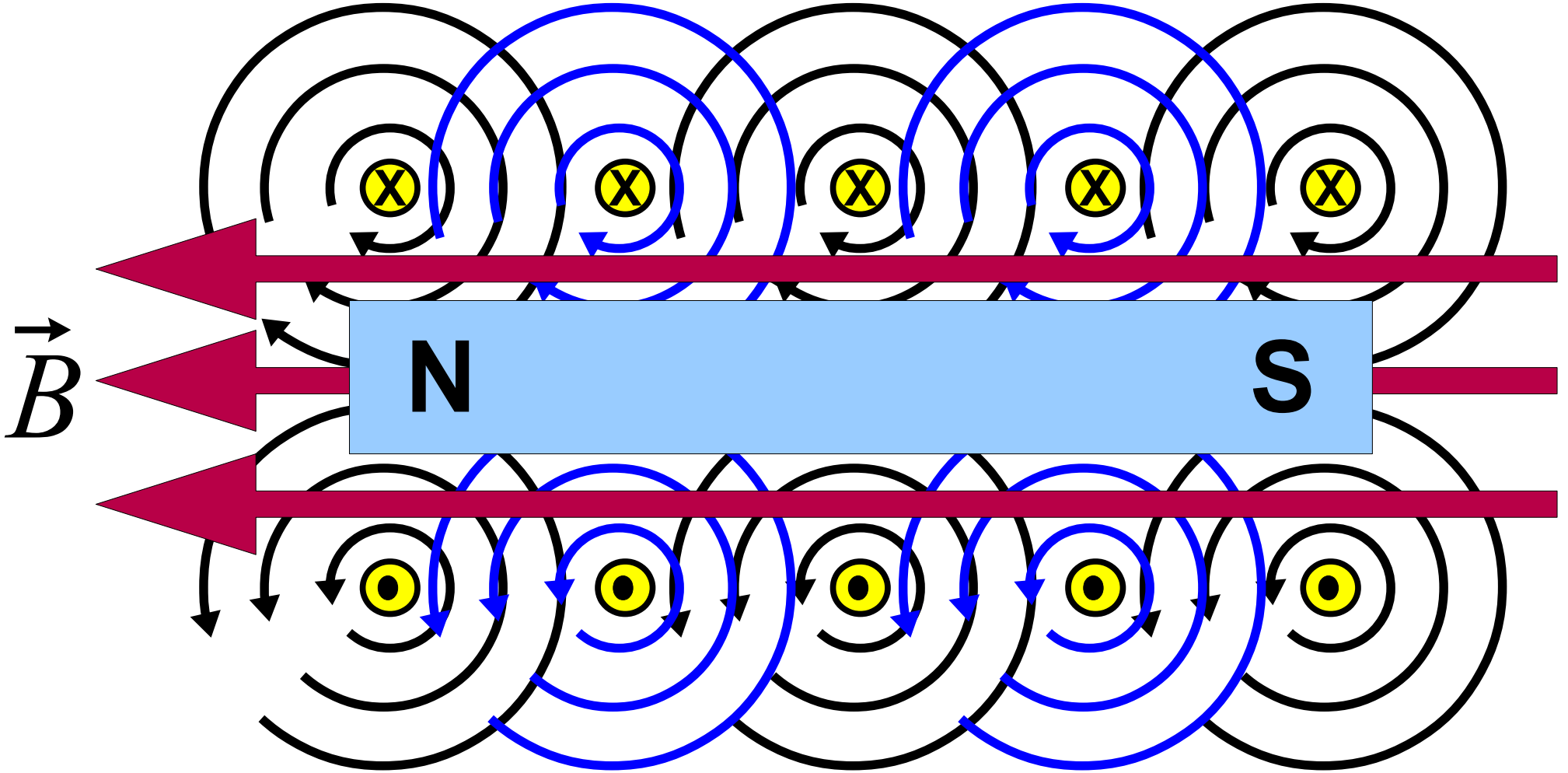
Coils and Solenoids



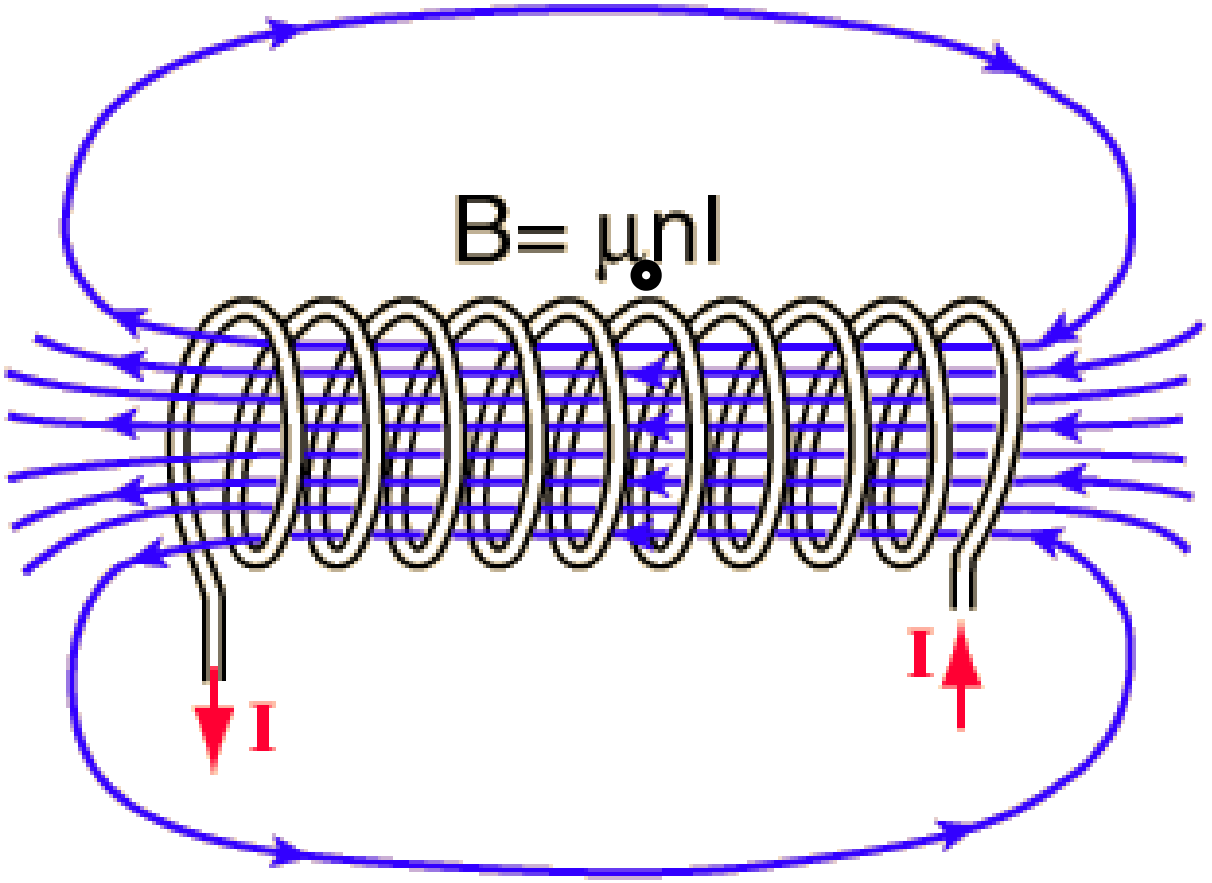
Coils and Solenoids



Coils and Solenoids



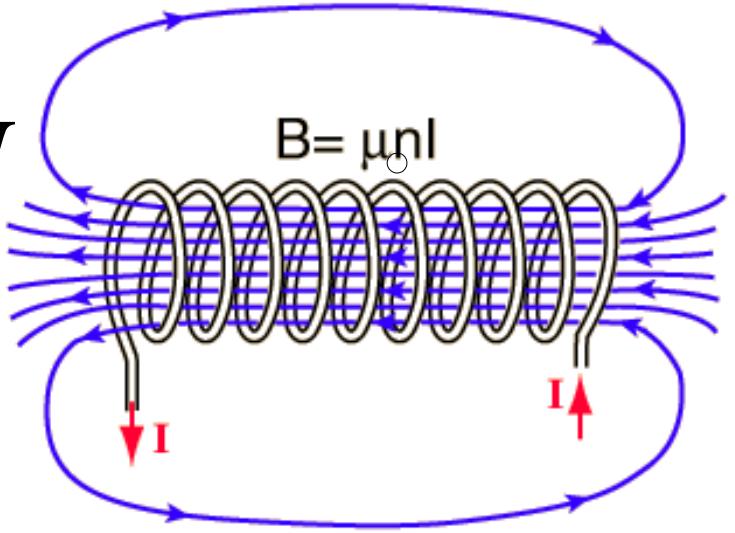
Coils and Solenoids



The magnetic field is concentrated into a nearly uniform field in the center of a long solenoid. The field outside is weak and divergent.

