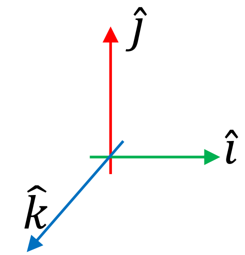
Midterm #2 Review

Very Magnetism-Focused

Regular Cross Product

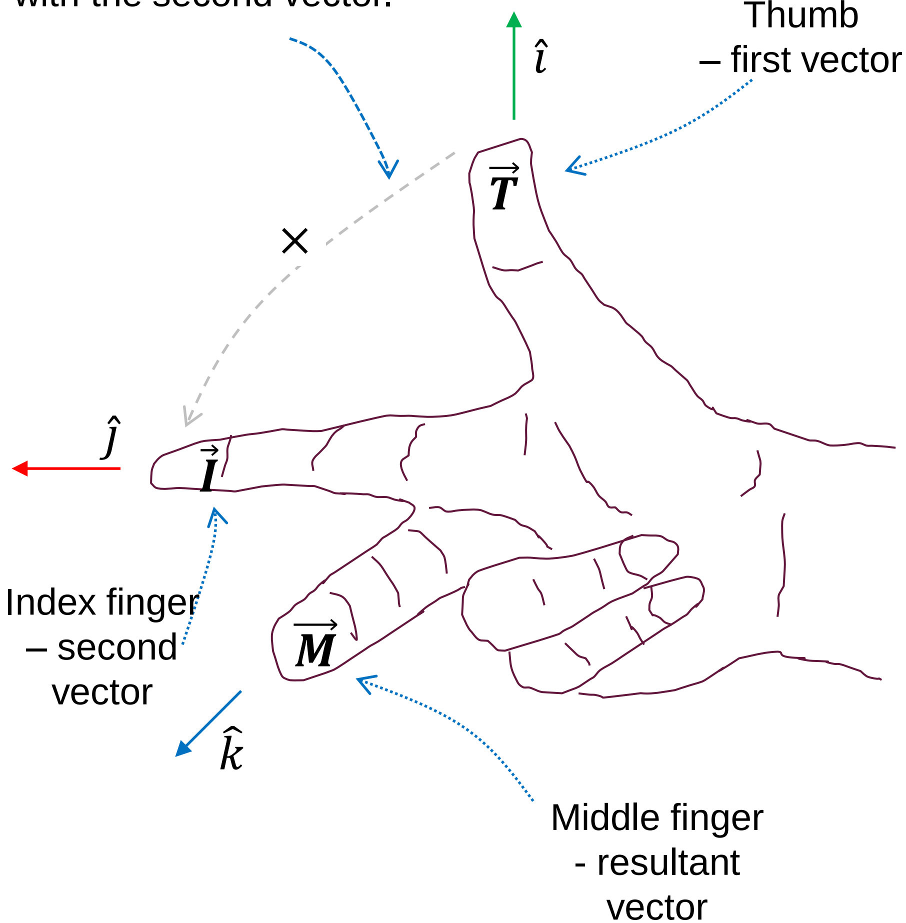
$(\mathbf{t}_{\mathbf{thumb}} - \mathbf{i}_{\mathbf{index}} - \mathbf{m}_{\mathbf{middle}})$

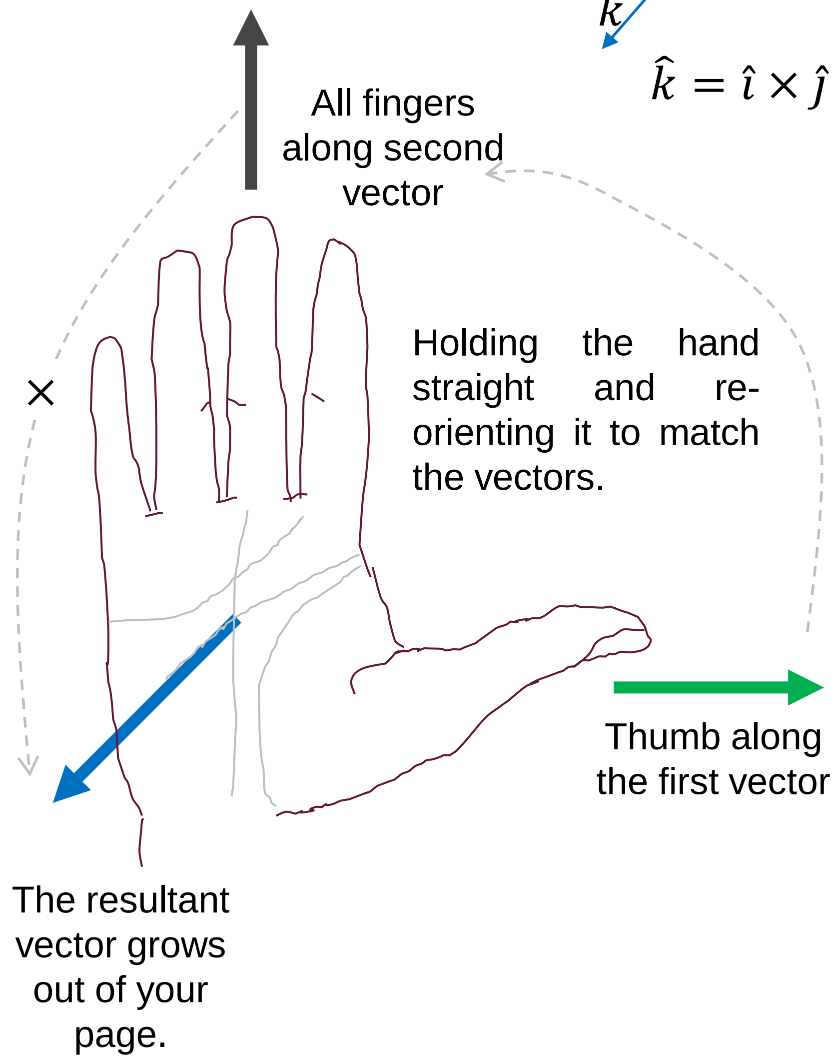


$$\hat{k} = \hat{\imath} \times \hat{\jmath}$$

$$\vec{T} \times \vec{I} = \vec{M}$$

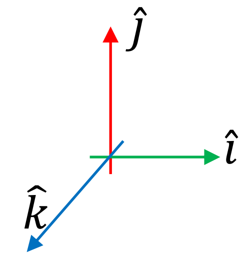
First vector is crossed with the second vector.





