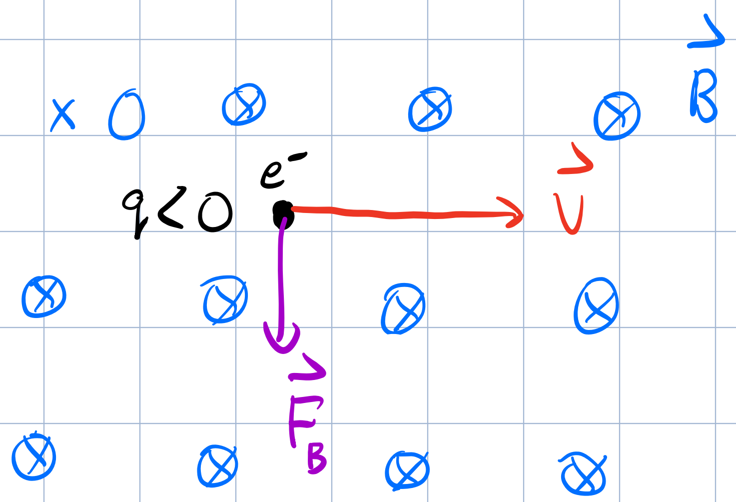
PHYS 121 March 25, 2024

- The next PrairieLearn HW is due Fri., Mar. 29
- Complete Pre-Lab #8 before the start of Lab #8
- If completing the Hands-On bonus project, send me the link to your YouTube video by Monday, Apr. 8 @ 23:59.
- No tutorials next week
- No class Friday, Mar. 29 & Monday, Apr. 1
- If willing to volunteer for PHYS 121 lab interview, please see Canvas announcement & send email today.

Last Time:

Force on a charge moving through a magnetic field

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



A charge moving ⊥ to a uniform magnetic field undergoes circular motion

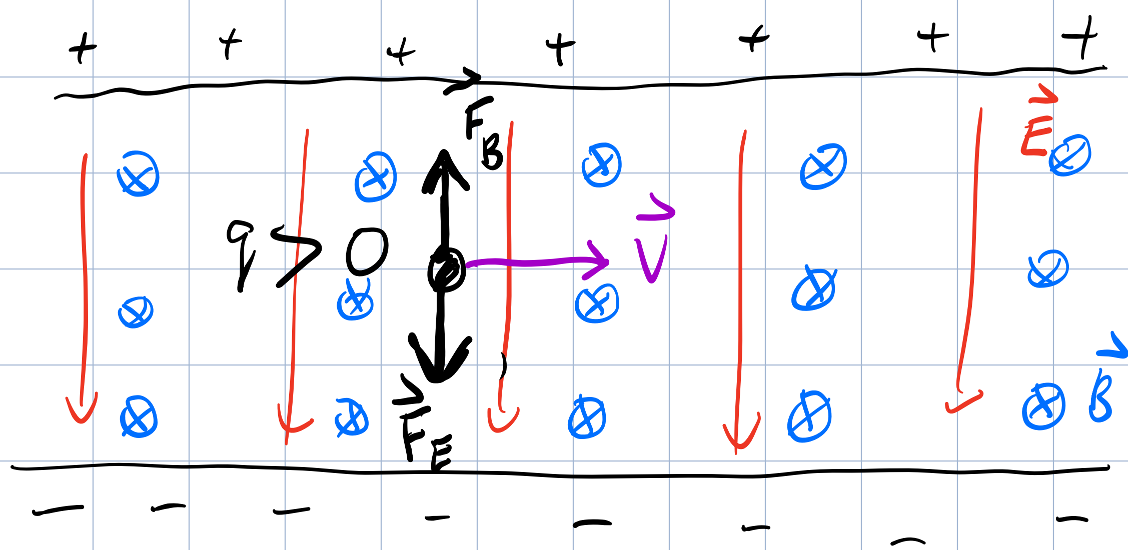
Radius: $r = \frac{mv}{qB}$

Period of circular motion: $T = \frac{2\pi m}{qB}$

Today: Design a velocity selector & a mass spectrometer (applications)

Velocity Selector

Start w/ a charged capacitor



Next, apply a uniform magnetic field $\vec{B} \perp$ to $\vec{E}$.

Now, fire a charged particle through the plates w/ velocity $\vec{v}$.

Electric exerts force $\vec{F}_E = q\vec{E}$ on charge.

tends to deflect q downwards.

Magnetic force on charge given by:

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

For the scenario above, $\vec{F}_B$ deflects q upwards.