Coils and Solenoids

$$B = \mu_o n I = \mu_o \frac{N}{l} I$$

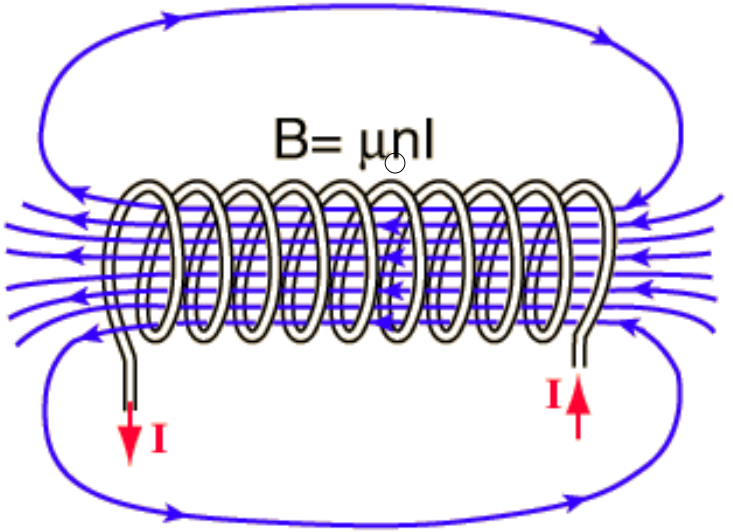


The magnetic field is concentrated into a nearly uniform field in the center of a long solenoid. The field outside is weak and divergent.

1000 Turns in 0.2 meters.
There is a current of 5 amps.

Coils and Solenoids

$$B = \mu_o \frac{N}{l} I$$

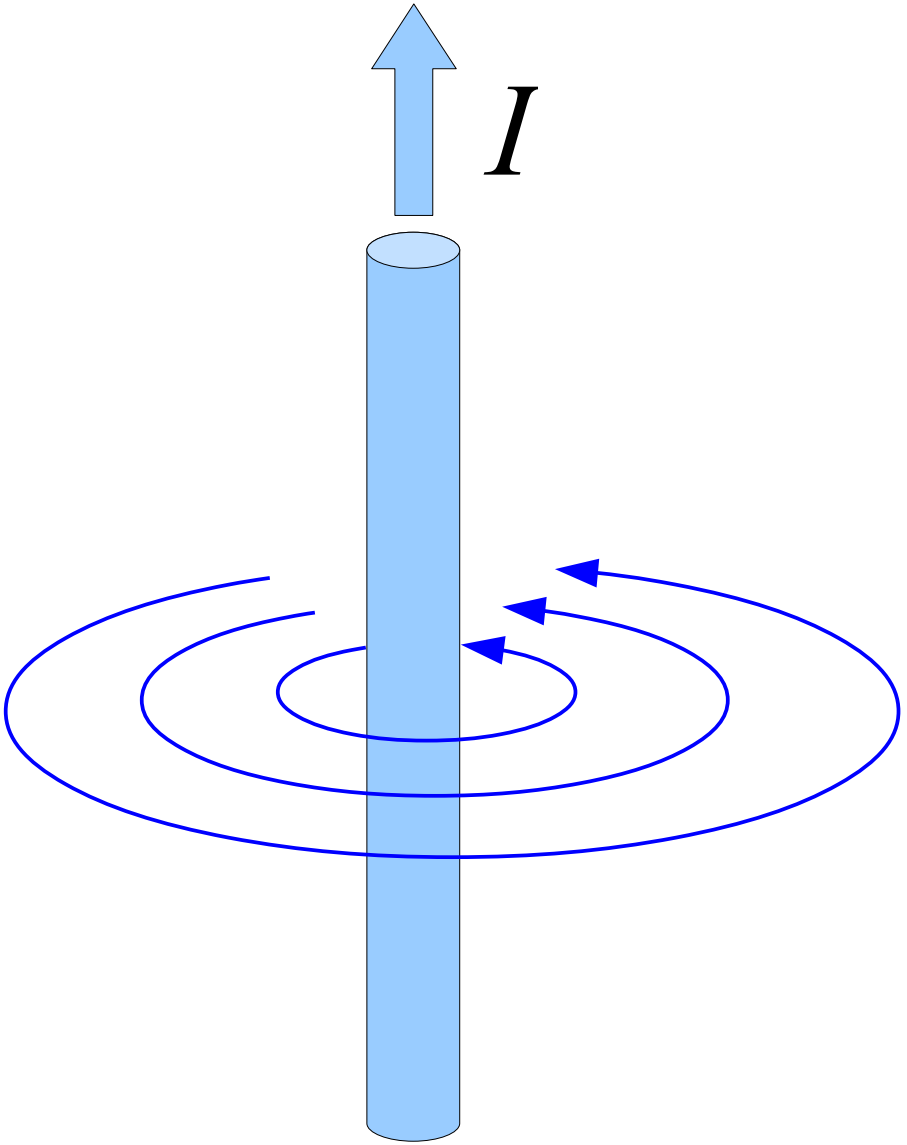


The magnetic field is concentrated into a nearly uniform field in the center of a long solenoid. The field outside is weak and divergent.

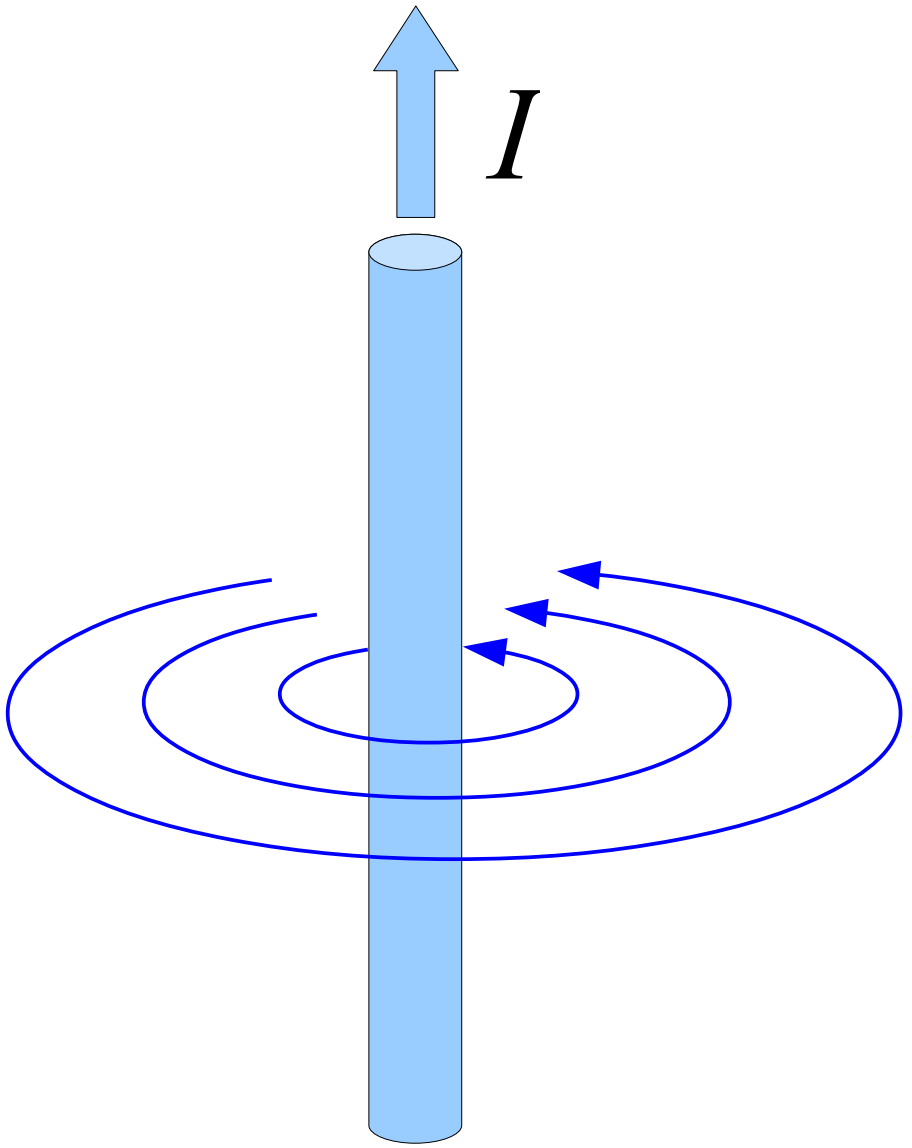
1000 Turns in 0.2 meters.
There is a current of 5 amps.

$$B = \mu_o \frac{N}{l} I = 4\pi \, X \, 10^{-7} \frac{Tm}{A} \left(\frac{1000}{0.2\,m} \right) 5\,A = 0.31\,T$$

Ampere's Law – Used to find the value of the magnetic field.