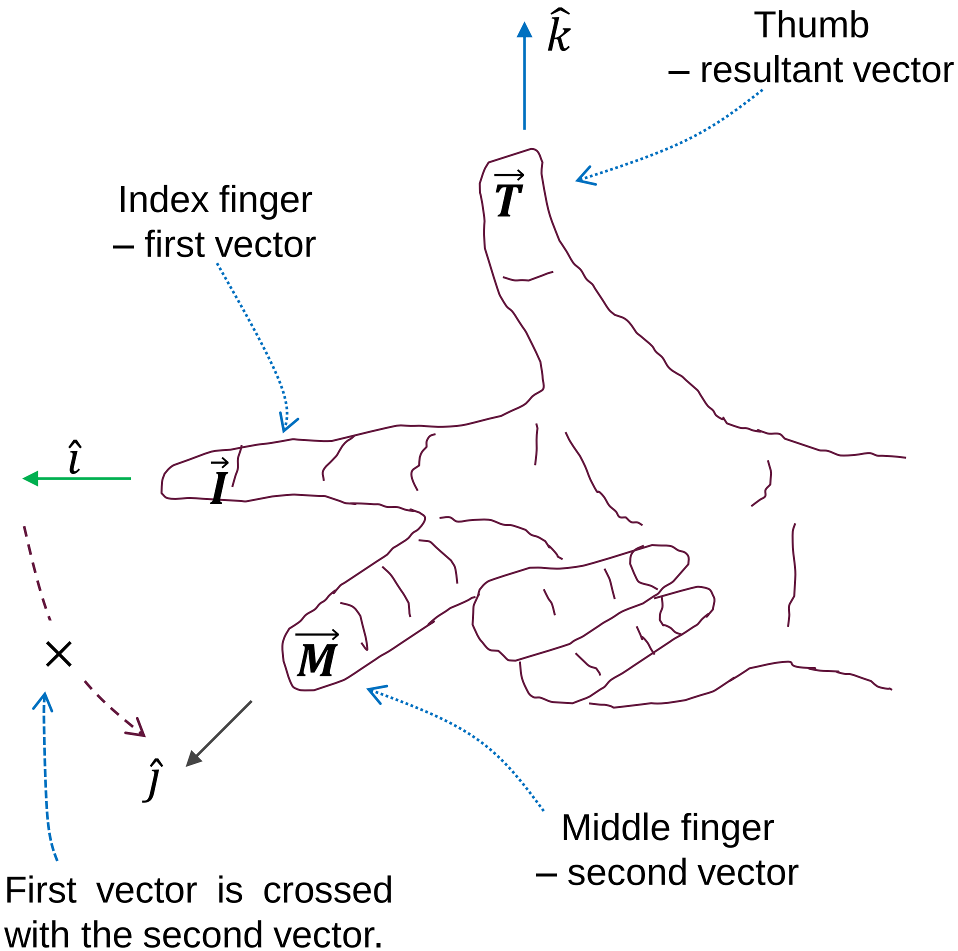
REGULAR CROSS PRODUCT

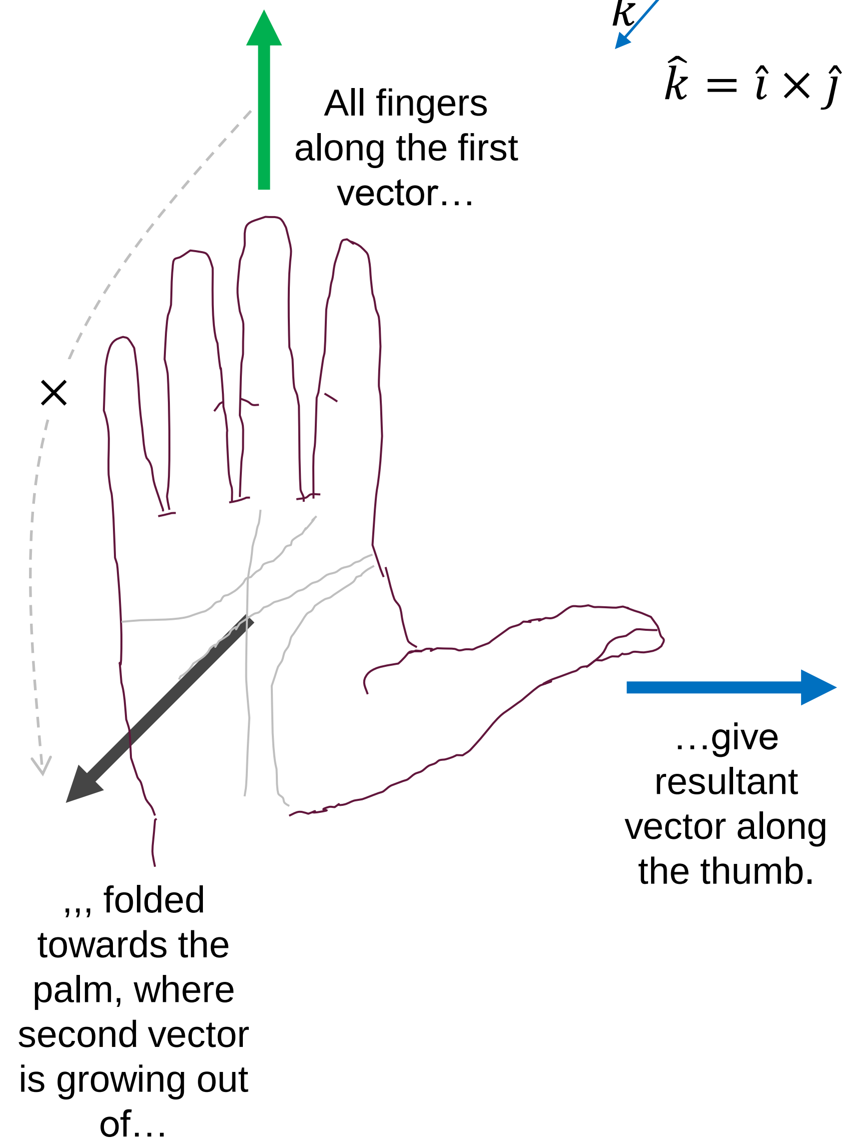
$(\mathrm{i}_{\mathrm{index}} - \mathrm{m}_{\mathrm{middle}} - \mathrm{t}_{\mathrm{thumb}})$



$$\hat{k} = \hat{\imath} \times \hat{j}$$

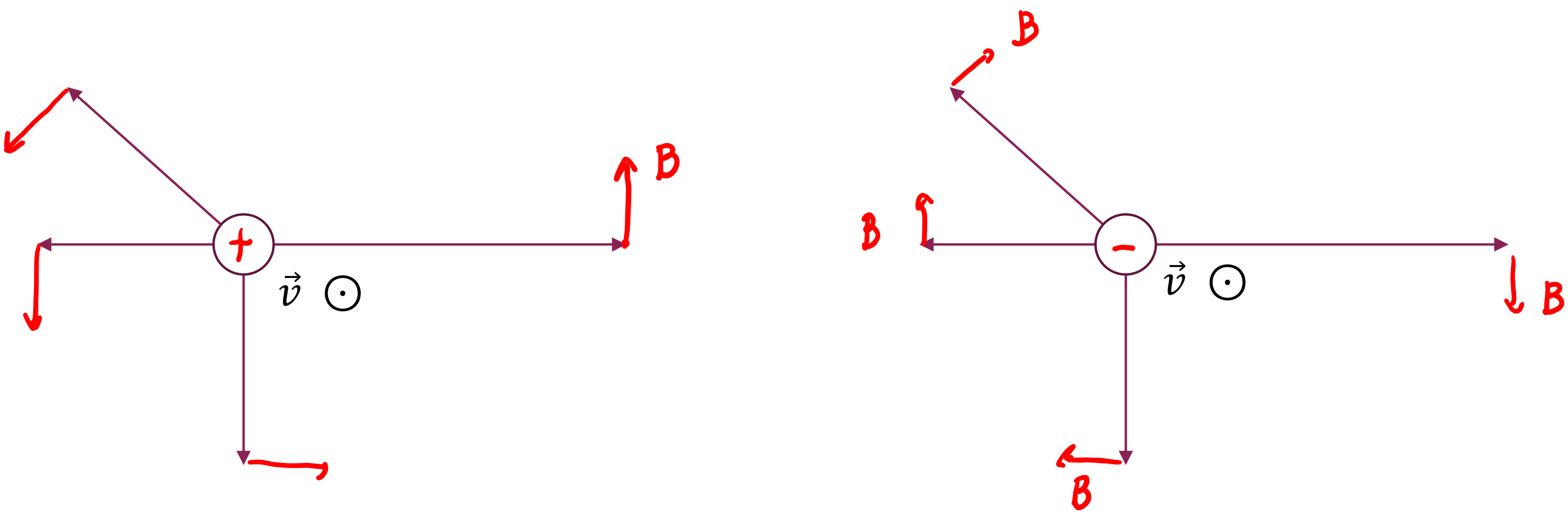
$$\vec{I} \times \vec{M} = \vec{T}$$





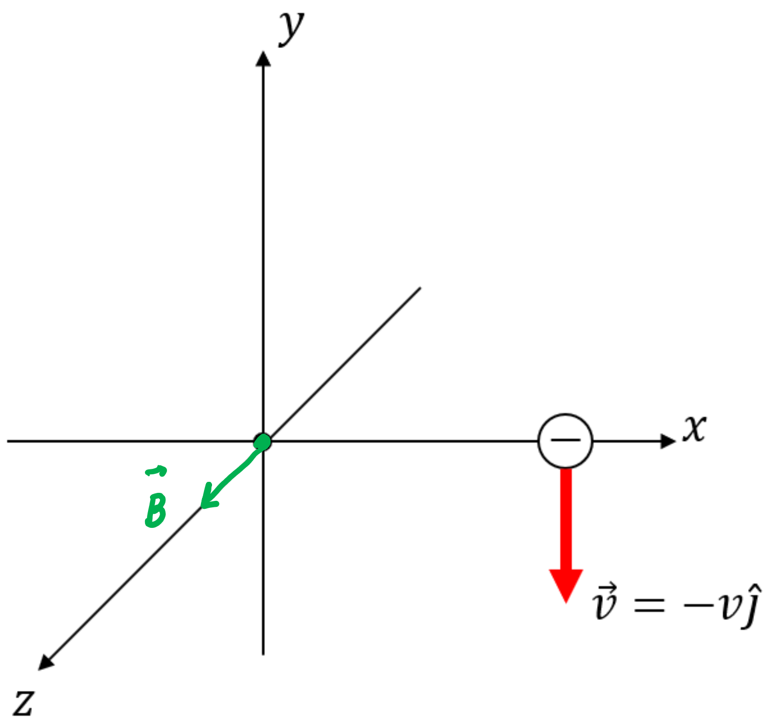
Moving charges create magnetic field:

$$\vec{B}_{moving\ Charge} = \frac{\mu_0}{4\pi}\frac{q(\vec{v}\times\hat{r})}{r^2}$$



