PHY117 HS2024

Today:

Kirchoff's rules
magnetism
Lorentz force
mass spectrometer

what's left to do:

magnetic field
waves
electromagnetic waves
optics

Week 10, Lecture 1
Nov. 19th, 2024
Prof. Ben Kilminster

GESUCHT! ‚Note-Taker:in‘ für Studentin mit einer studienerschwerenden Beeinträchtigung

Die Fachstelle Studium und Behinderung FSB sucht für das HS24 eine:n Student:in welche:r Notizen in Form einer Mitschrift **in einem oder mehreren der folgenden Modulen** nimmt und diese zuverlässig übermittelt:

- 07SMPHY117.1 Physik für die Life Sciences
- 07SMPHY117.2 Übungen Physik für die Life Sciences
- 07VLBIO113.1 Evolution und Biodiversität 1
- 07PRBIO113.2 Evolution und Biodiversität 1 Praktikum
- 07VLBIO112.1 Zellbiologie
- 07PRBIO112.2 Cell Biology (Practical Course)

Die Fachstelle entschädigt jede Mitschrift pro Veranstaltung mit 5 CHF

Aufgaben:

- Ausführliche Mitschrift beim Besuch der Veranstaltungen
- Zuverlässige Übermittlung der Notizen

Die Fachstelle steht jederzeit für Fragen zur Verfügung. Wenn Sie Interesse haben, diese Aufgabe **oder Teile davon zu übernehmen**, kontaktieren Sie uns bitte so schnell wie möglich und geben Sie die Inseratnummer (NT07112024) an.

Kontakt

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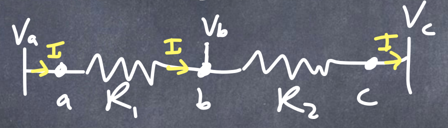
Was asked to show this slide :

LAST WEEK:

Resistors in series:

Note: opposite rules as for capacitors



Equivalent resistance $\boxed{R_{eq} = R_1 + R_2 + \ldots}$

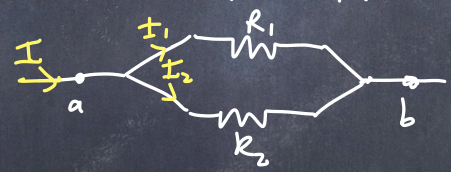
$V_b = V_a - I R_1$

$V_c = V_a - I R_1 - I R_2$

$I_a = I_b = I_c = I$

Potential decreases, current stays same.

Resistors in parallel:



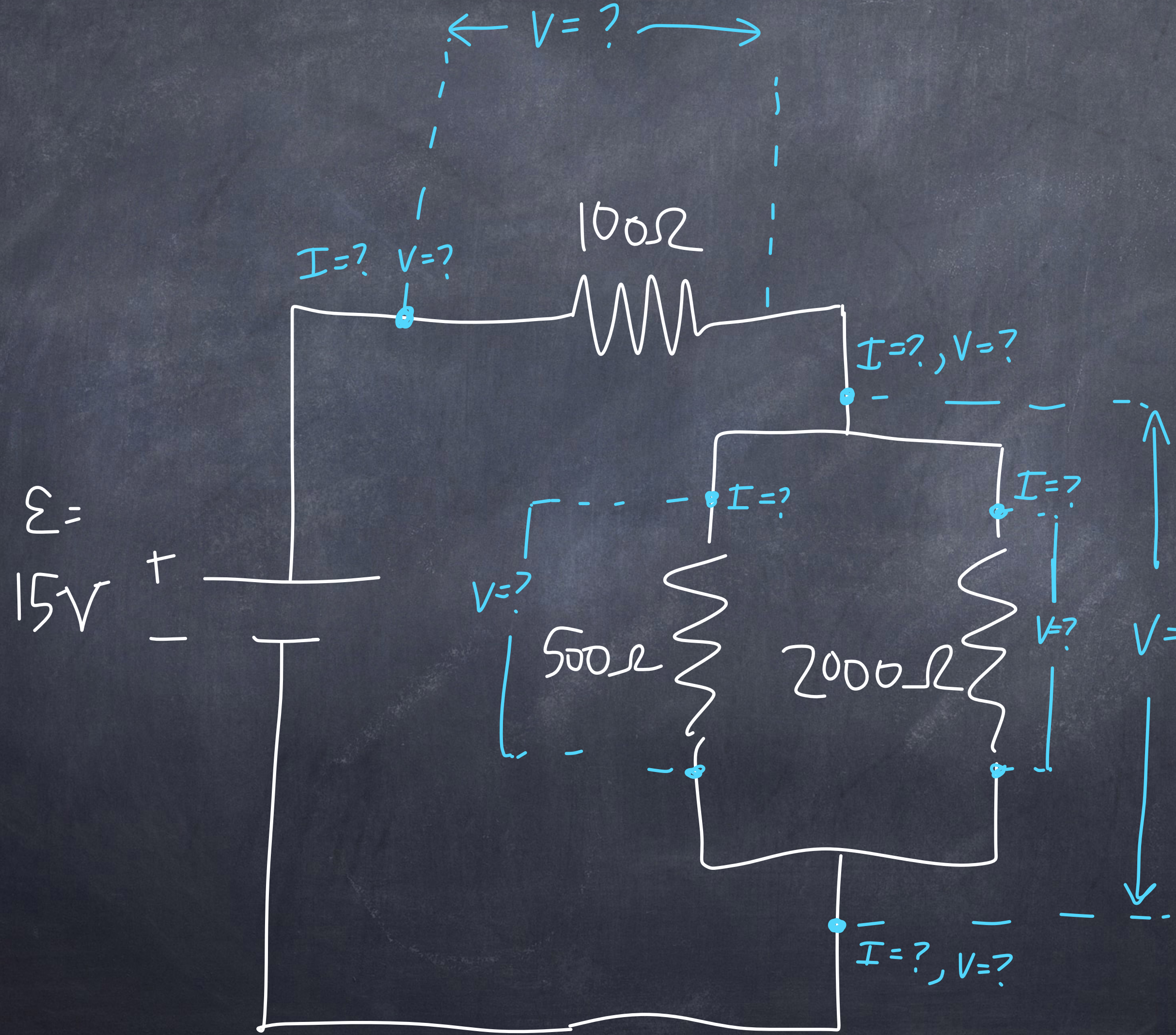
Equivalent resistance decreases. (More ways for current to flow)