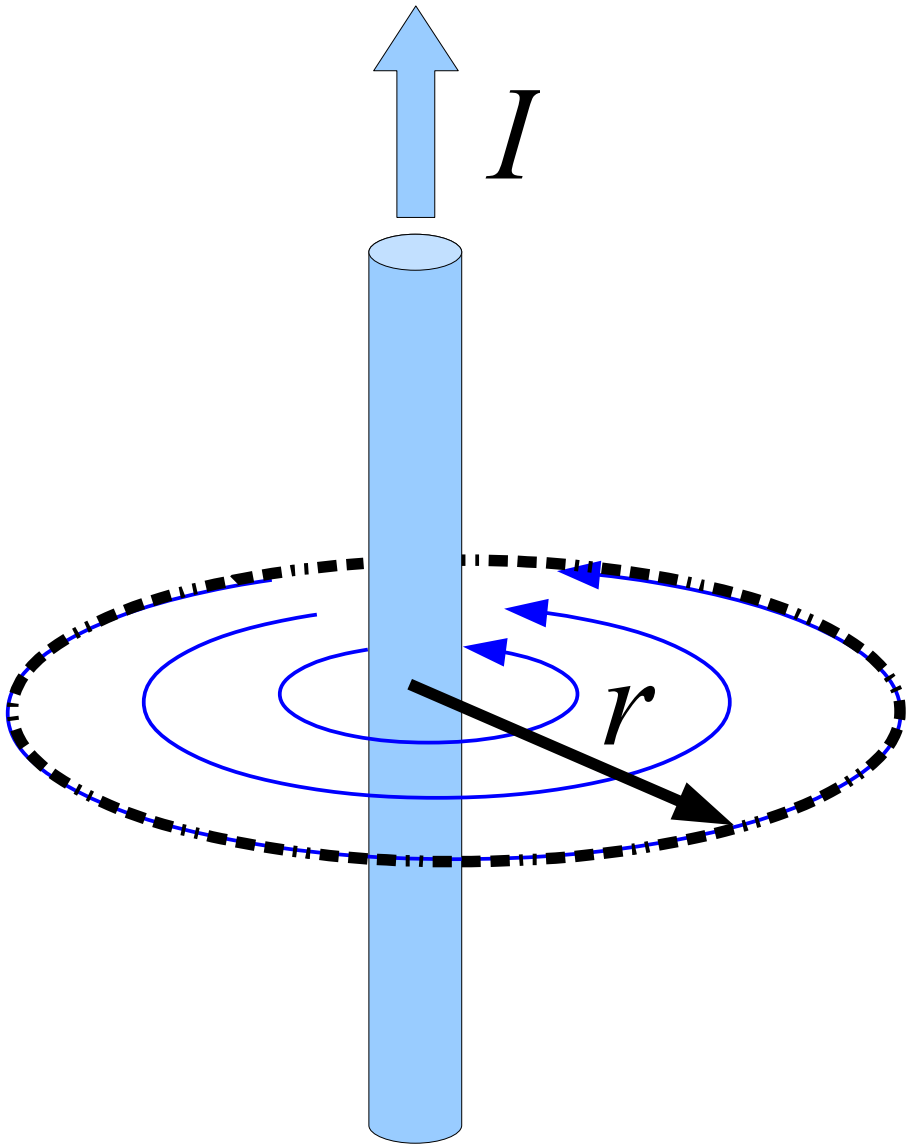


Ampere's Law – Used to find the value of the magnetic field.



$$\sum B_{\parallel} \Delta l = \mu_o I$$

Ampere's Law – Used to find the value of the magnetic field.



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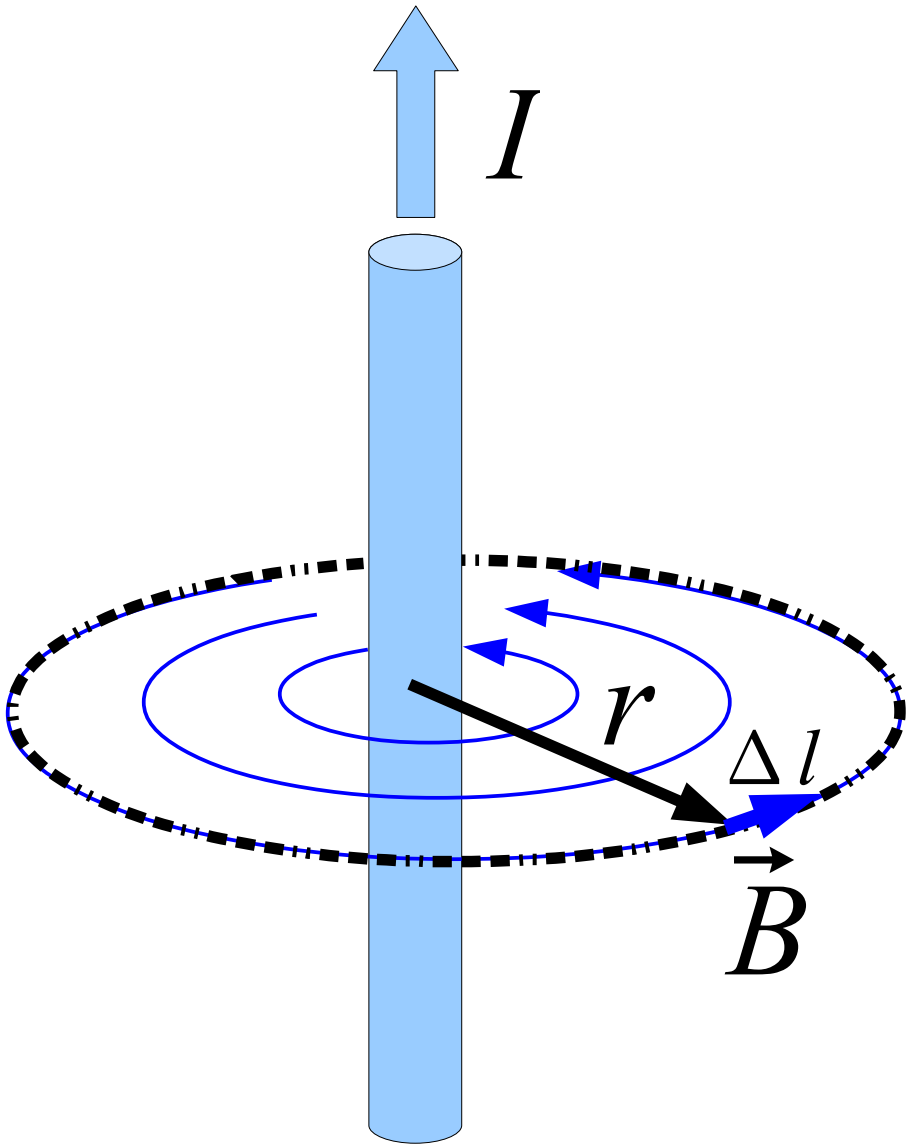

$$\sum B_{\parallel} \Delta l = \mu_o I$$

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Ampere's Law – Used to find the value of the magnetic field.

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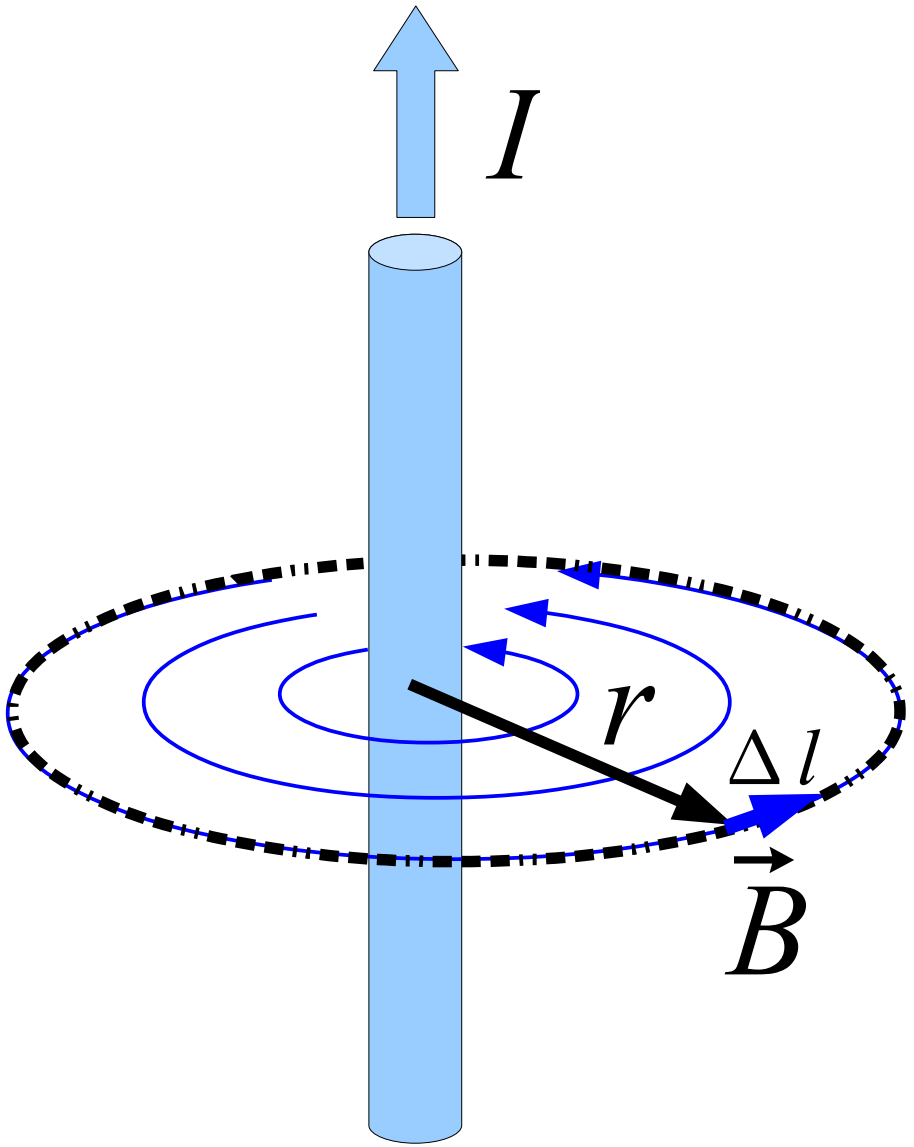

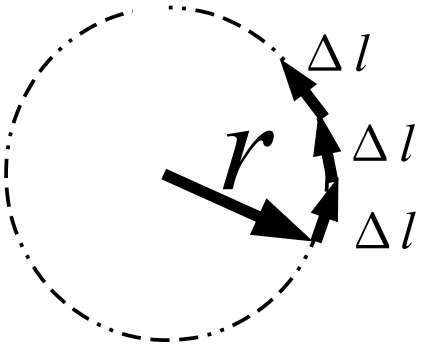

Ampere's Law – Used to find the value of the magnetic field.