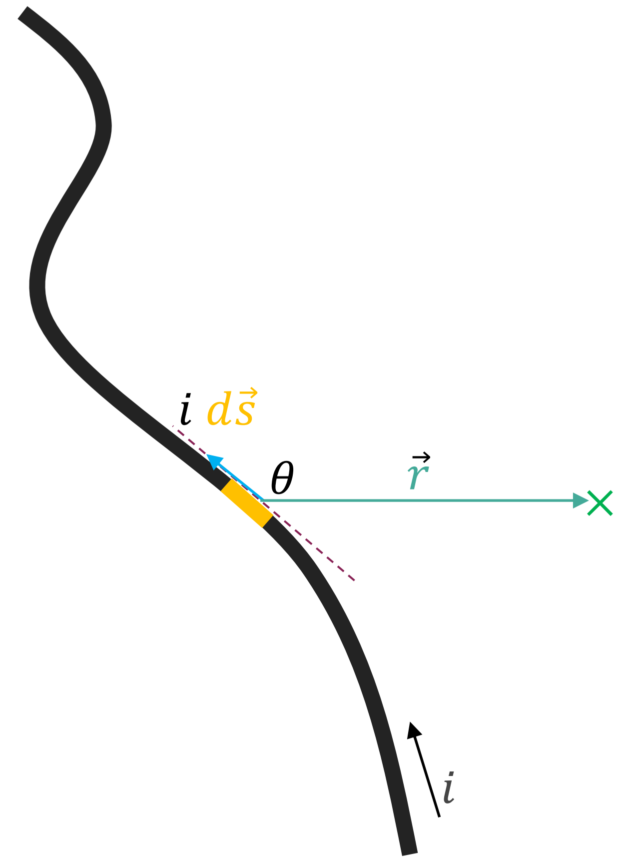
Many moving charges (current) do that as well!

Which way is the field created by this particle at the origin?



Magnetic Field due to a Current

Consider a wire of arbitrary shape carrying a current i.



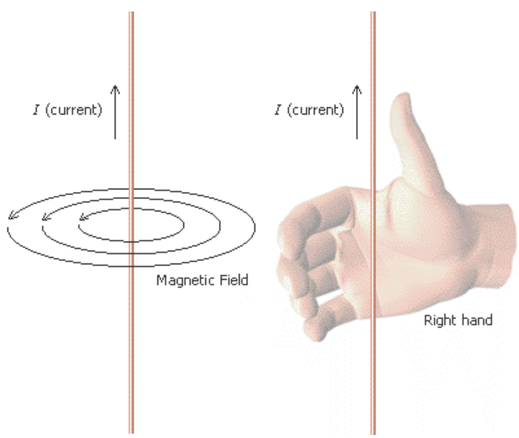
Magnetic field due to a length element $d\vec{s}$ carrying current i at point P located distance r from the element is defined by Biot-Savart Law:

$$d\vec{B} = \frac{\mu_0}{4\pi}\frac{i d\vec{s} \times \hat{r}}{r^2} \rightarrow \boldsymbol{B_{longwire} = \frac{\mu_0 I}{2\pi d}}, \boldsymbol{B_{loop} = \frac{\mu_0 I}{2d}}$$

Note: magnitude of the field element $dB = \frac{\mu_0}{4\pi}\frac{ids\sin\theta}{r^2}$

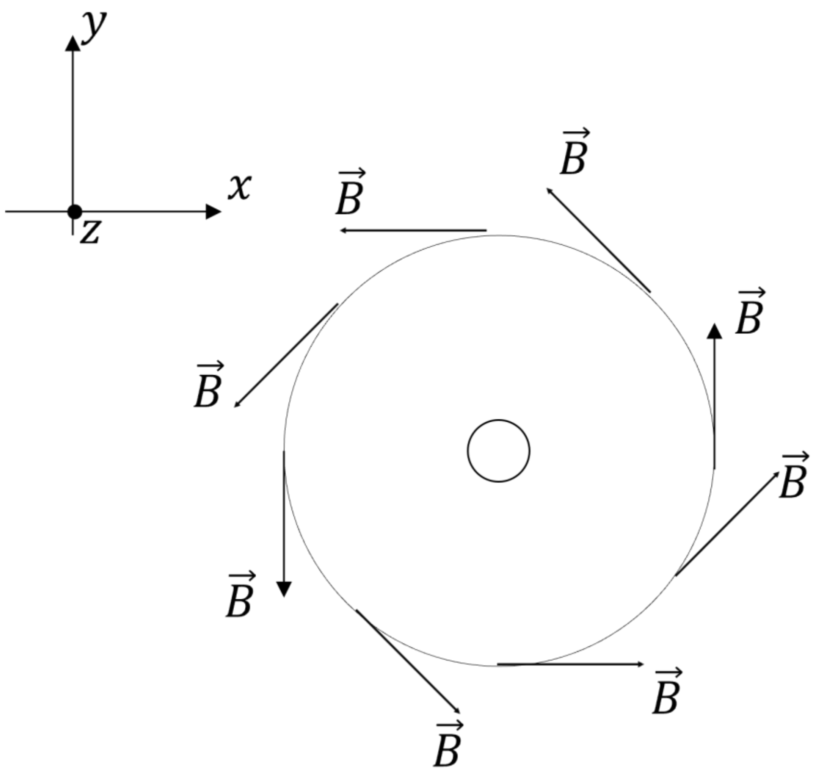
The direction can be determined using a hand rule.

oooor this handy cheat:



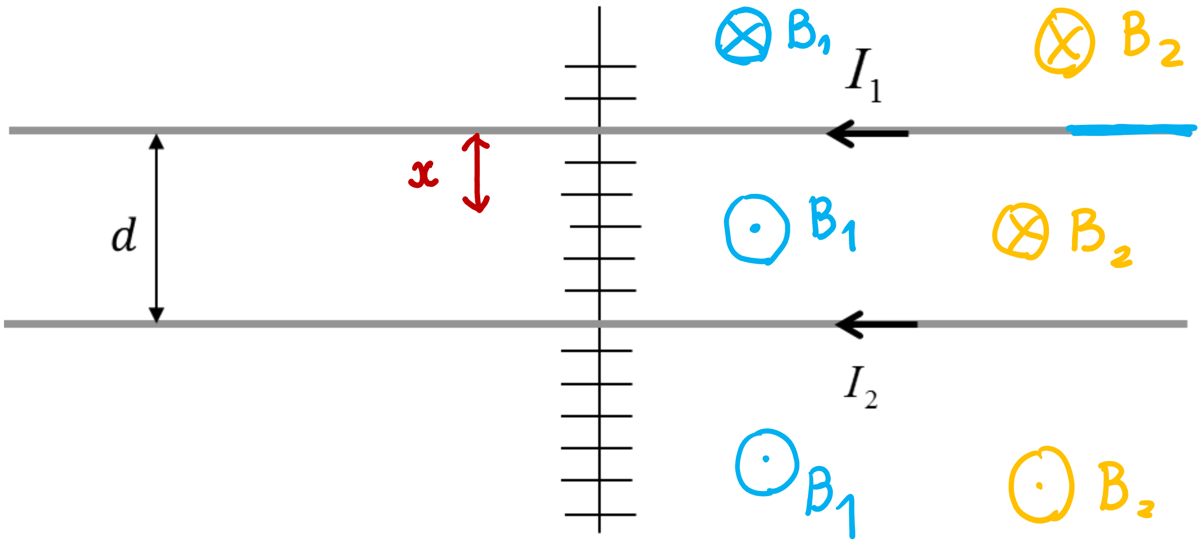
$$\mu_0 = 4\pi \times 10^{-7}\, T \cdot \frac{m^2}{A}$$

Which way is the conventional current?



Magnetic Field from Two Wires

Two very long lines ($L = 4.6\, m\ each$) carrying currents $I_1 = 0.5\, A$ and $I_2 = 1.0\, A$ in the same direction are separated by distance $d = 6.0$ mm.
Where along the vertical line drawn in the picture would the net magnetic field be zero?