$I = I_1 + I_2$

$$\boxed{\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots}$$

voltage drop $V_a - V_b$ is same across both paths: $V_{ab} = I_1 R_1 = I_2 R_2$

A battery with 15 V is connected to some resistors. What are the requested voltages & currents?



First, rules:

To calculate voltages + currents in a circuit, we can follow Kirchoff's rules:

i) Assume any direction for the current, I. If I found to be negative, it means the current is moving opposite the assumption.

ii) Any complete loop around a circuit has a total potential change of zero.
(Potential difference between 2 points is always the same, no matter which path)

iii) For a battery, if the potential increases, − to +, then add it. If decreases from + to −, subtract it.

iv) The sum of currents into a junction must equal the sum of currents out of the junction.

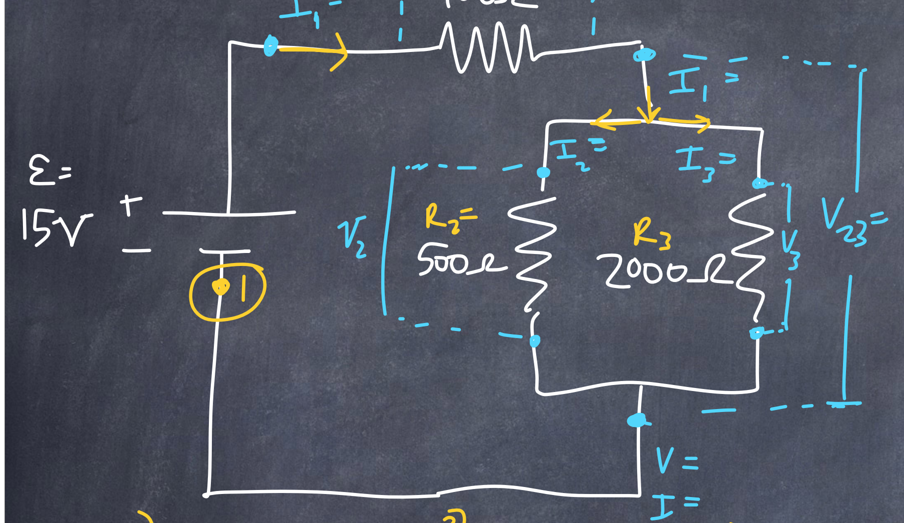
v) Simplify using R_{eq} formulas

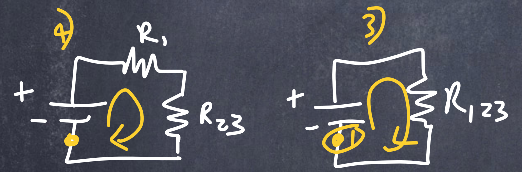
Example of circuit with resistors in parallel + series:

what are values of labeled currents + voltages?