$$\sum B_{\parallel} \Delta l = \mu_o I$$

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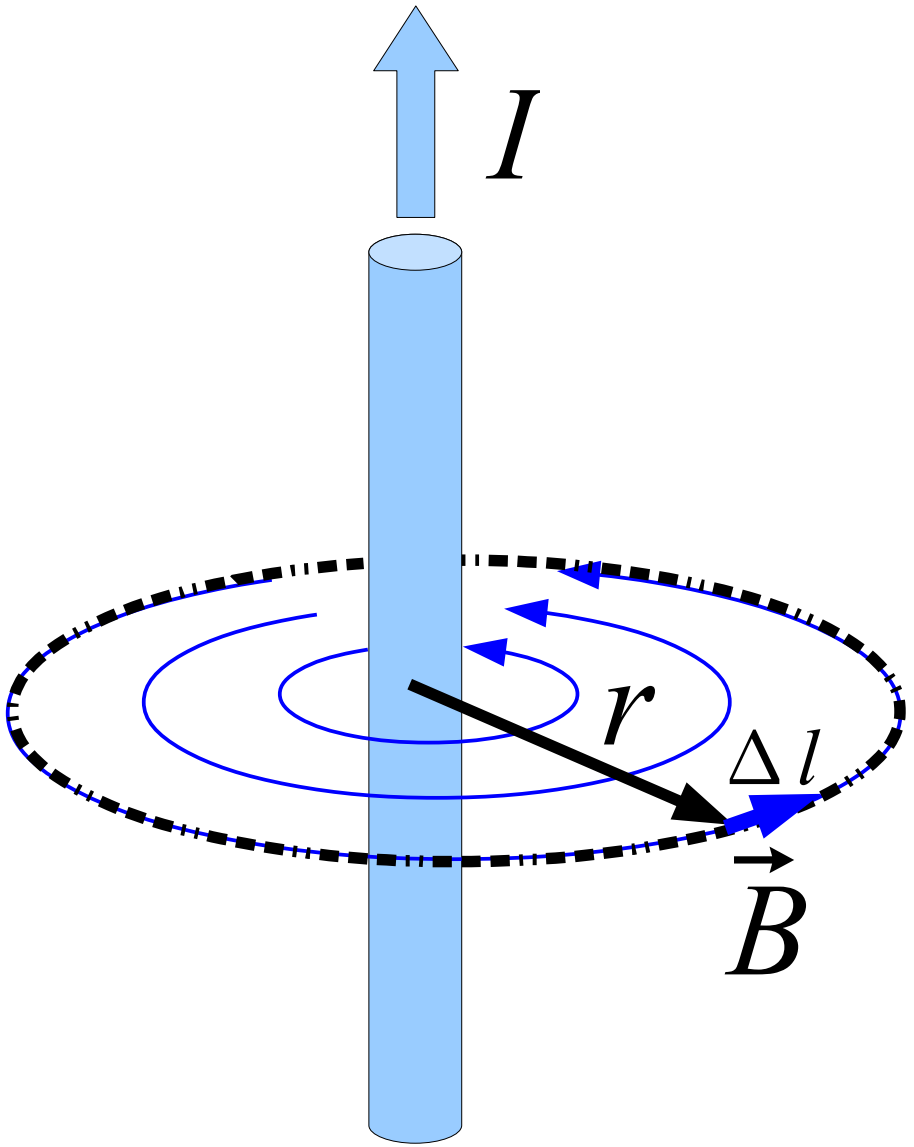
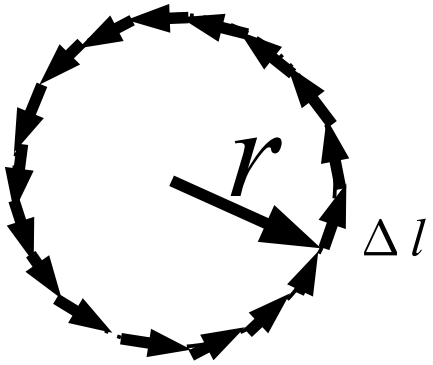
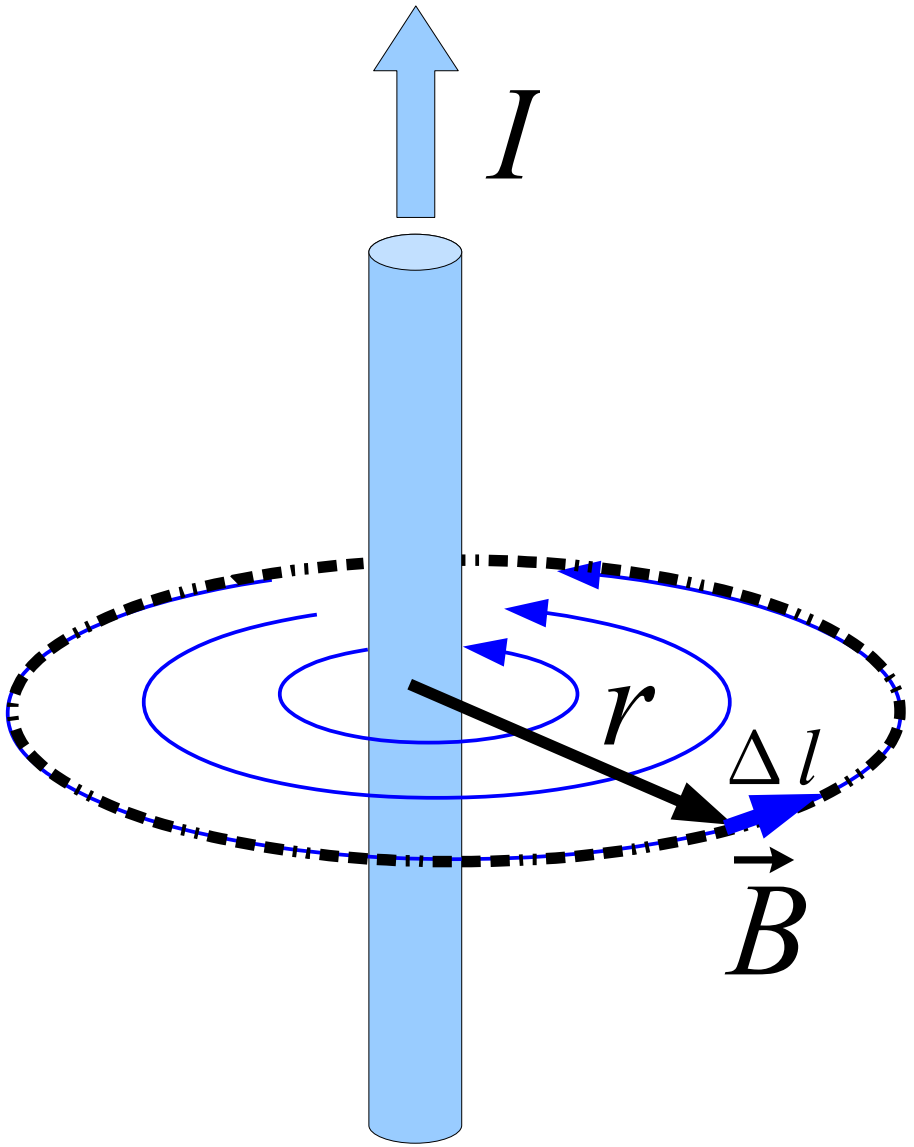




$$\sum \Delta l = 2\pi r$$

Ampere's Law – Used to find the value of the magnetic field.