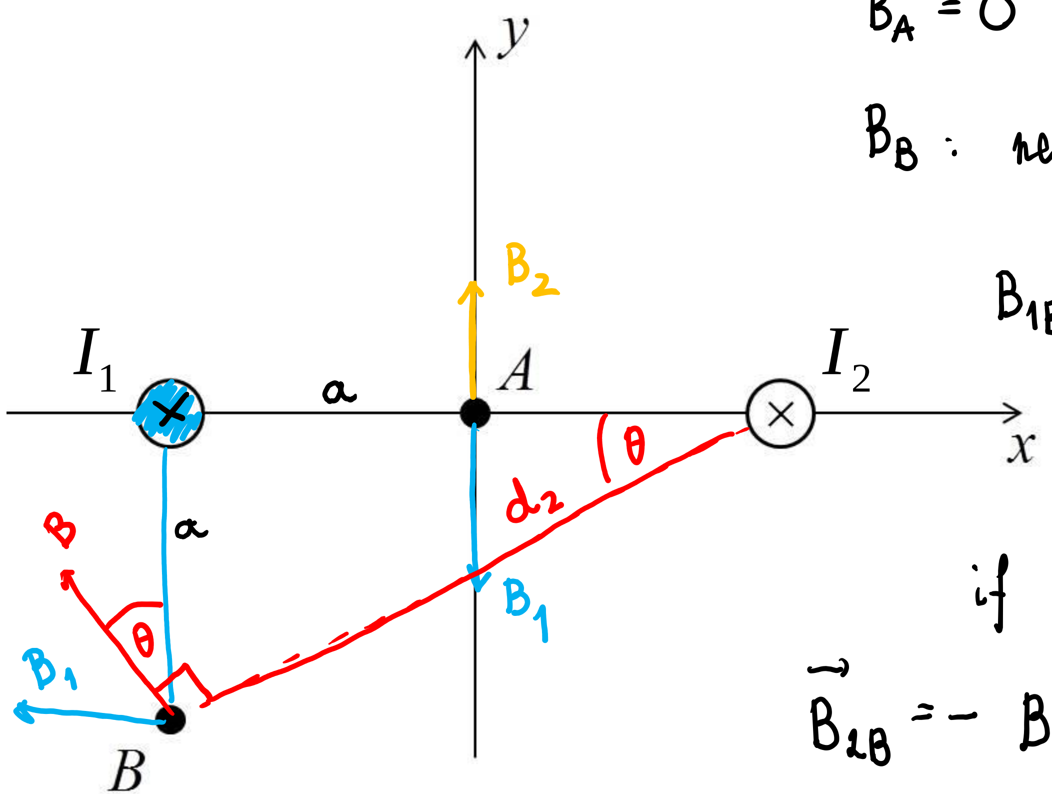
$$\frac{\cancel{\mu_0} I_1}{\cancel{2\pi} x} = \frac{\cancel{\mu_0} I_2}{\cancel{2\pi}(d-x)} \rightarrow \frac{I_1}{x} = \frac{I_2}{d-x}$$

$$I_1 d - I_1 x = I_2 x$$

$$I_1 d = (I_2 + I_1) x \rightarrow x = \frac{I_1 d}{I_1 + I_2}$$

EXAMPLE

Two wires separated by 20.0 cm are carrying identical current $I_1 = I_2 = 2.0\ \text{A}$ into the page create magnetic field around them. What is the net magnetic field at point A, located mid-way between them and point B, located 10 cm under the left wire?



$B_A = 0$

B_B : need to add two vectors

$$B_{1B} = \frac{\mu_0 I_1}{2\pi a} \ (-x)$$

$$B_{2B} = \frac{\mu_0 I_2}{2\pi \sqrt{a^2 + (2a)^2}}$$

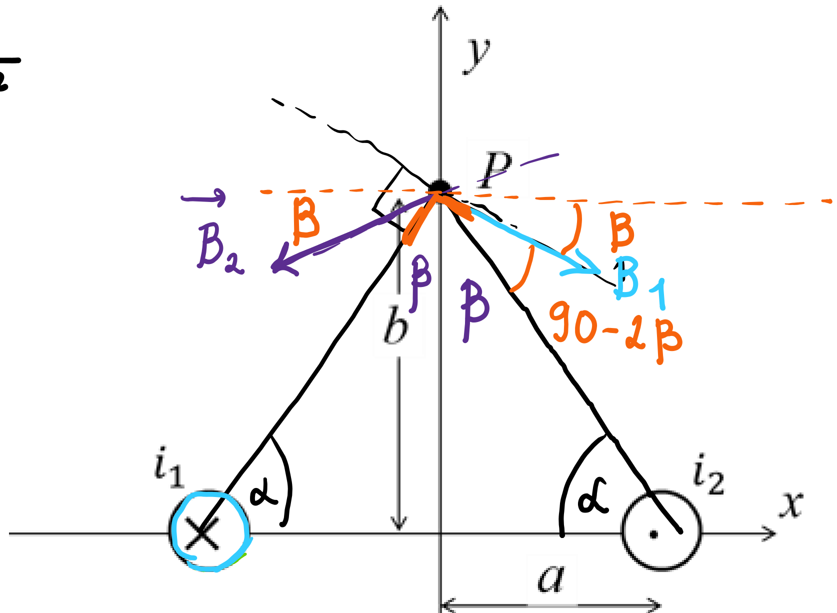
if you want components:

$$\vec{B}_{2B} = -B_{2B} \sin\theta + B_{2B} \cos\theta$$

What is the net magnetic field at point P, expressed symbolically.

$$B_1 = \frac{\mu_0 i_1}{2\pi\sqrt{a^2+b^2}}$$

$$B_2 = \frac{\mu_0 i_2}{2\pi\sqrt{a^2+b^2}}$$



DIRECTIONS

$$\vec{B}_1 = B_1 \cos\beta\,\hat{x} - B_1 \sin\beta\,\hat{y}$$

$$\vec{B}_2 = -B_1 \cos\beta\,\hat{x} - B_2 \sin\beta\,\hat{y}$$

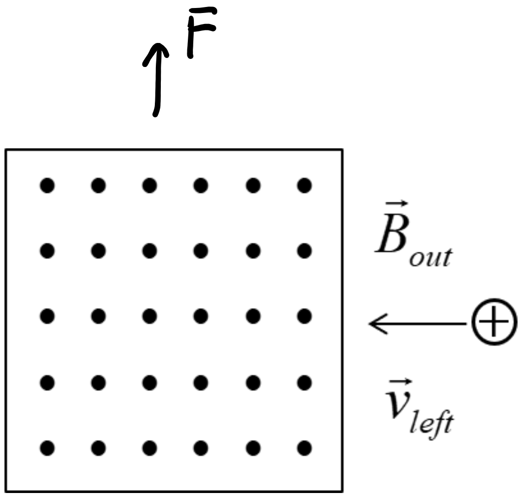
$\hat{x}$ cancels out!

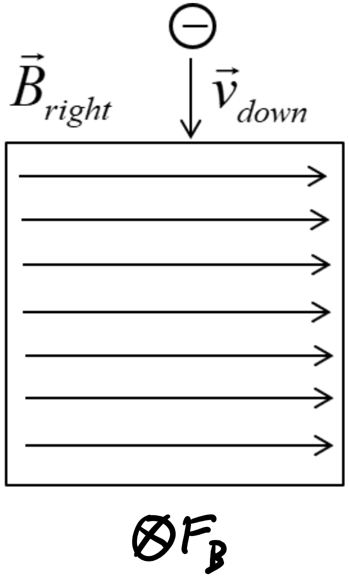
MOVING CHARGES RESPOND TO MAGNETIC FIELD

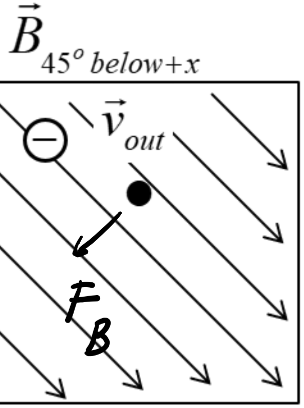
(LIKE IN LIFE, YOU RESPOND TO WHAT YOU SEND)