- If $\vec{E}$ dominates, q deflected downwards
- " $\vec{B}$ " " " upwards.
- If we balance $\vec{E}$ & $\vec{B}$ s.t. $|\vec{F}_B| = |\vec{F}_E|$, then charge passes through undeflected.

Know $|\vec{F}_E| = qE$

$$|\vec{F}_B| = qvB \underbrace{\sin 90^\circ}_{1} \text{ for } \vec{v} \perp \vec{B}$$

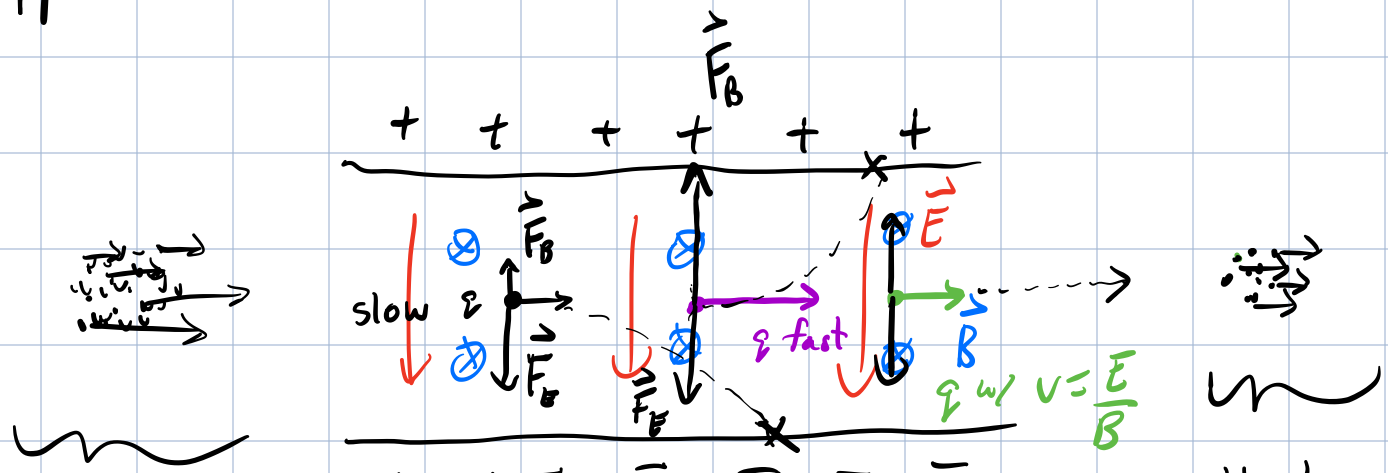
$$= qvB$$

Condition $|\vec{F}_E| = |\vec{F}_B|$ requires:

$$\cancel{q}E = \cancel{q}vB$$

If $v = \frac{E}{B}$, the charge is undeflected

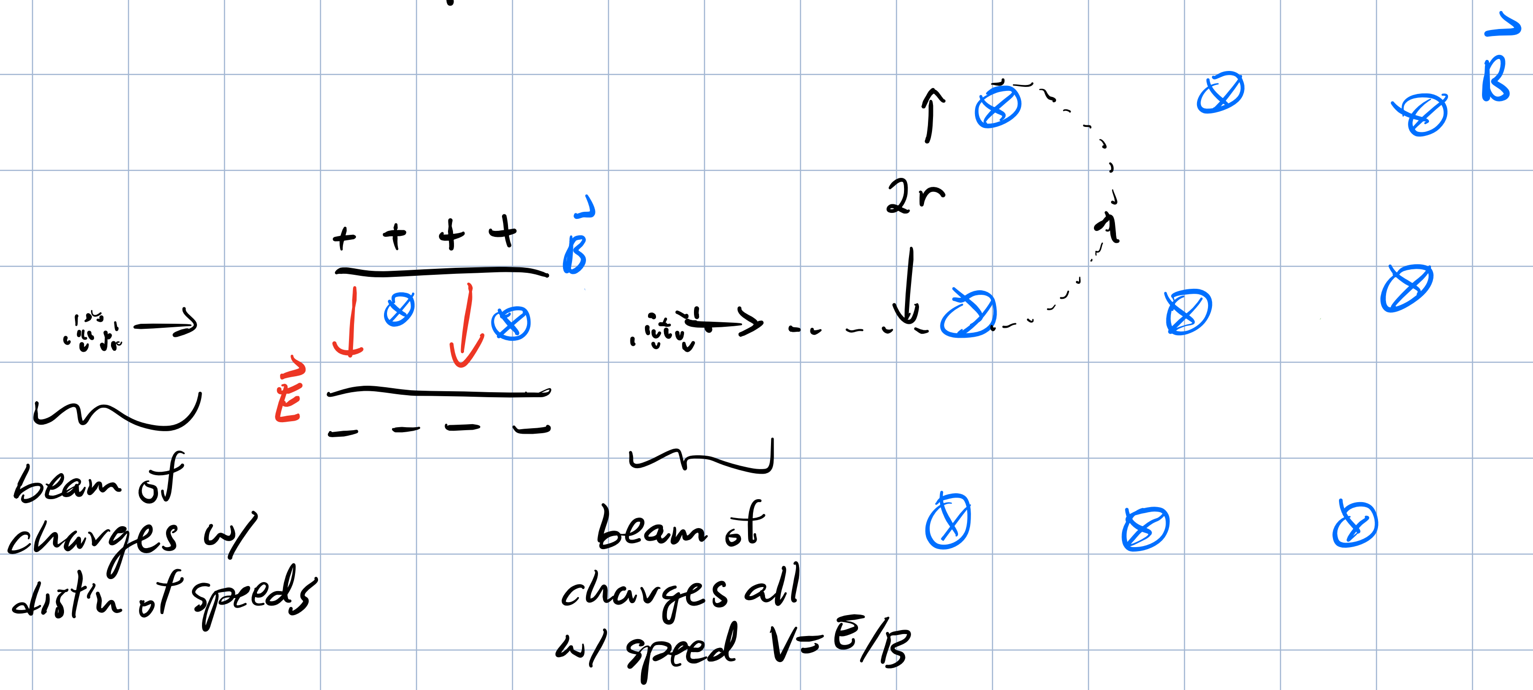
Application



collection of charges moving towards velocity selector w/ a dist'n of speeds (some slow, some fast)

collection of charges all moving w/ speed $v=\frac{E}{B}$

Use the velocity selector to design a appartus that can determine the mass of the particles. ⇒ Mass spectrometer.



After charges leave velocity selector, they enter a uniform magnetic field $\vec{B}$ w/ $\vec{v} \perp \vec{B}$ & undergo circular motion w/ radius

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

Measure the radius of circular.

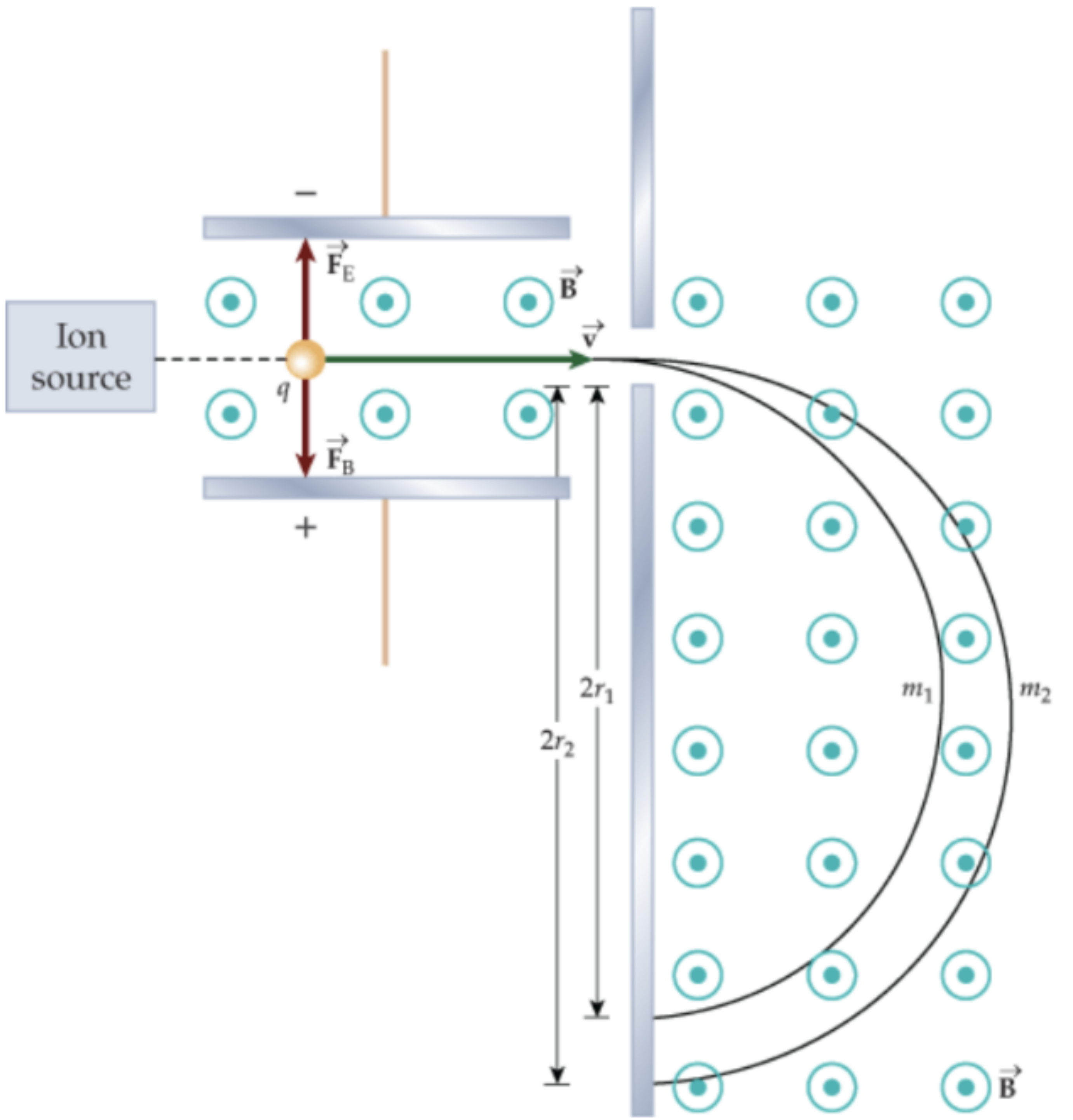
meas.