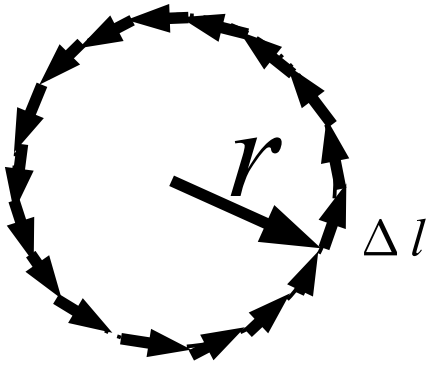


$$\sum B_{\parallel}\Delta l=\mu_o I$$

$$B_{\parallel}\sum \Delta l=\mu_o I$$

$$B_{\parallel}\left(2\pi r\right)=\mu_o I$$

$$B_{\parallel}=\frac{\mu_o I}{2\pi r}$$



$$\sum \Delta l=2\pi r$$

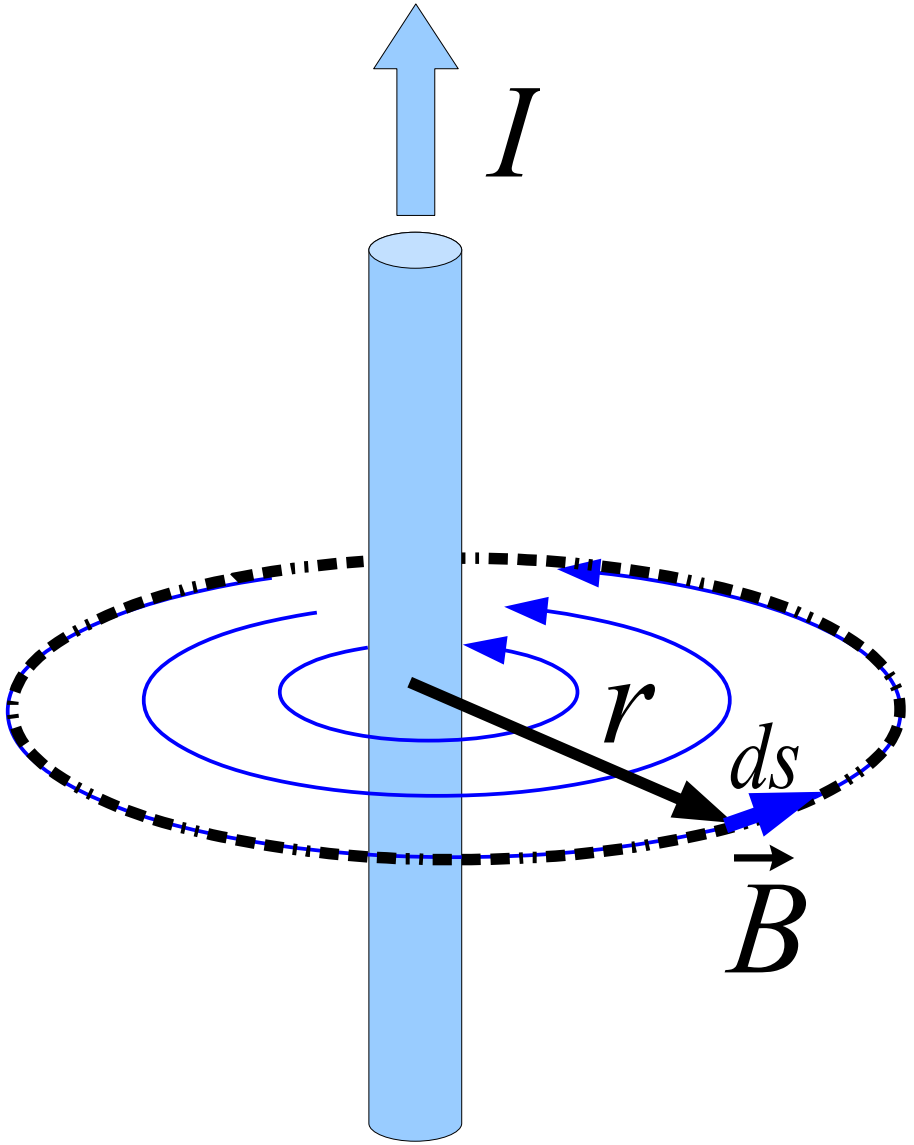
Ampere's Law – Used to find the value of the magnetic field.

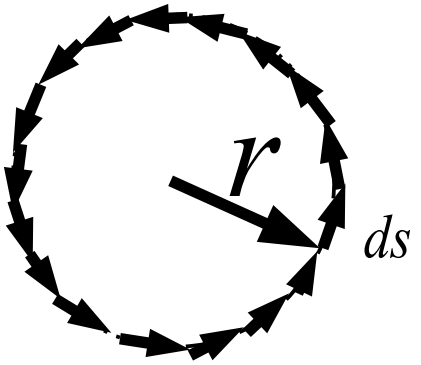
$$\oint \vec{B} \cdot d\vec{s} = \mu_o I_{\text{enclosed}}$$