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

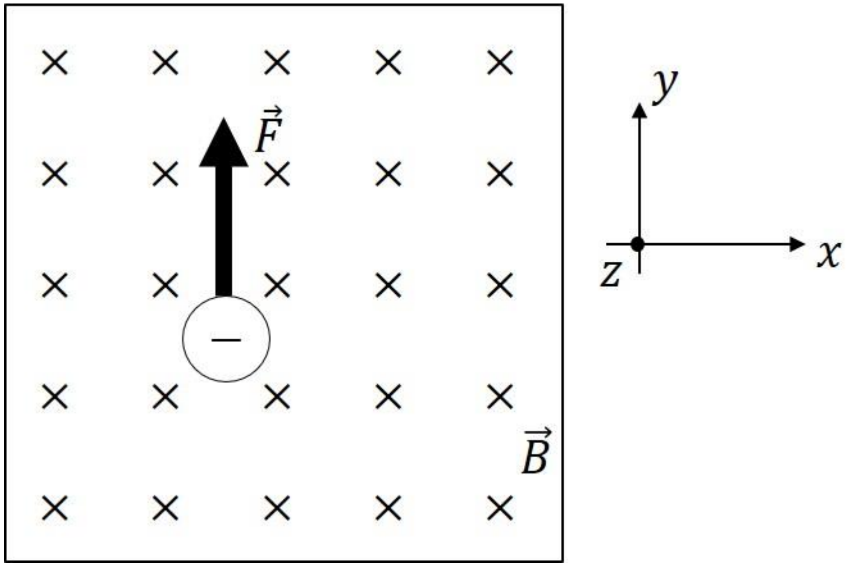
$$F = qvB\sin\theta$$

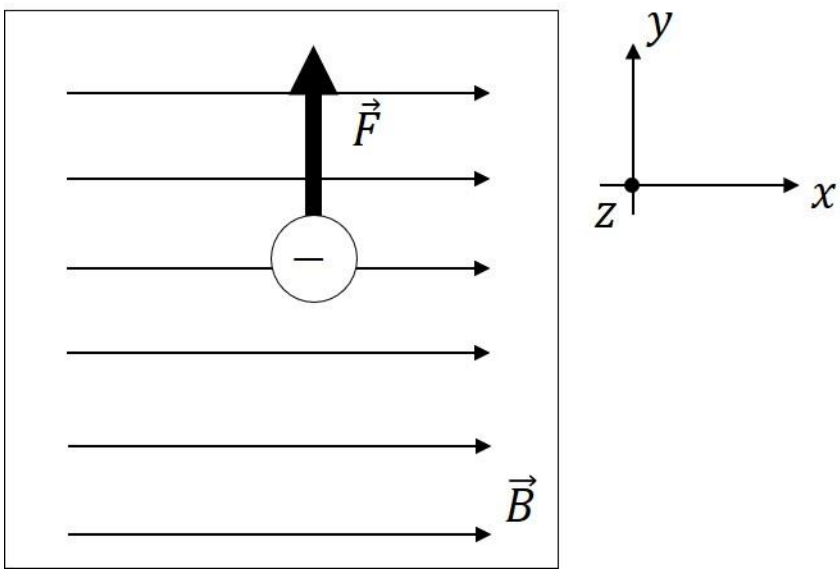




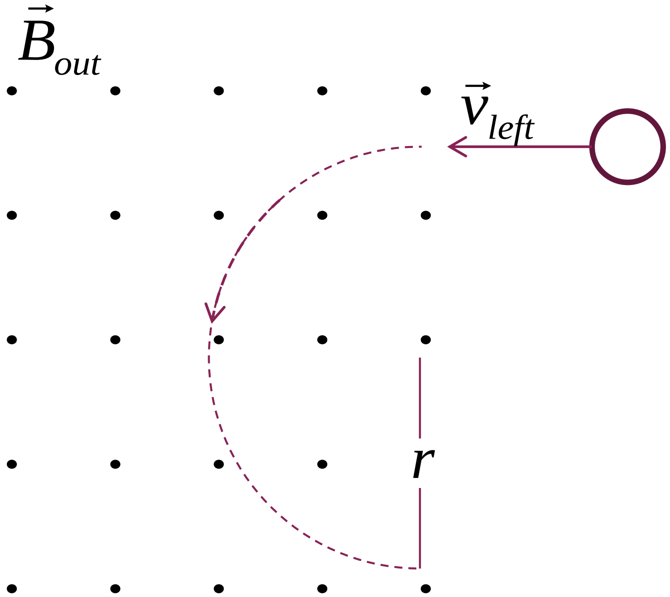


Which way are they moving?





EXAMPLE



What is the sign of this particle?

A) POSITIVE
B) NEGATIVE
C) NEUTRAL
D) NOT ENOUGH INFORMATION

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

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

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

PROTON IN THE MAGNETIC FIELD

A proton ($q = e, m_p = 1.67 \times 10^{-27} kg$) enters the magnetic field $B = 0.125\,T$ after accelerating across the potential difference $\Delta V = 12.0\,V$. What is the radius of the particle's path if the velocity vector is perpendicular to the magnetic field?

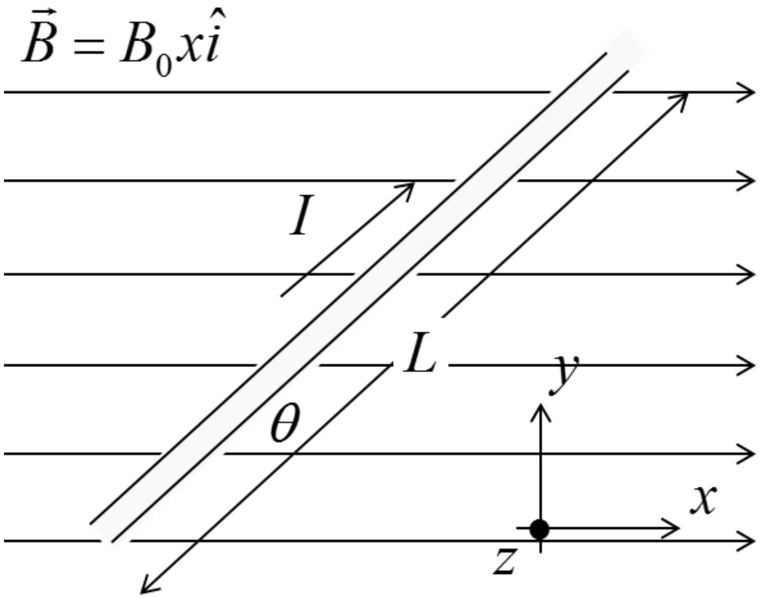
a) $R = 4.00\,mm$

b) $R = 2.83\,mm$

c) $R = 1.00\,\mu m$

d) $R = 2.00\,\mu m$

EXAMPLE – FORCE ON A CURRENT CARRYING WIRE



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

$$F_B = ILB\sin\theta$$

Force on this current carrying wire due to the magnetic field B will be

A) Out of the page

B) Into the page

C) Upwards

D) Downwards

E) To the left and up

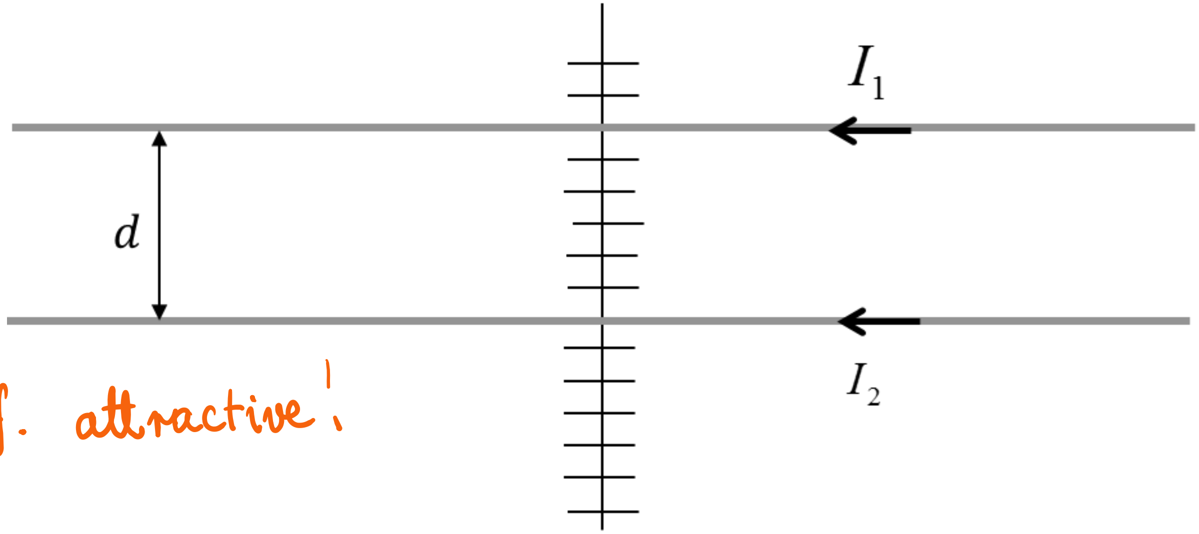
F) To the right and down

G) To the left

H) To the right

FORCE BETWEEN TWO WIRES

Two very long lines ($L = 4.6\, m\; each$) carrying currents $I_1 = 0.5\, A$ and $I_2 = 1.0\, A$ in the same direction are separated by distance $d = 6.0\,\mathrm{mm}$.
What is the force per units length that these wire exert on each other?



def. attractive!