1) Label resistors + currents

2) Calculate R_{eq} (parallel first, then series)





3) Loop from ⊙1: $\varepsilon - I_1(R_{123}) = 0$

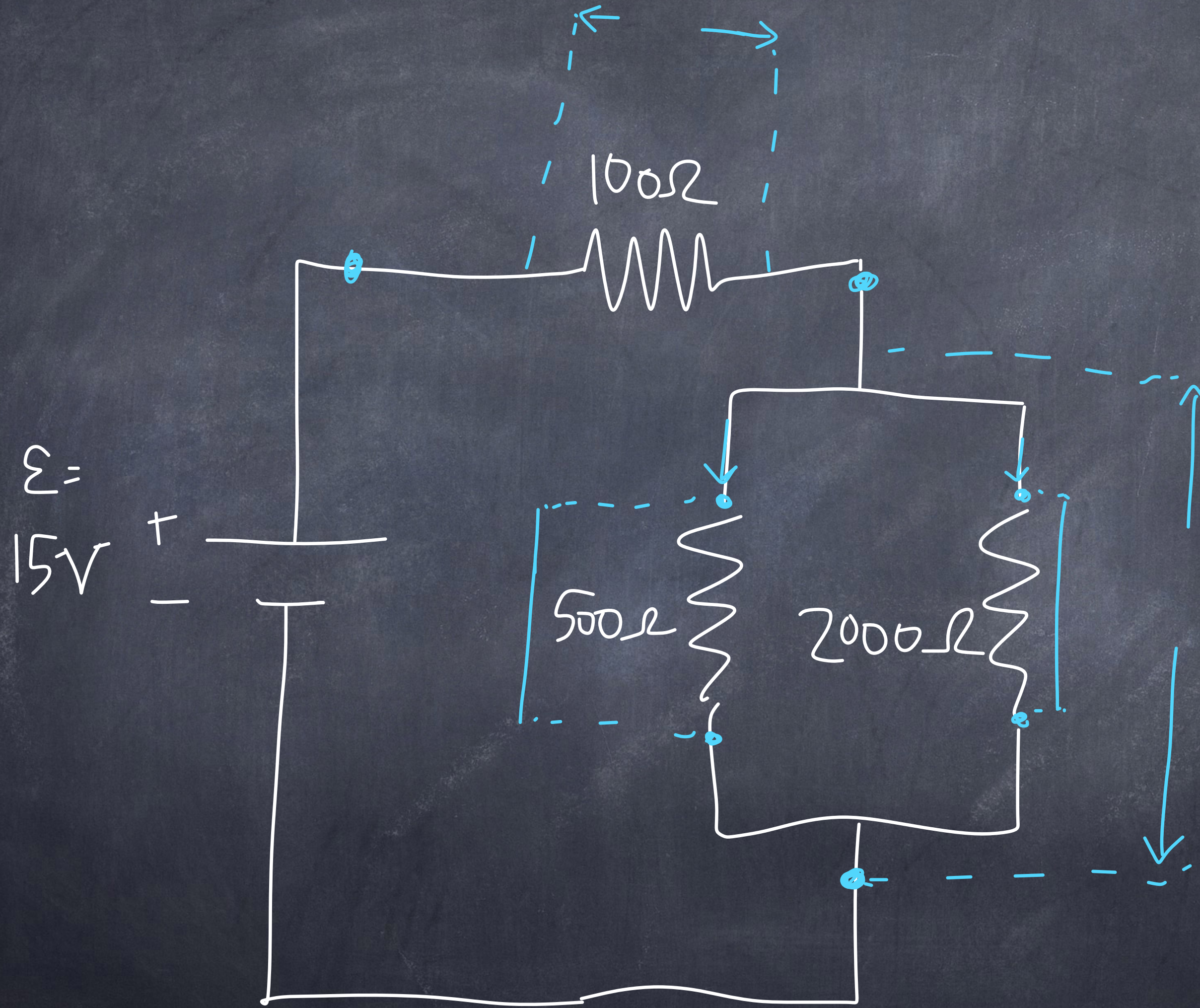
4) we also know that starting at ⊙1: $\varepsilon - V_1 - V_{23} = 0 \Rightarrow$

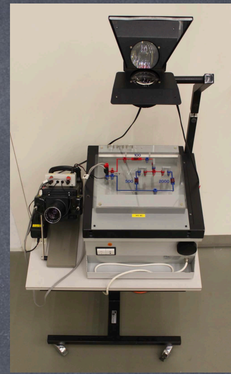
5) The voltage drop across $R_2 + R_3$ must be the same: $V_{23} = V_2 = V_3$

$$I_2 R_2 = V_2 = V_{23} \Rightarrow$$

$$I_3 R_3 = V_3 = V_{23} \Rightarrow$$

Solution:





Magnetism

Basic observations:

Red = north

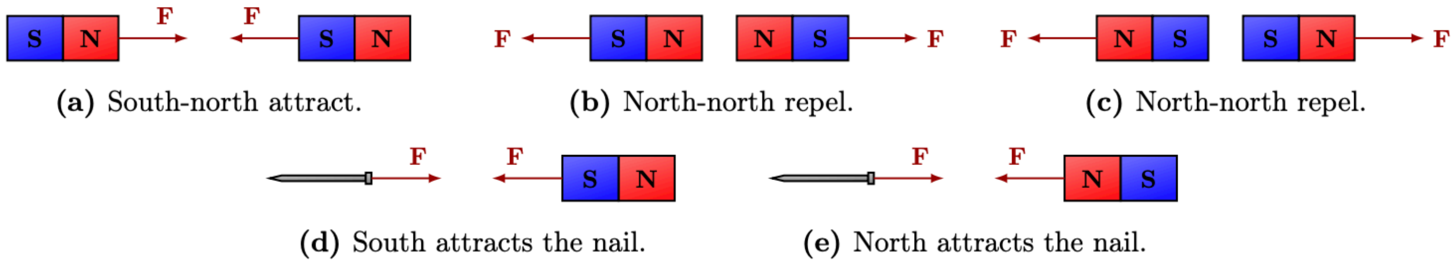


Figure 7.1: The magnetic force between two bar magnet depends on their orientation, but between a non-magnetic nail and bar magnet, orientation does not matter.

Magnetic Field labeled with $\bar{B}$

(a) The magnetic field of bar magnet looks like the electric field of an electric dipole. The field lines close their loops inside the bar magnet.

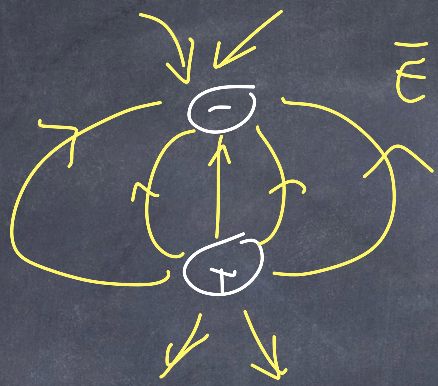
(b) Earth's magnetic field looks like that of a bar magnet. Magnetic compasses point to Earth's geographic north pole, the magnetic south pole.

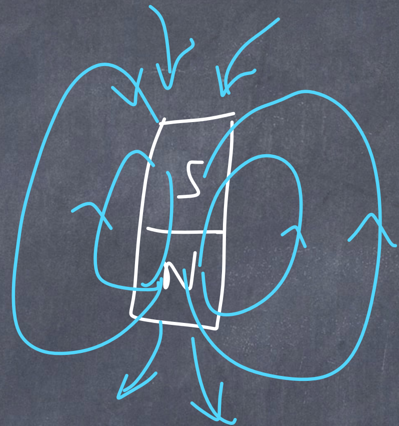
Figure 7.2: Bar magnets and the Earth create a magnetic dipole field (purple).

- B-field $N \rightarrow S$ outside the magnet, but $\bar{B}$-field is a complete loop (so $\bar{B}$ goes $\underline{S \rightarrow N}$ inside magnet)
- Earth's geographic north pole is actually the magnetic south pole!

Your compass N points to magnetic south

This may remind you of the $\bar{E}$-field of a dipole.



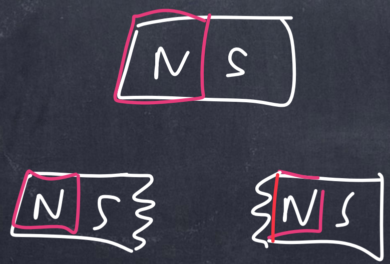


However, there are no magnetic charges!

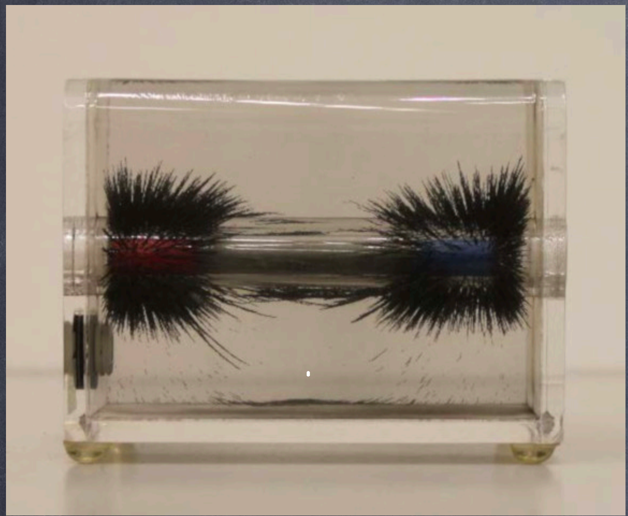
No Ⓝ charge, no Ⓢ charge.

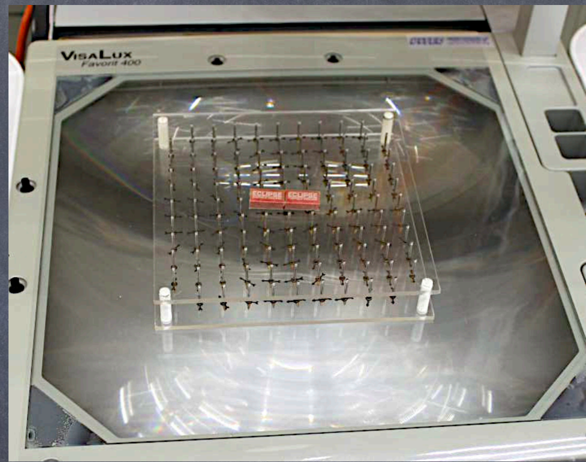
No single magnetic charge (magnetic monopole) has ever been observed.