$$B \oint ds = \mu_o I$$

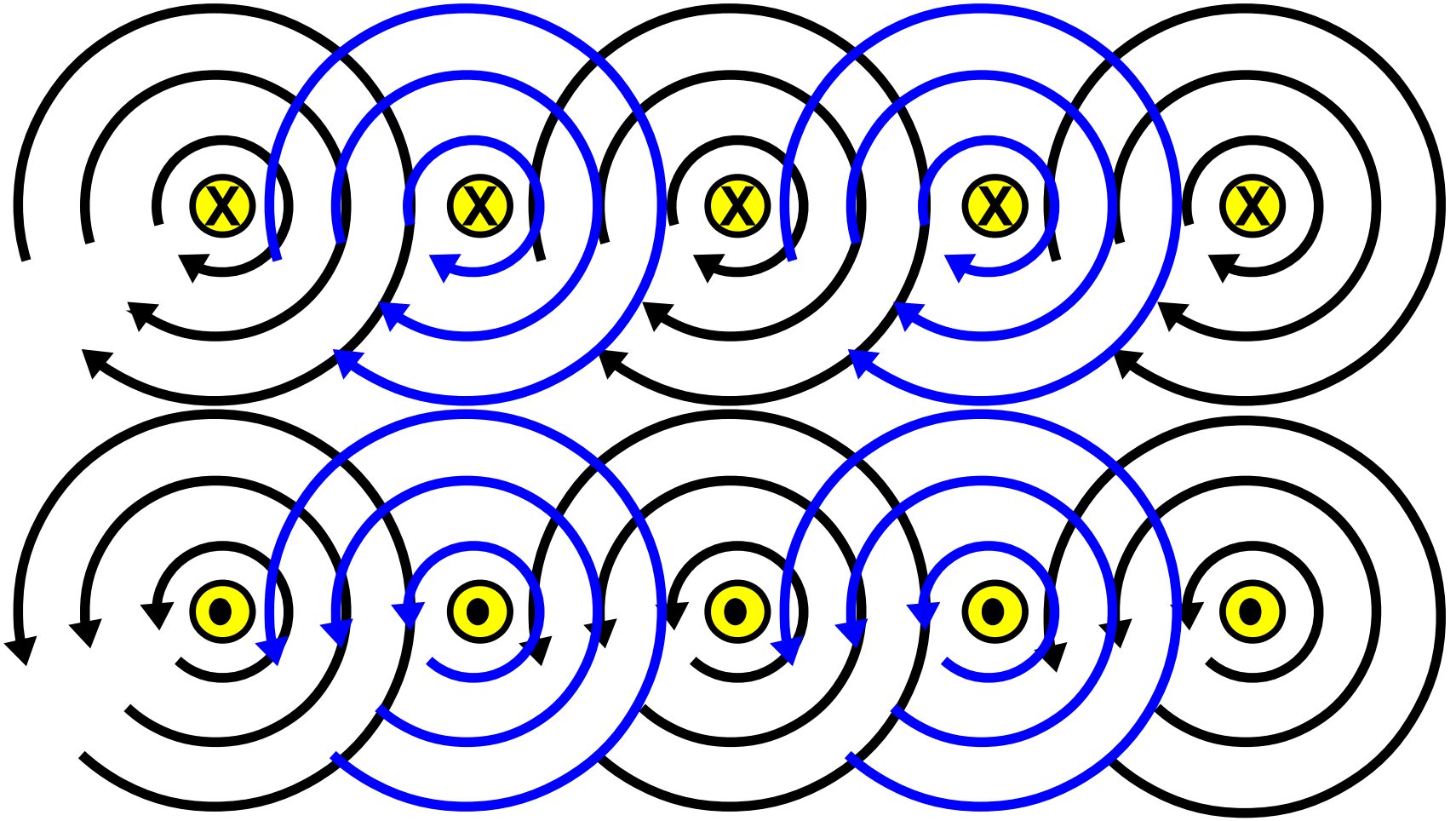
$$B(2\pi r) = \mu_o I$$

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



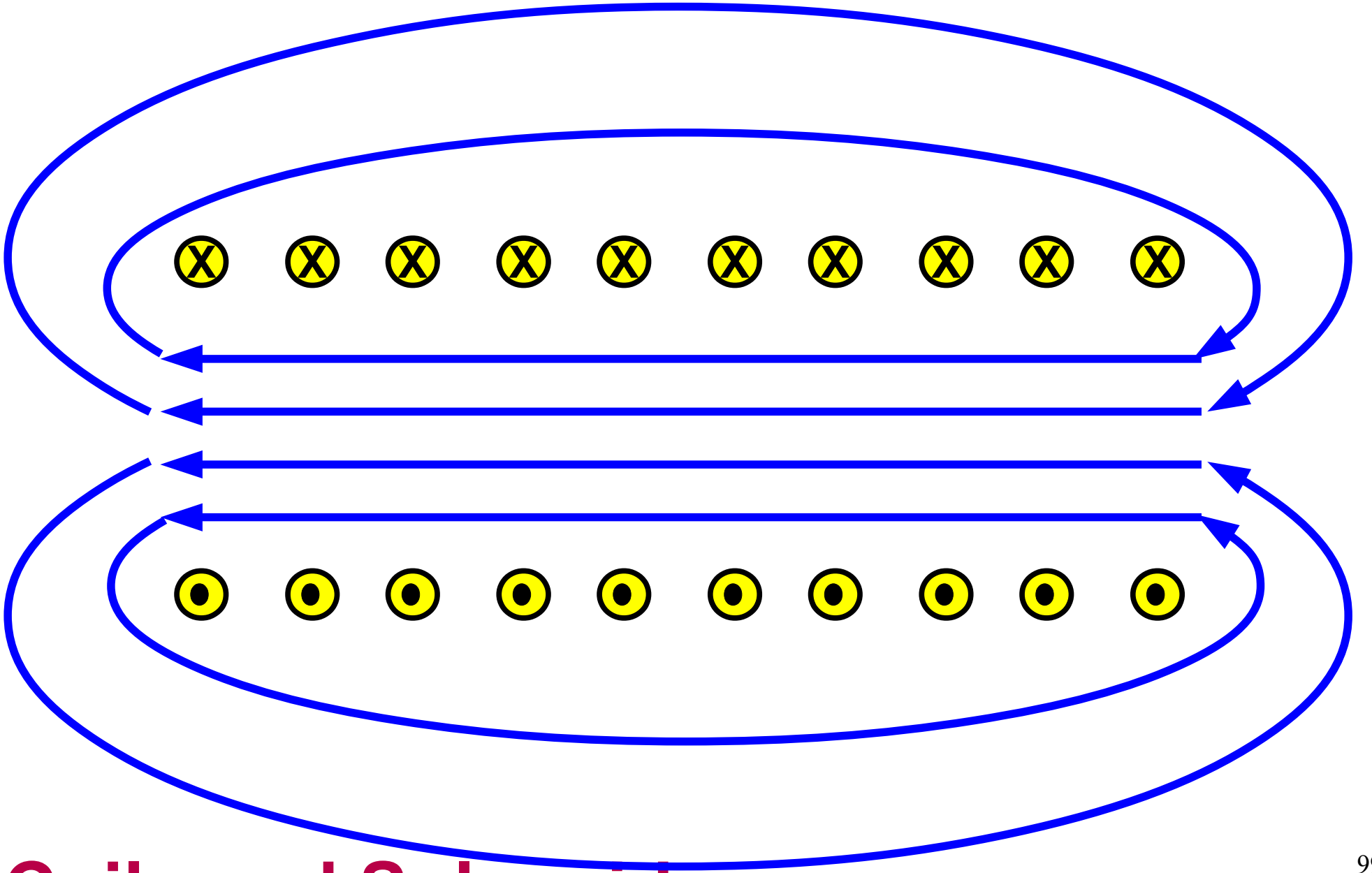


Ampere's Law – Used to find the value of the magnetic field.

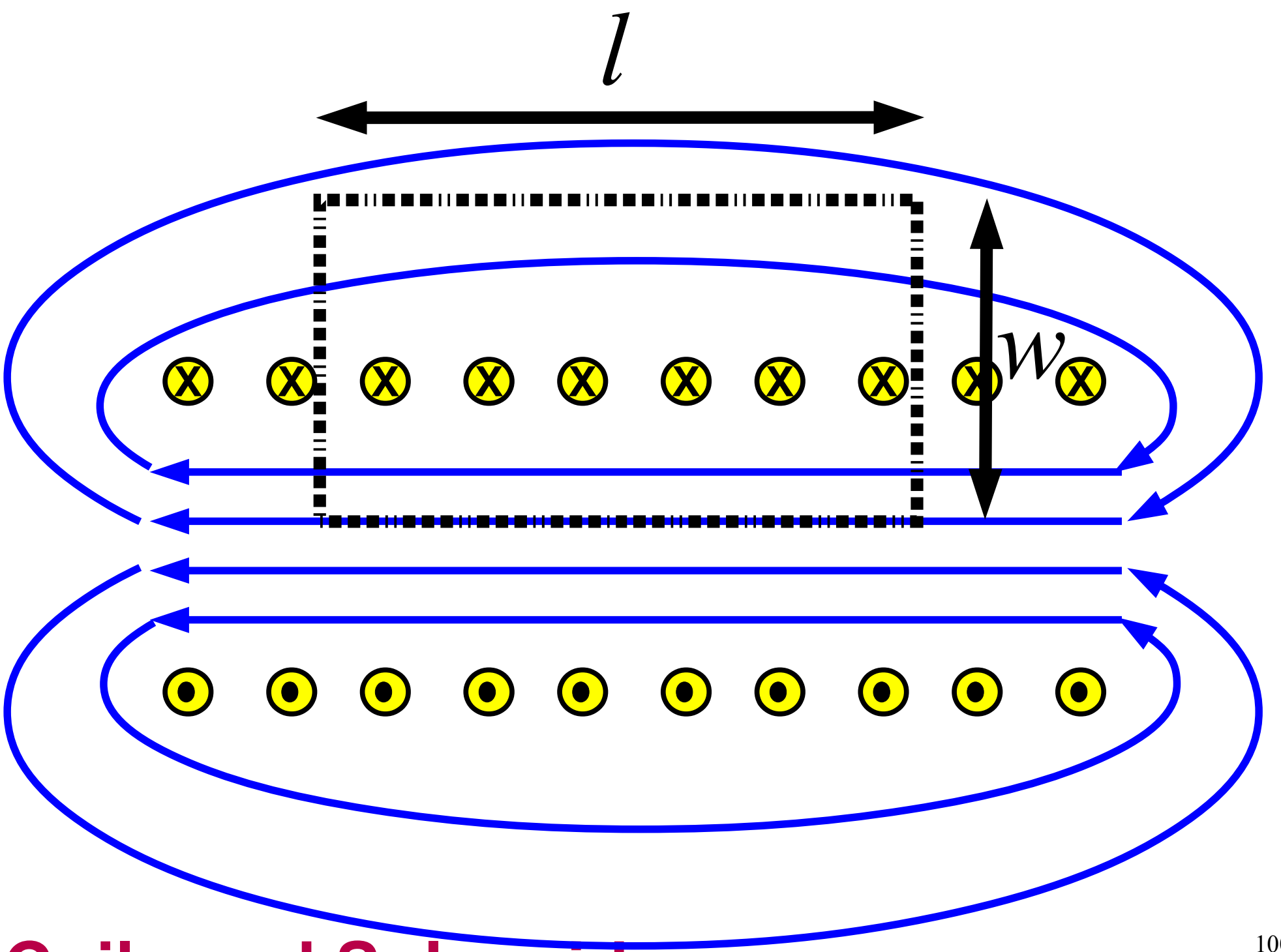


Coils and Solenoids

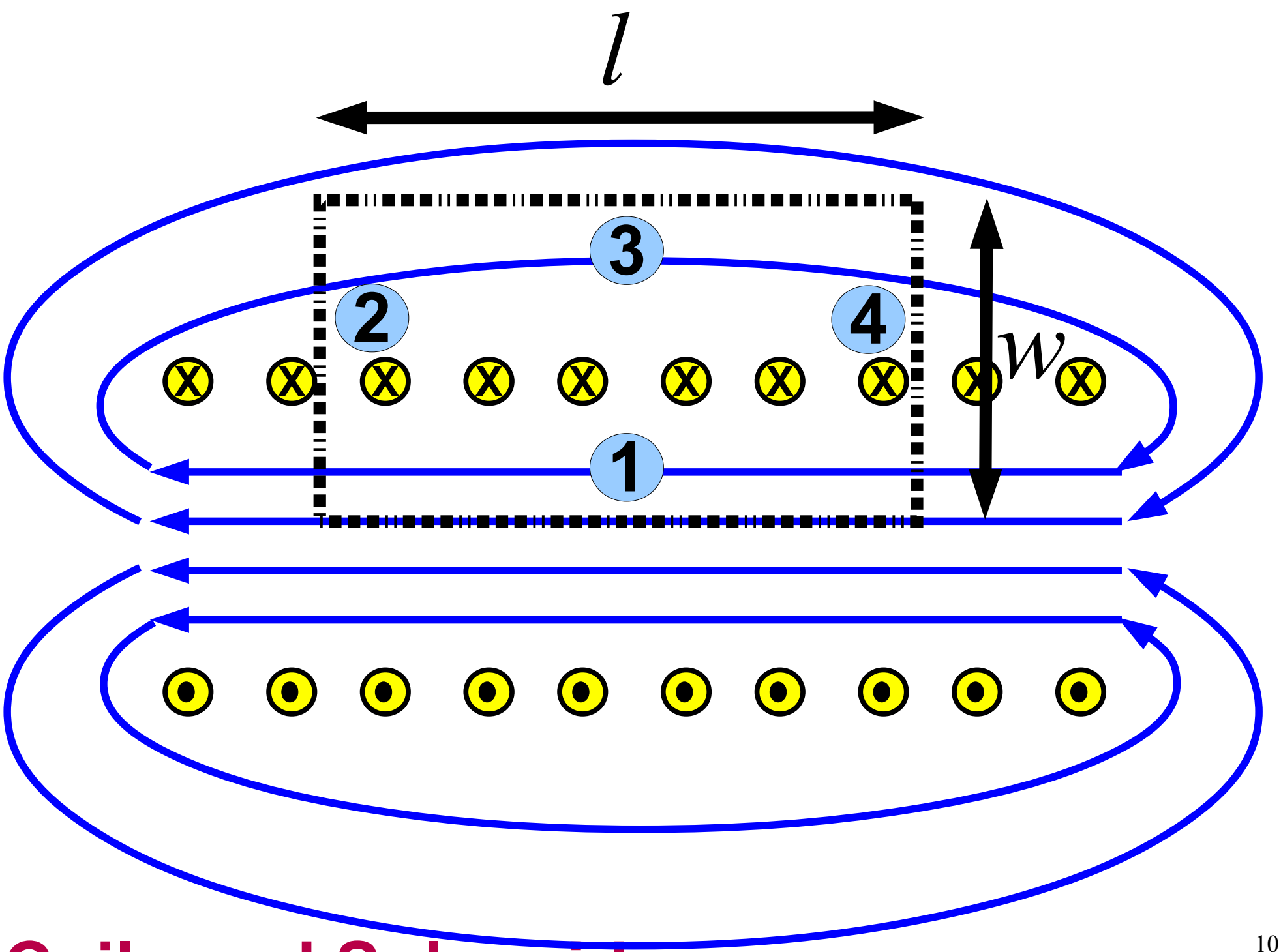
Ampere's Law – Used to find the value of the magnetic field.