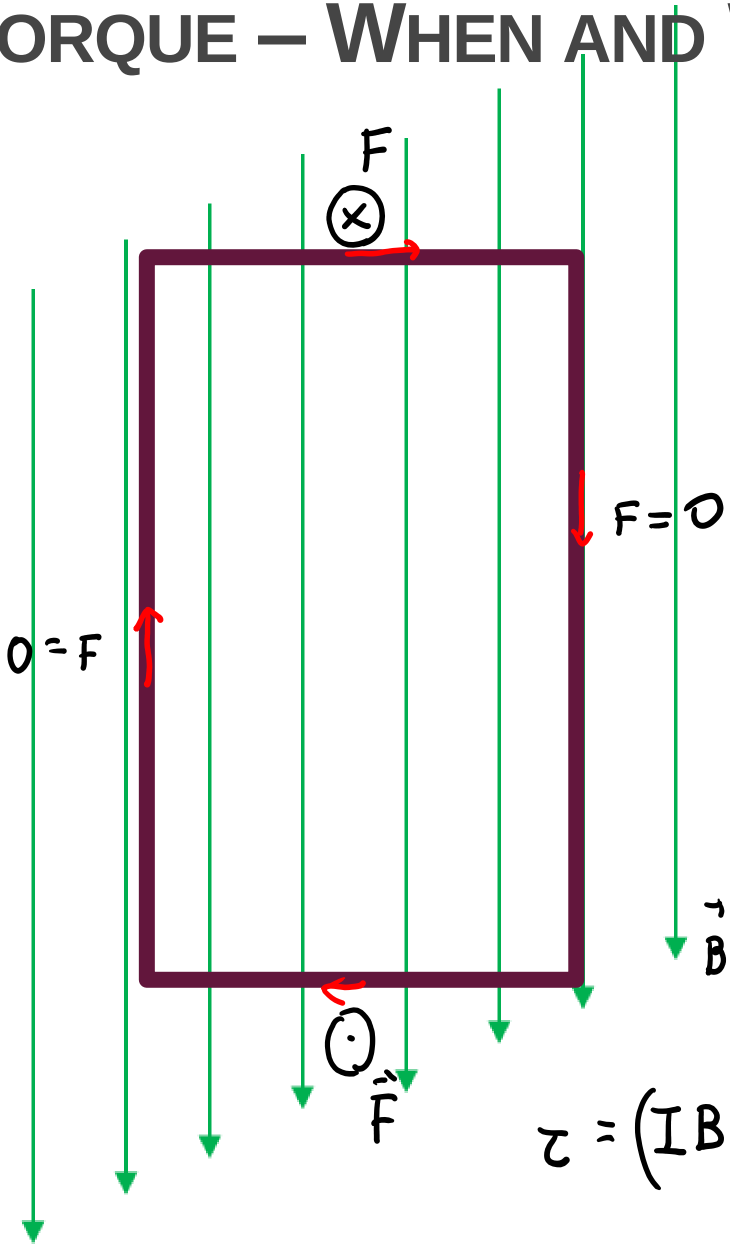
a) $\frac{F}{L} = 77\, \frac{\mu N}{m}$, attractive

b) $\frac{F}{L} = 17\, \frac{\mu N}{m}$ attractive

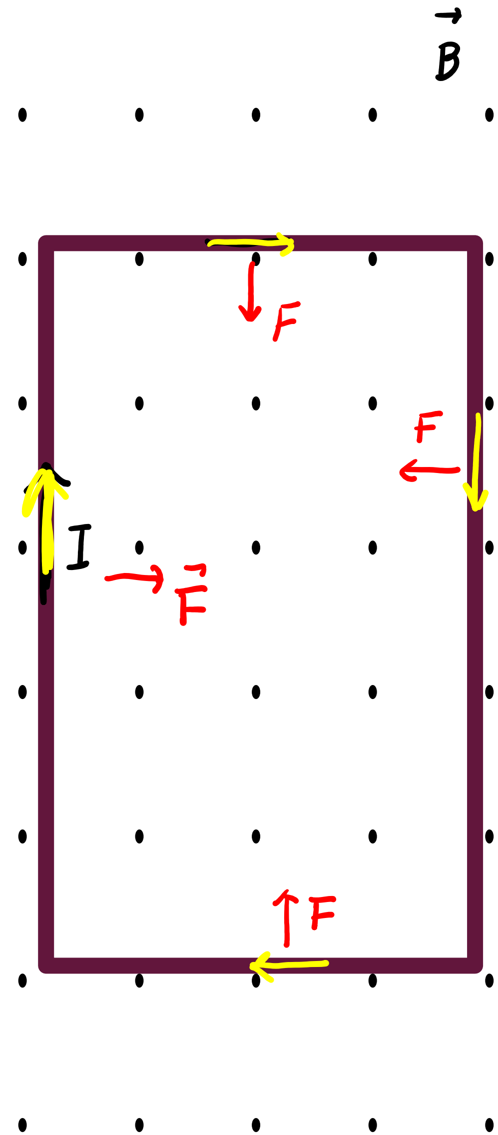
c) $\frac{F}{L} = 77\, \frac{\mu N}{m}$ repulsive

d) $\frac{F}{L} = 17\, \frac{\mu N}{m}$ repulsive

Torque – When and When not



$$\tau = (IB)A$$

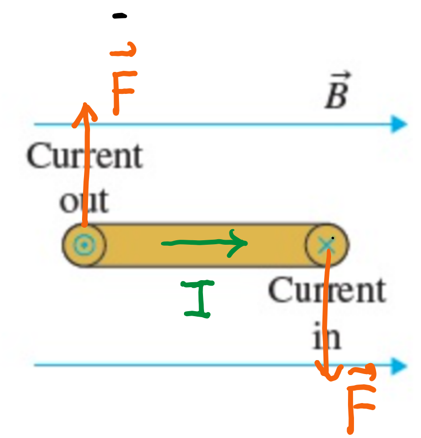


Torque – When and When not

A 4.0-A current runs through a 0.12 m^2 -area loop. The loop is in a 0.10-T $\vec{B}$ field. Consider three orientations shown in the figures.