Solve for $m = \frac{qBr}{v}$

know $q, v, B \Rightarrow$ calc. m.

↑ velocity selector

Mass Spectrometer.

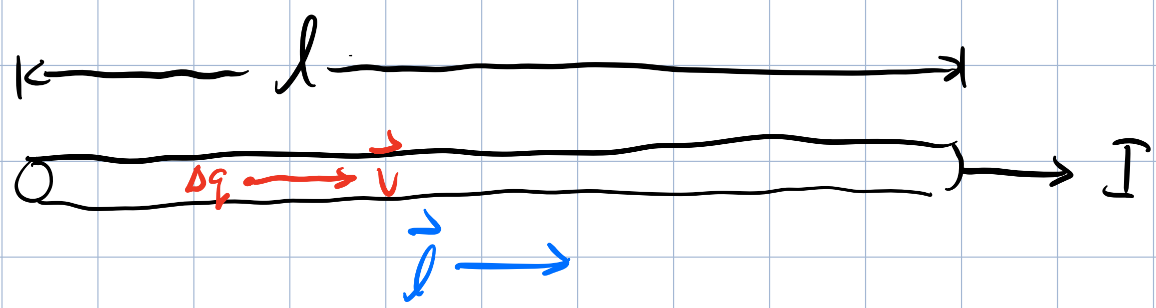


Magnetic Force on a Current.

Know for a single pt. charge in a magnetic field

$$\vec{F} = q\vec{v} \times \vec{B} \quad (1).$$

What is the force on a current (collection of moving charges) in a magnetic field?



The time Δt for a collection of charges Δq to move the length of the wire is:

$$\Delta t = \frac{l}{v}$$

$v \leftarrow$ speed of charges.

Current $I = \frac{\Delta q}{\Delta t} = \frac{\Delta q}{\left(\frac{l}{v}\right)} = v \frac{\Delta q}{l}$

$\therefore \quad \Delta q \, v = I \, l$

define $\vec{l}$ s.t. its dir'n is given by dir'n of the current.