If you break a magnetic in half:



still have dipoles with N + S.

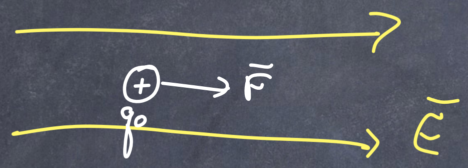



VisaLux
Favorit 400

One of the other differences is how $\bar{E}$ + $\bar{B}$ produce forces on an electric charge:

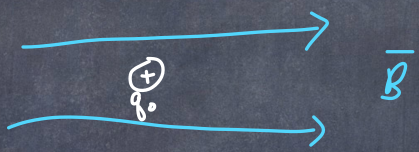
$$\bar{F}_E = q_0 \bar{E}$$

$$\bar{F}_B = q_0 \bar{V} \times \bar{B}$$

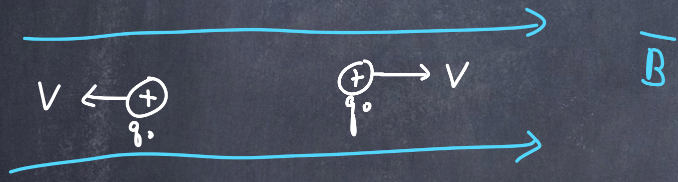


$\bar{F}_E = q\bar{E}$ electric force

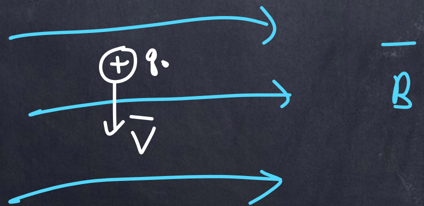
$\bar{F}$ is in the same direction as $\bar{E}$



If q_0 is not moving, $\bar{V}=0$, then $\bar{F}$ is 0



If q_0 has $\bar{V} \parallel \bar{B}$, then $\underline{\underline{F=0}}$
($\bar{V}$ constant)



If $\bar{V}$ + $\bar{B}$ are not completely parallel, then there is a force.

$$\bar{F}_B = q_0 \bar{V} \times \bar{B}$$

units for $B = \frac{F}{qV} = \frac{[N][s]}{[C][m]}$ = Tesla = T

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

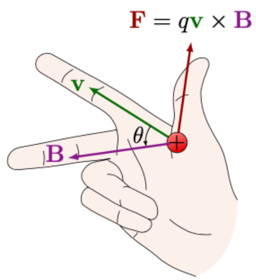
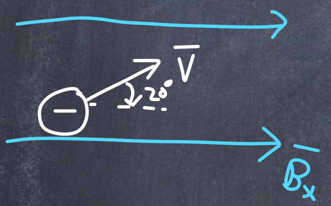


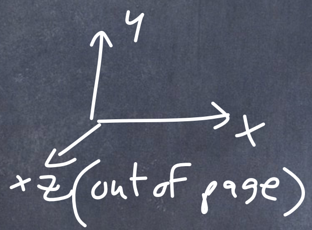
Figure 7.4: Right-hand rule for the magnetic force on a positive charge $q > 0$.

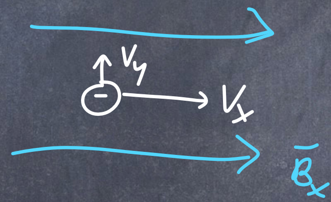
$$|\bar{V}\times\bar{B}| = VB\sin\theta$$

negative charges need left hand.

Consider negative charge in magnetic field. Force? Trajectory?

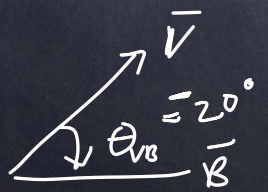


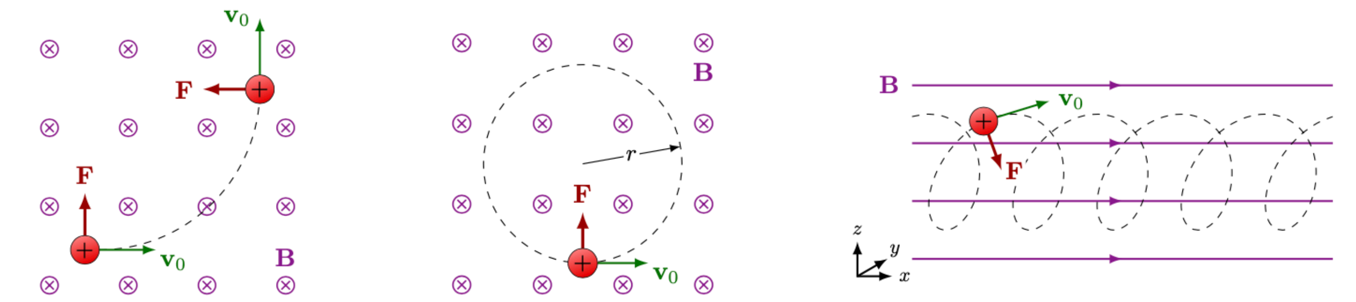




$\bar{F}$ is ⊙

Force results from $V_y \perp B_x$: $\bar{F} = \boxed{q}\,\bar{V}\times\bar{B} =$