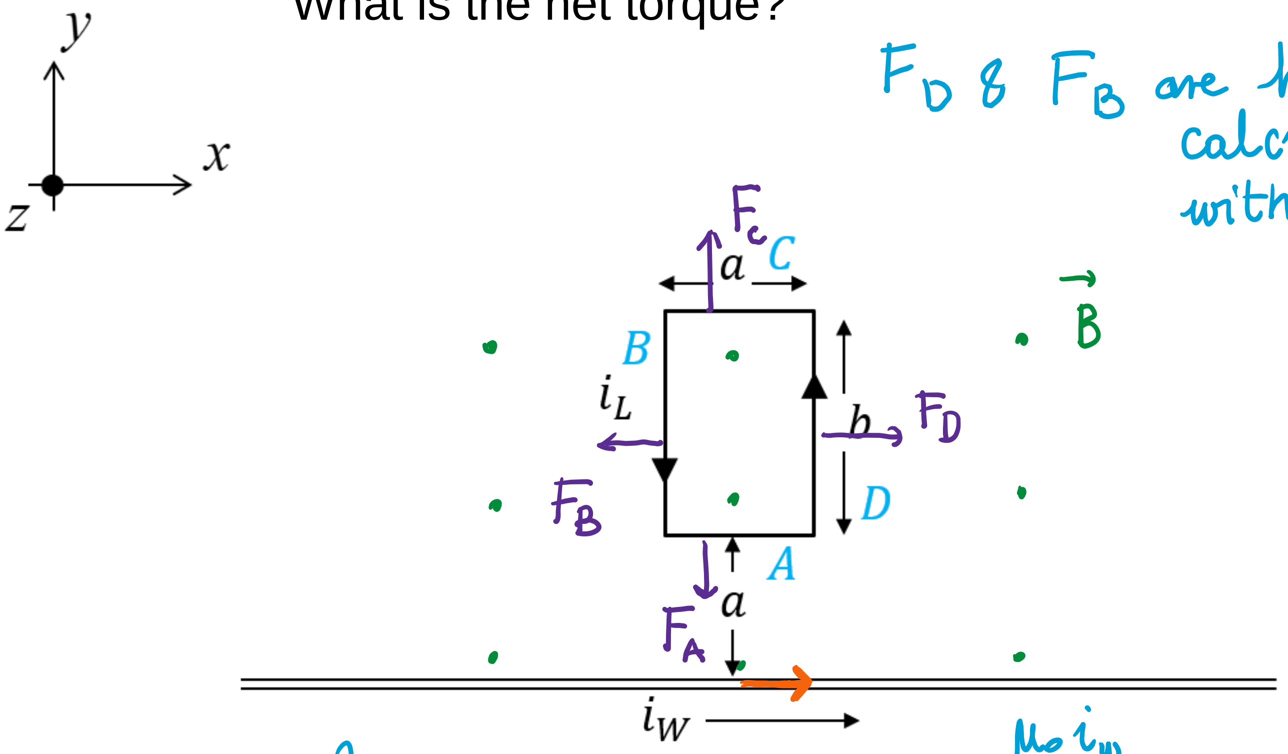
Figure

1 of 3



A wire that is held stationary carries current i_w.
A small loop is brought in the vicinity of the wire.
What is the net force on this loop?
What is the net torque?

F_D & F_B are hard to calculate without integrals



$$B_A = \frac{\mu_0 i_w}{2\pi a}$$

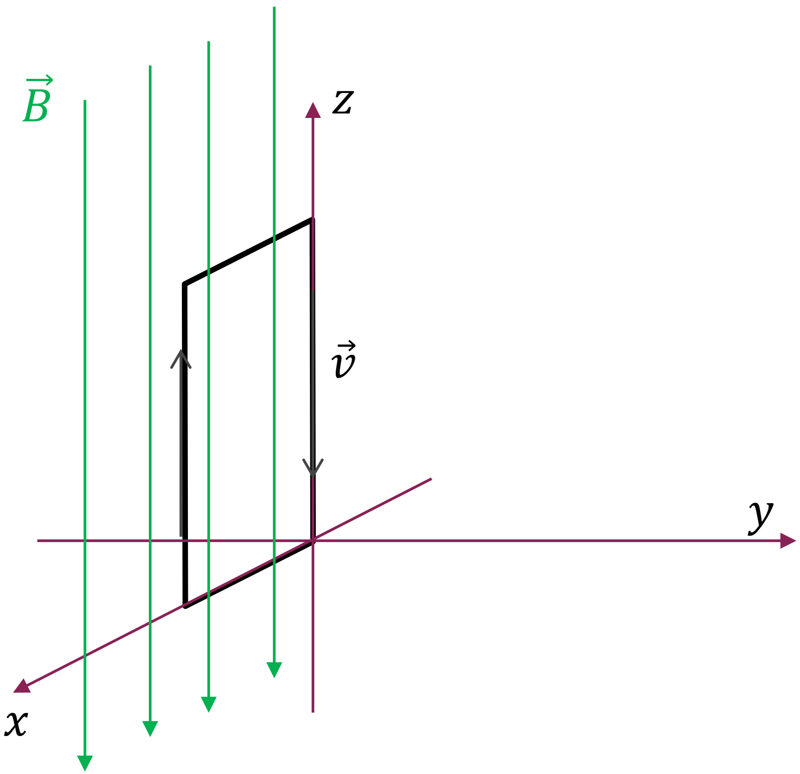
$$B_C = \frac{\mu_0 i_w}{2\pi (a+b)}$$

$$\left.\begin{aligned} F_A &= I_L a B_A \\ F_C &= I_L a B_C \end{aligned}\right\}$$ not the same forces

net force: $F_A - F_C$, toward wire

TORQUE

What is the direction of the torque on the loop shown in the picture?



$A)\ \vec{\tau} = \tau\hat{\imath}$

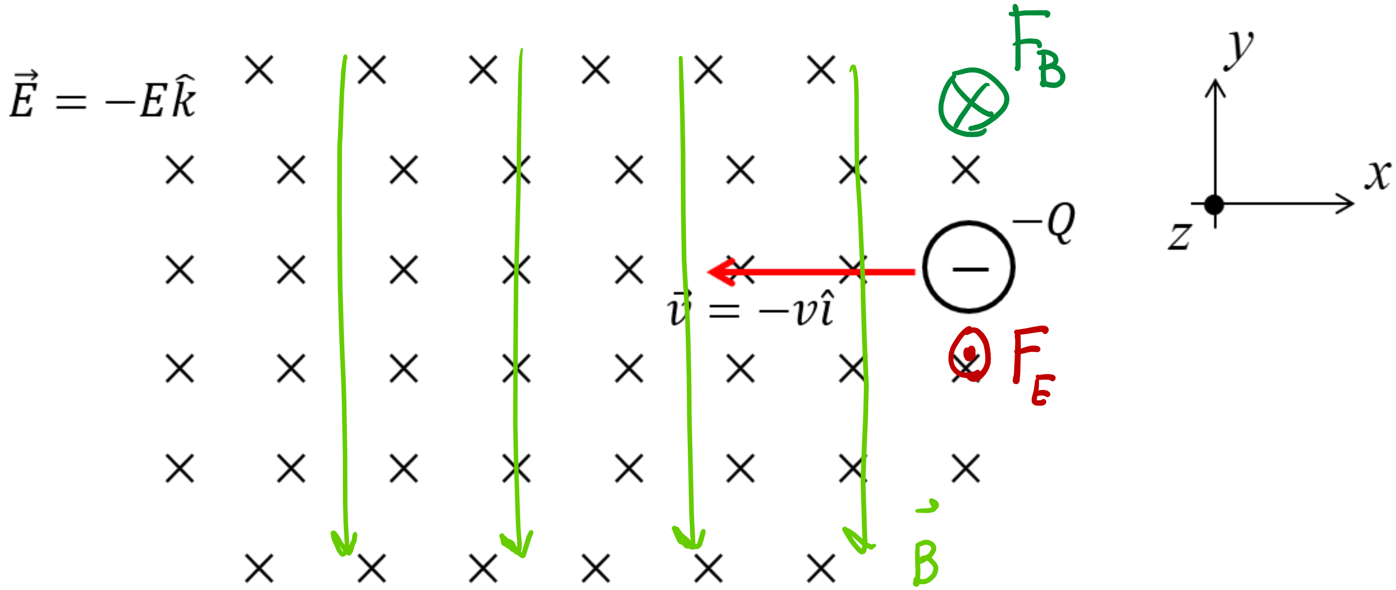
$B)\vec{\tau} = -\tau\hat{\imath}$

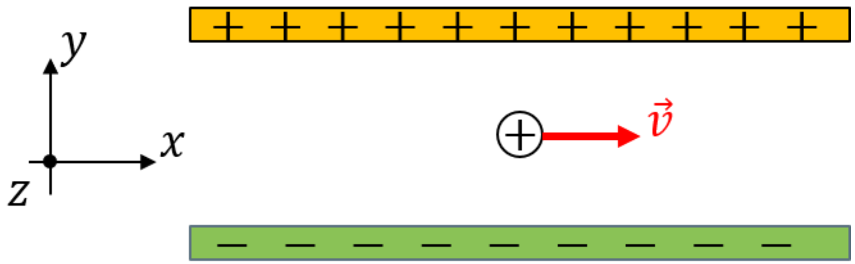
C) $\vec{\tau} = 0$

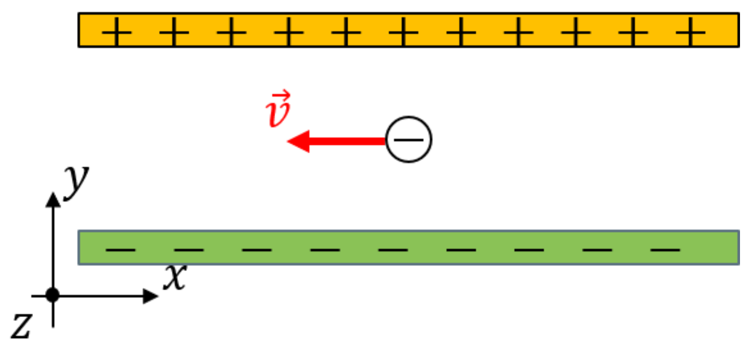
D) $\vec{\tau} = \pm\tau_x\hat{\imath} \pm \tau_y\hat{\jmath}$

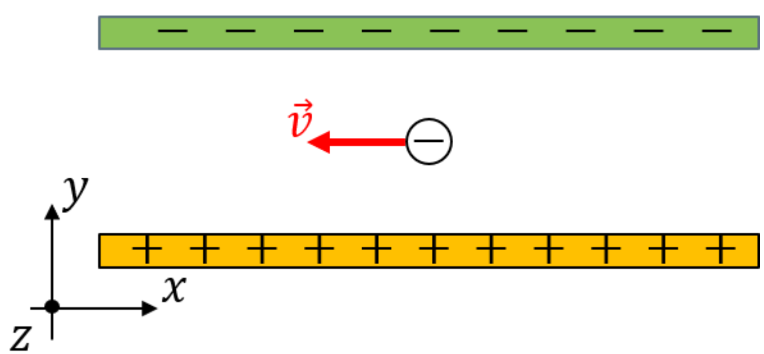
And, of course, electric and magnetic fields very much coexist!