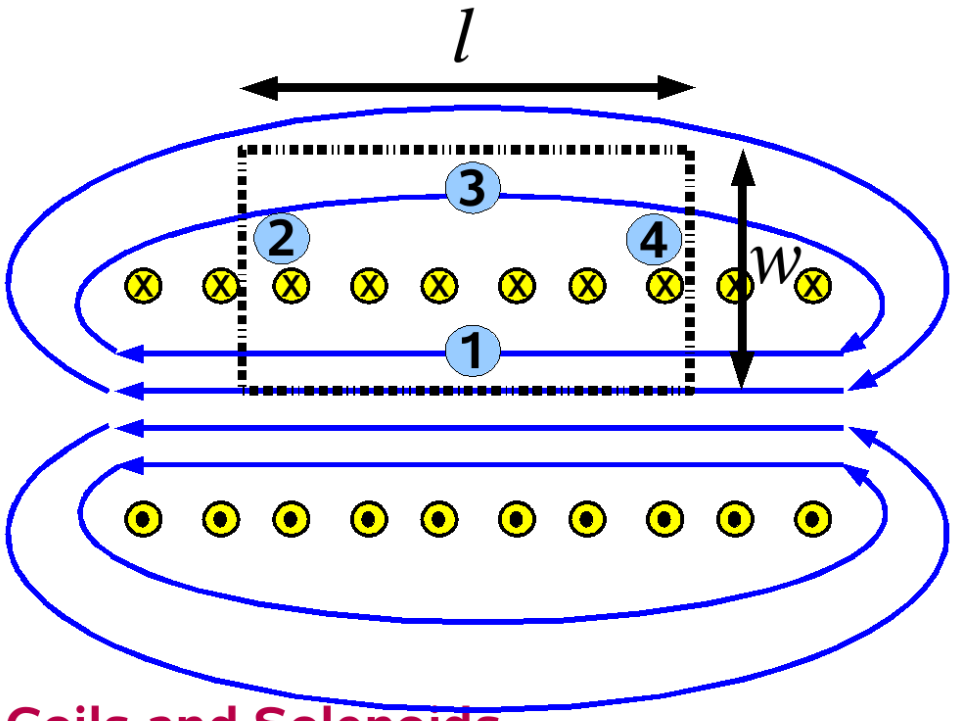
Coils and Solenoids



Coils and Solenoids



Coils and Solenoids



$N =$ Number of coil in Ampere's Surface

$$n = \frac{N}{l}$$

$$\oint B \cdot ds = \mu_o I_{\text{enclosed}}$$

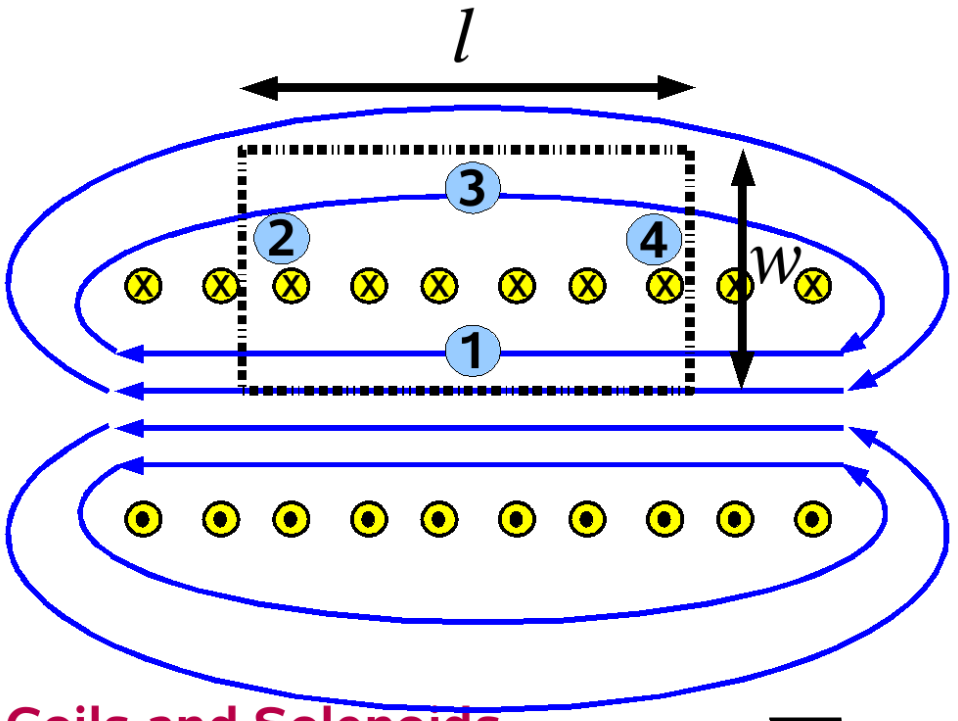
$$\sum_{\text{loop}} B_{\parallel} \Delta s = \mu_o I$$

Coils and Solenoids

$$B_{\parallel} \Delta s_1 + B_{\parallel} \Delta s_2 + B_{\parallel} \Delta s_3 + B_{\parallel} \Delta s_4 = \mu_o N I$$

$$B l + 0 + 0 + 0 = \mu_o N I$$

$$B = \mu_o \frac{N}{l} I = \mu_o n l$$



$N =$ Number of coil in Ampere's Surface

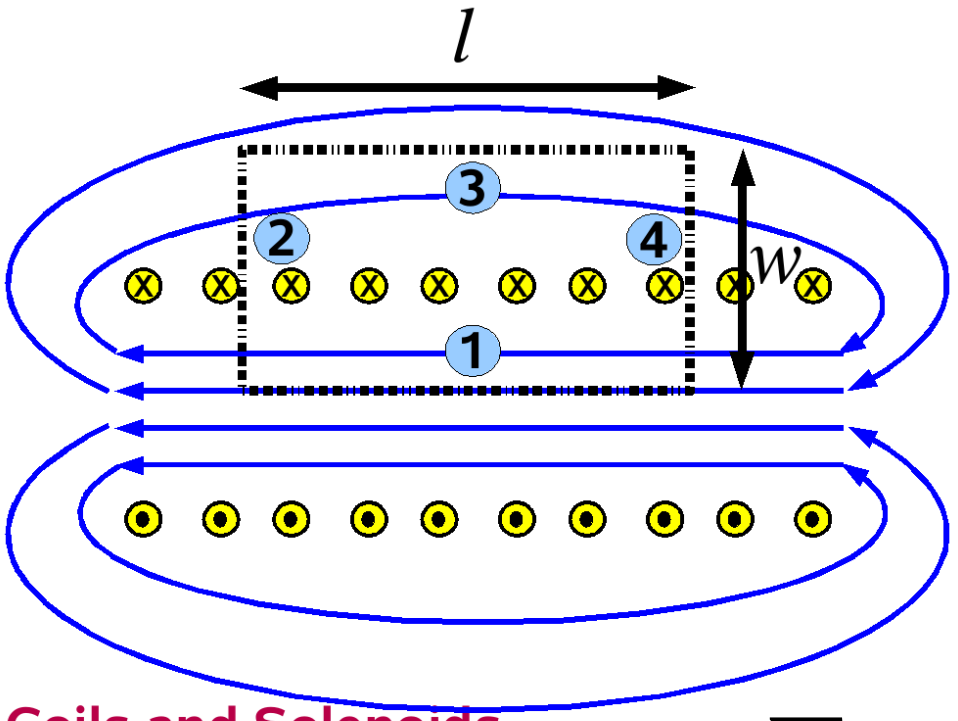
$$\sum_{\text{loop}} B_{\parallel} \Delta l = \mu_o I$$

Coils and Solenoids

$$\sum_{\text{loop}} B_{\parallel} \Delta l = \mu_o I$$

$$\sum_{1} B_{\parallel} \Delta l + \cancel{\sum_{2} B_{\parallel} \Delta l} + \cancel{\sum_{3} B_{\parallel} \Delta l} + \cancel{\sum_{4} B_{\parallel} \Delta l} = \mu_o N I$$

$$\cancel{\sum_{2} B_{\parallel} \Delta l} \quad 0 \qquad \cancel{\sum_{3} B_{\parallel} \Delta l} \quad 0 \qquad \cancel{\sum_{4} B_{\parallel} \Delta l} \quad 0$$



$N =$ Number of coil in Ampere's Surface

$$\sum_{\text{loop}} B_{\parallel} \Delta l = \mu_o I$$

Coils and Solenoids

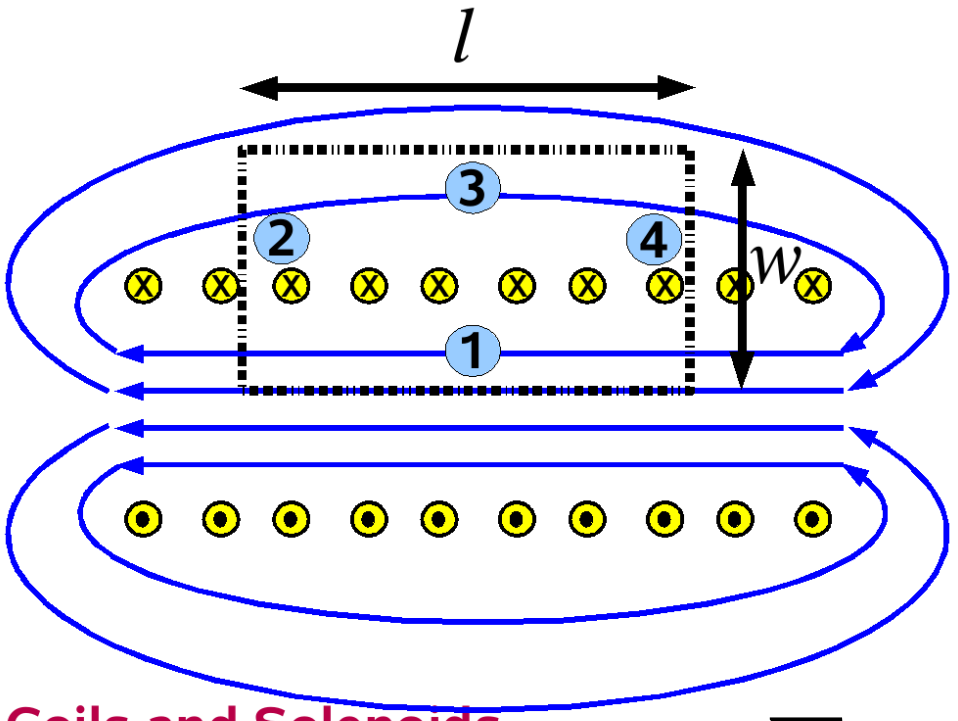
$$\sum_{\text{loop}} B_{\parallel} \Delta l = \mu_o I$$