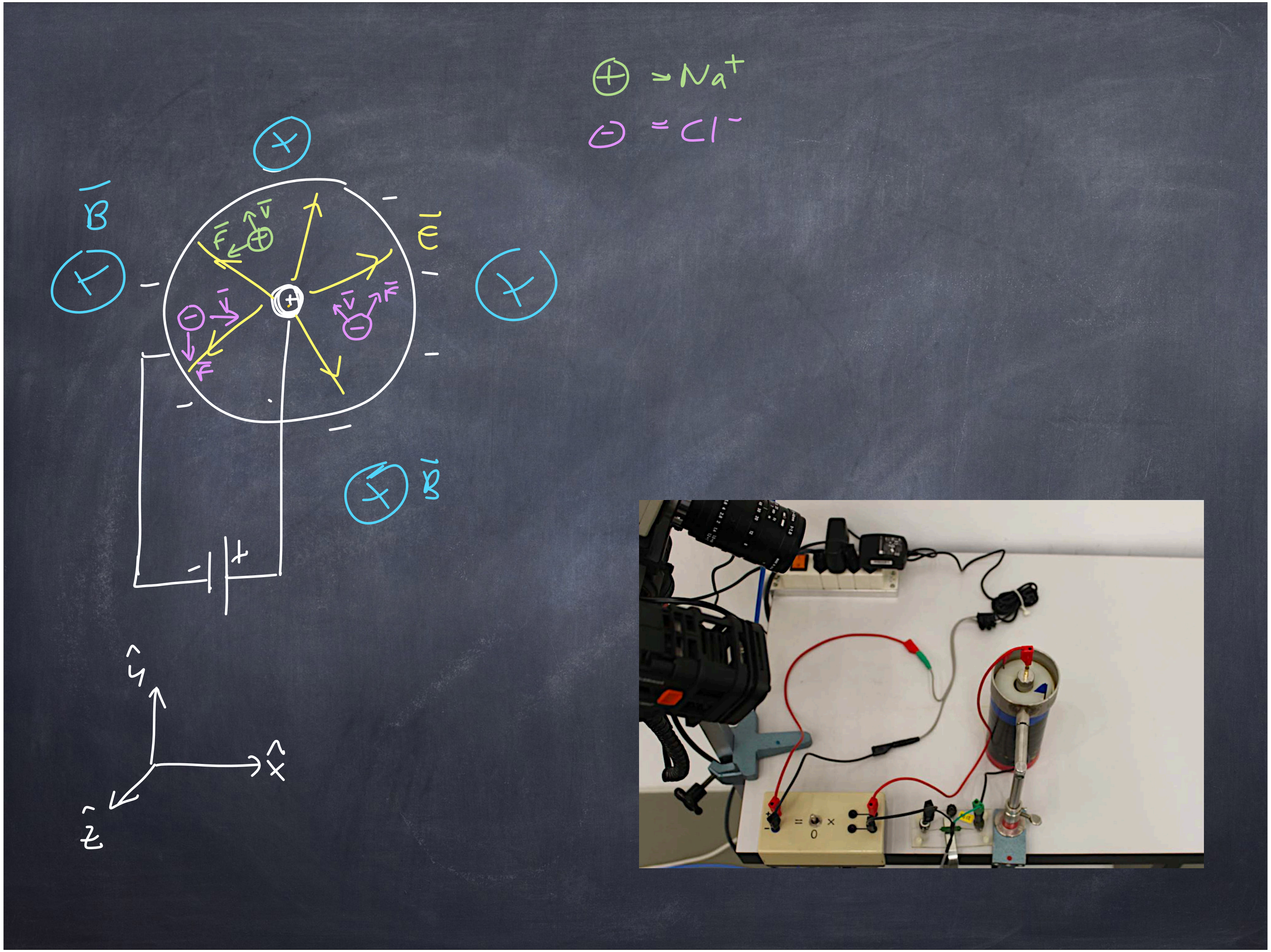


(a) Charge is bent in a magnetic field **B**.

(b) Charge with a constant velocity, perpendicular to **B** makes circles.

(c) Charge with constant velocity, not perpendicular to **B**, makes makes spirals.

Figure 7.5: Charge with a non-zero velocity, not parallel to a uniform magnetic field **B**, experiences a force perpendicular to the velocity and magnetic field.