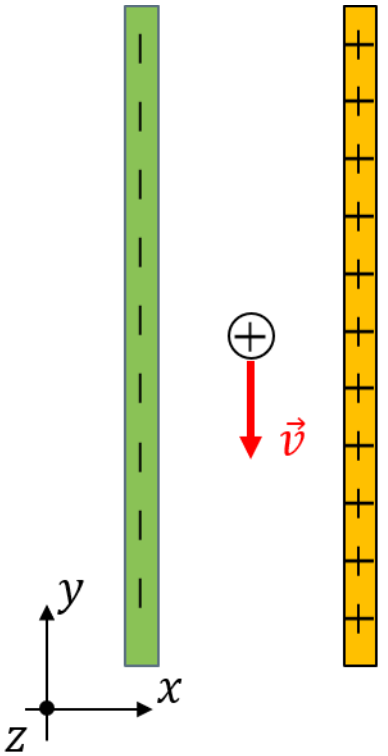
$$\vec{F} = \vec{F}_E + \vec{F}_B = q\vec{E} + q\vec{v} \times \vec{B}$$



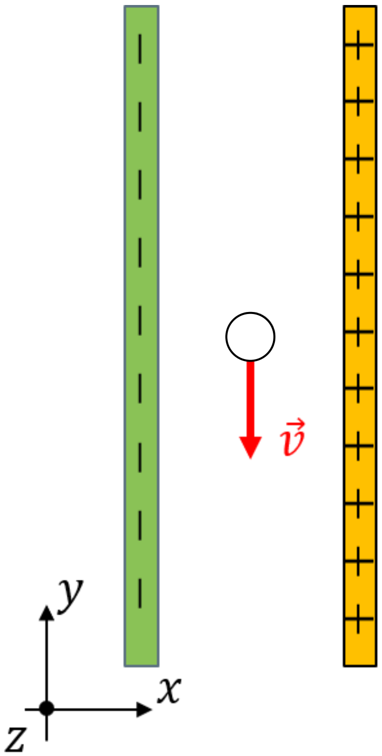

y
x
z
$\vec{v}$


$\vec{v}$
y
x
z

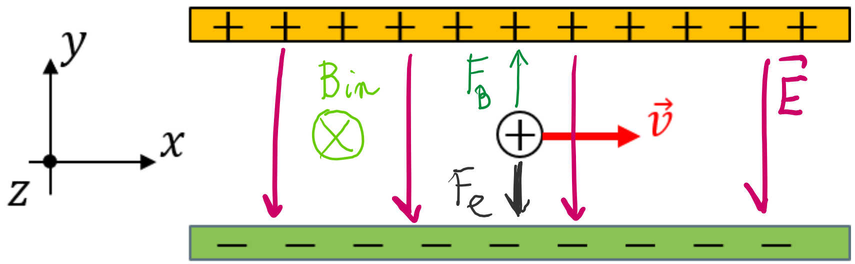

$\vec{v}$
y
x
z



$\vec{v}$
y
x
z



$\vec{v}$
y
x
z



$$\vec{F} = \vec{F_e} + \vec{F_B}$$

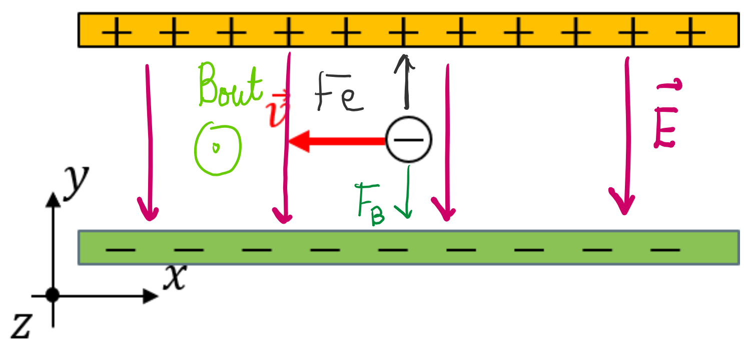
$$= q\vec{E} + q\vec{v} \times \vec{B}$$

in velocity selector

$$\vec{F} = 0$$

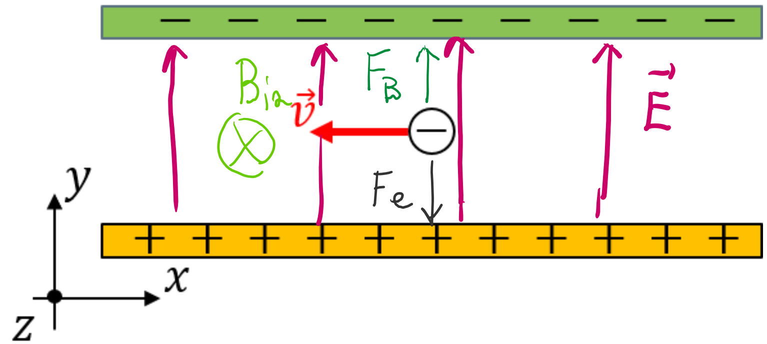
& $F_e = F_B$

$$qE = qvB$$



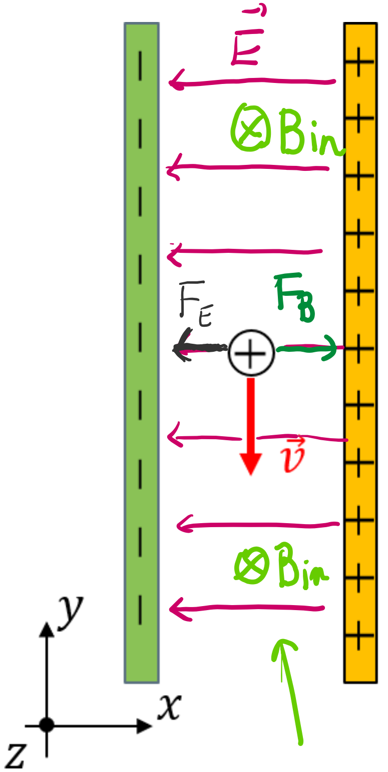
$$E = vB$$

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



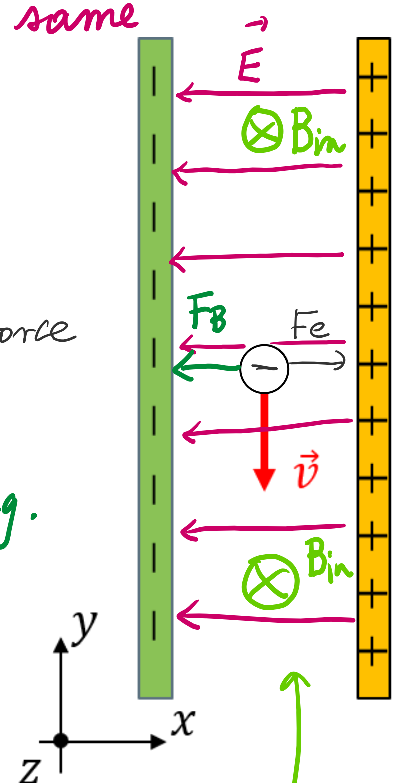
Sign of the charge does not matter for the configuration of $\vec{E}$ & $\vec{B}$ in the velocity selector

same $\vec{E}$ as the plates are the same



directions of electric force on the charge is opposite

so are those of mag. forces as they have to oppose each other



same $\vec{B}$

AND INFLUENCE ONE ANOTHER!

Determine the direction of the induced current, the direction of the induced magnetic field and the directions of the forces on each of the wires of the loop.