$$\sum_{1} B_{\parallel} \Delta l + \sum_{2} B_{\parallel} \Delta l + \sum_{3} B_{\parallel} \Delta l + \sum_{4} B_{\parallel} \Delta l = \mu_o N I$$

$$\sum_{2} B_{\parallel} \Delta l = 0 \qquad \sum_{3} B_{\parallel} \Delta l = 0 \qquad \sum_{4} B_{\parallel} \Delta l = 0$$

$$\sum_{1} B_{\parallel} \Delta l = \mu_o N I$$

$$B_{\parallel} l = \mu_o N I$$



$N =$ Number of coil in Ampere's Surface

$$B_{\parallel} = \mu_o \frac{N}{l} I = \mu_o n I$$

$$n = \frac{N}{l} = \text{\# couils per length}$$

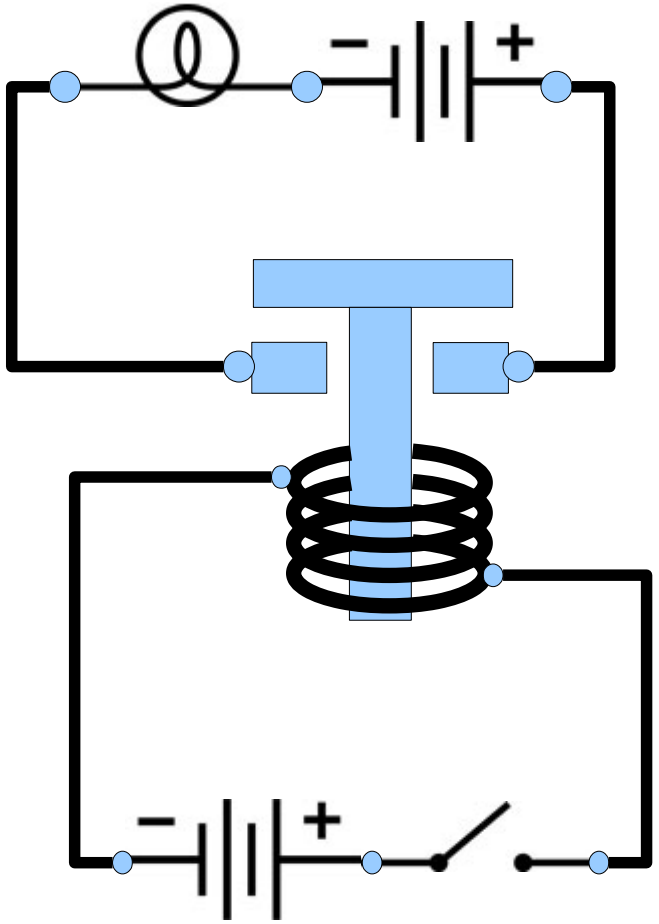
Coils and Solenoids

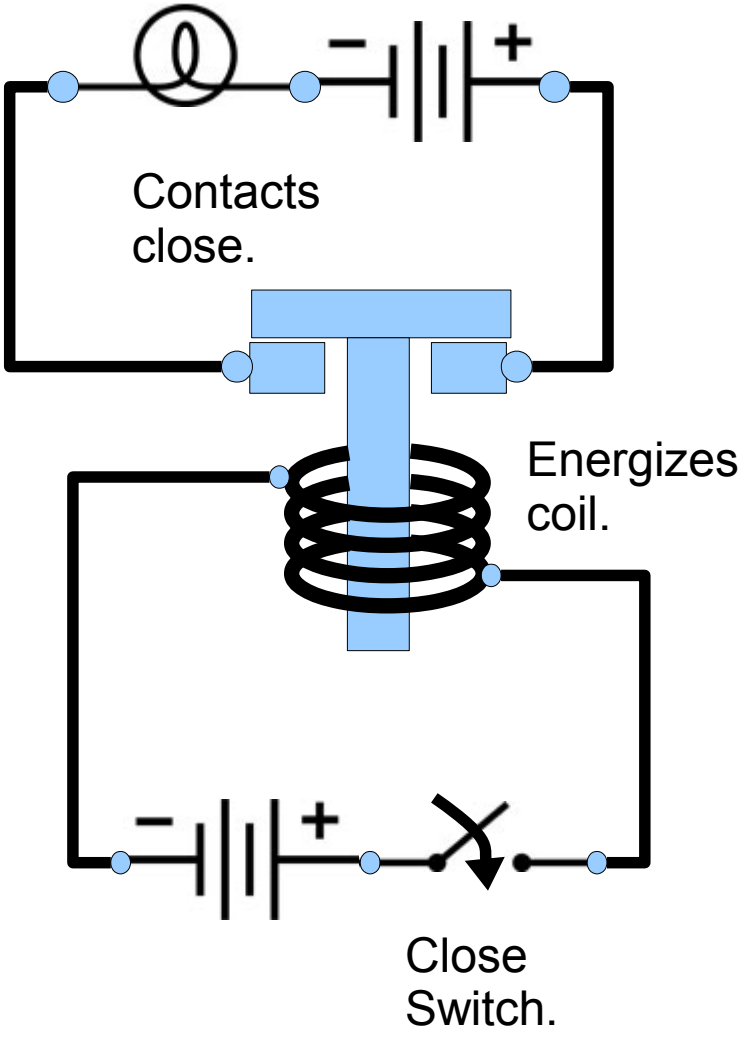
$$\sum_{\text{loop}} B_{\parallel} \Delta l = \mu_o I$$

$$\sum_{1} B_{\parallel} \Delta l + \cancel{\sum_{2} B_{\parallel} \Delta l} + \cancel{\sum_{3} B_{\parallel} \Delta l} + \cancel{\sum_{4} B_{\parallel} \Delta l} = \mu_o N I$$

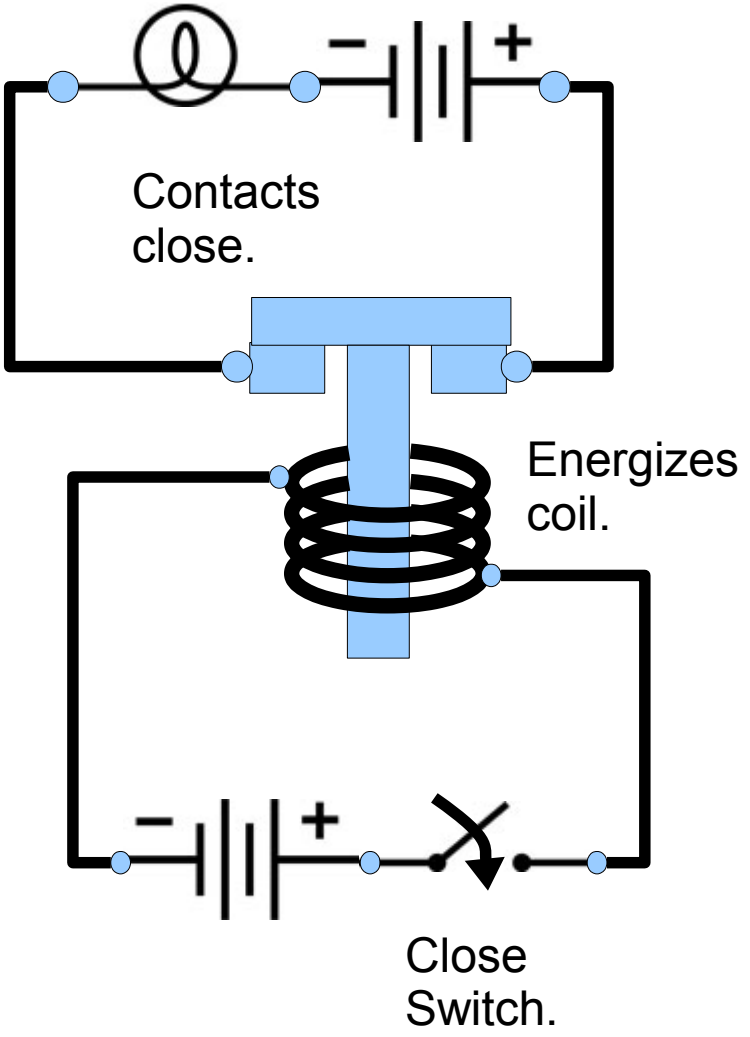
$$\sum_{1} B_{\parallel} \Delta l = \mu_o N I$$

$$B_{\parallel} l = \mu_o N I$$





Solenoid used as a switch or contact.



Solenoid used as a switch or contact.

Television