⊕ = Na+
⊖ = Cl−
B
E
F
v
x̂
ŷ
ẑ

The motion of a charged particle in a $\bar{B}$-field is always of constant speed. (initial velocity component parallel to $\bar{B}$ doesn't change at all)

Circular motion when $\bar{V} \perp \bar{B}$, so $|\bar{V} \times \bar{B}| = VB\sin(90^\circ) = VB$

$$\Sigma F = ma$$

circular motion: $a = \frac{V^2}{r}$ (when constrained in a circle)

$$q\bar{V} \times \bar{B} = \frac{mV^2}{r}$$

$$q\cancel{V}B = \frac{mV^{\cancel{2}}}{r}$$

① $$\boxed{r = \frac{mV}{qB}}$$

radius of curvature of charge in B-field

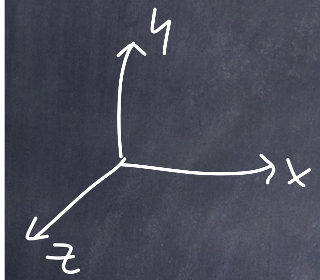
$$\omega = \text{angular velocity} = \frac{V}{r} = \frac{q\cancel{r}B}{m\cancel{r}} = \frac{qB}{m}$$

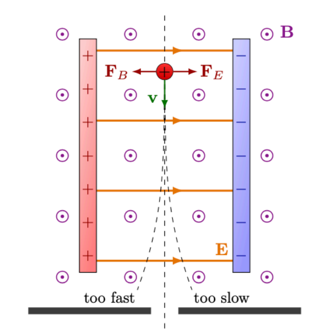
$\omega = 2\pi f$

f: frequency of rotation

$$\Longrightarrow \text{then} \quad \boxed{f = \frac{\omega}{2\pi} = \frac{qB}{2\pi m}}$$

"velocity selector" – we can balance the electric force + the magnetic force, but only at a specific velocity.





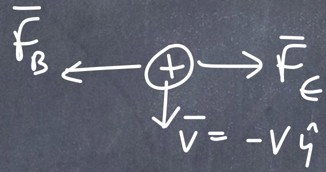
(a) Velocity selector.

$\bar{E}\,(\hat{x})$

$\bar{B}\,(\hat{z})$

$\bar{F}_E = qE\hat{x}$

$\bar{F}_B = q\bar{v}\times\bar{B}$
$= qvB(-\hat{x})$



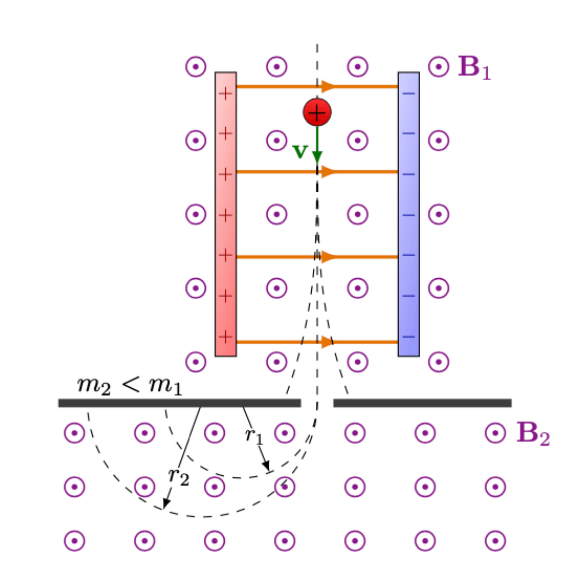
we require $\sum F_x = 0 = \bar{F}_E + \bar{F}_B = qE - qvB = 0$

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

$$v = \frac{E}{B} \Rightarrow \bar{v} = \frac{E}{B}(-\hat{y}) \qquad \Big(\underset{(-\hat{y})}{\bar{v}} \text{ is } \perp \text{ to } \underset{(\hat{x})}{\bar{E}} + \underset{(\hat{z})}{\bar{B}}\Big)$$

At this velocity there is no net force. No deflection.

Mass spectrometer – separates isotopes



(b) Mass spectrometer.

Source of positive ions, same Z, different mass (different A).

1st stage: we select ions with a speed $V = \frac{\mathcal{E}}{B_1}$

2nd stage:
we determine the mass from the radius of curvature:

from ① $\rightarrow$ $r_1 = \frac{m_1 V}{q B_2}$ where $V = \frac{\mathcal{E}}{B_1}$