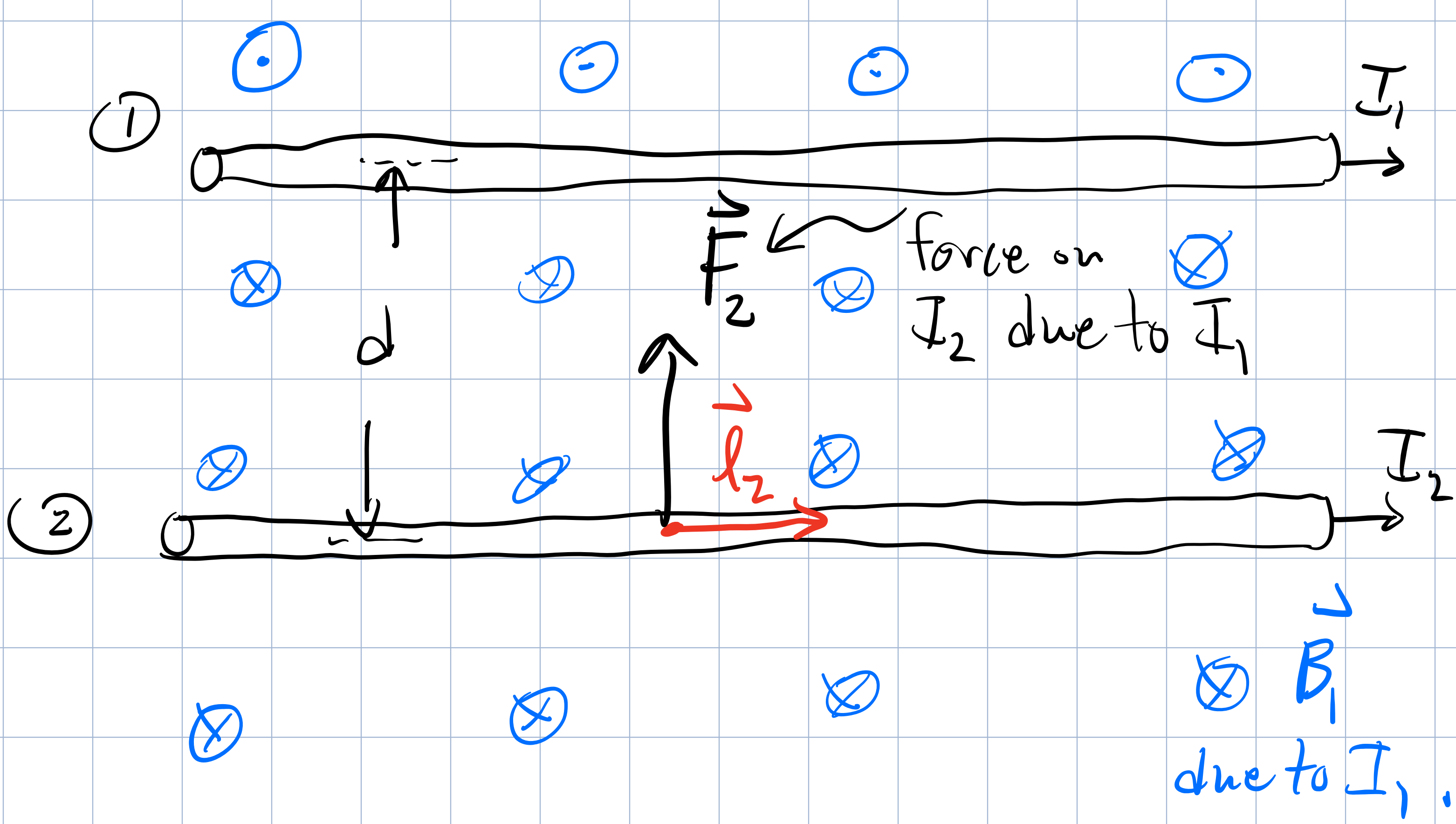
$\Delta q \, \vec{v} = I \vec{l}$ sub into ①

$\vec{F} = q \, \vec{v} \times \vec{B}$ Force on pt. charge

$$\boxed{\vec{F} = I \vec{l} \times \vec{B}}$$

Force on current in a magnetic field $\vec{B}$

Example: Force between Parallel Currents.



What is the force on I_2 due to magnetic field of I_1?

I_1 makes a magnetic field $\vec{B}_1$ that is into the screen at position of I_2.

Force on I_2 is given by

$$\vec{F}_2 = I_2 \vec{l}_2 \times \vec{B}_1$$

Since $\vec{l} \perp \vec{B_1}$, $\vec{l_2} \times \vec{B_1} = l_2 B_1$

$$F_2 = I_2 l_2 B_1$$

recall that $\vec{B}$ due to a long, straight current is given by:

$$B_1 = \frac{\mu_0 I_1}{2\pi d}$$

assume $l_1 = l_2 \equiv l$

$$F_2 = \frac{\mu_0 I_1 I_2 l}{2\pi d}$$

By newton's 3rd Law

$F_1 = F_2$, but have opp. dir'ns.