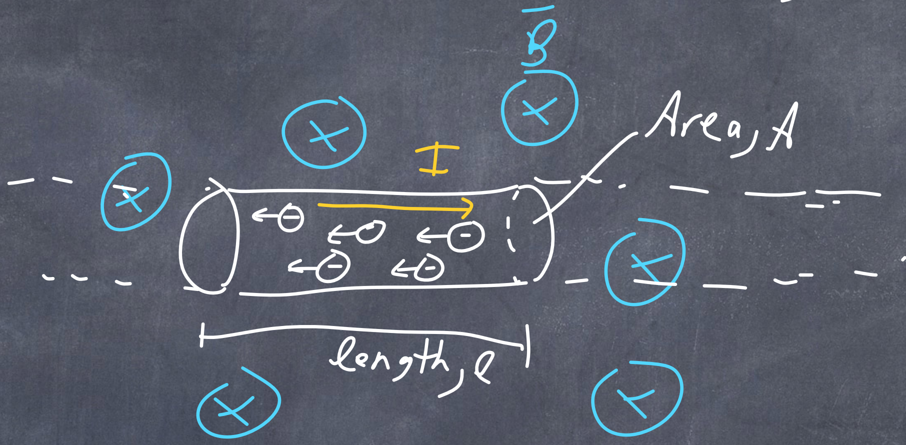
So $r_1 = \frac{m_1 \frac{\mathcal{E}}{B_1}}{q B_2}$ $\Rightarrow$ we can calculate the mass of our isotopes.

This technique is how we discovered many stable isotopes of elements.

$\left(90\% \; {}^{20}_{10}Ne\right) + \left(10\% \; {}^{22}_{10}Ne\right)$: Neon

What if we have current of electric charges I moving $\perp$ $\bar{B}$-field ?

A wire carrying electric current in a $\bar{B}$-field



Then $\bar{F}_{B_{TOTAL}} = (q\,\bar{V}_d \times \bar{B})$ (total # of charges)

$\bar{V}_d$ ← drift velocity

total # of charges ← $\underbrace{A \cdot \ell}_{\text{volume}} \cdot \underbrace{n}_{\#\text{ charges/volume}}$

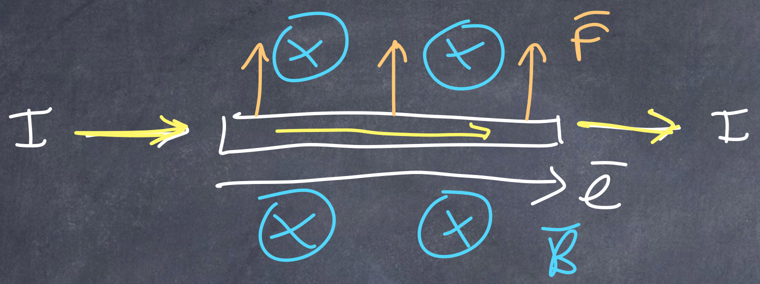
$\bar{F}_{B_{TOT}} = q V_d B n A \ell$ $\quad \bar{V} \perp B$, so $\sin 90° = 1$

Previously, we saw that $n q V_d A = I$ = current

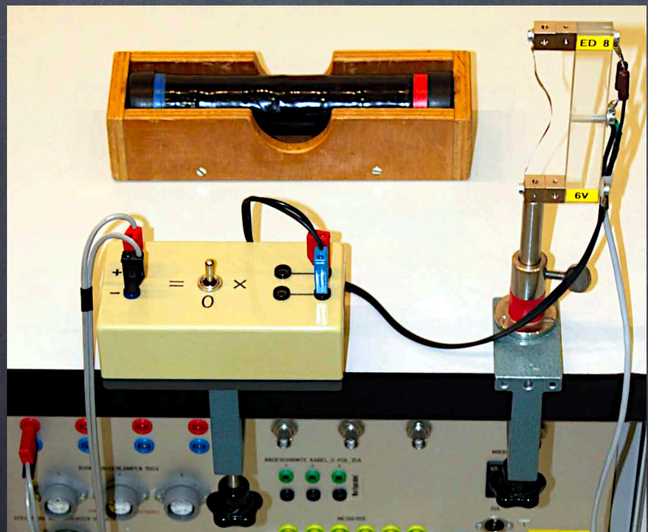
$$\boxed{\bar{F}_B = I \bar{\ell} \times \bar{B}}$$

This is the magnetic force on a straight wire with current I in a B-field.

If $\bar{\ell} \perp \bar{B}$, then $F = I\ell B = \boxed{BI\ell = F}$



The wire feels a force pointing up.



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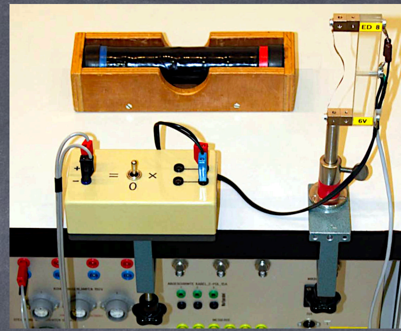

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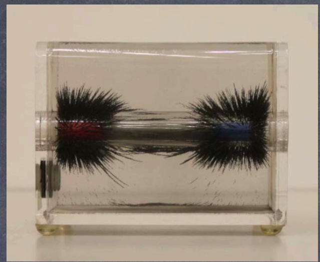

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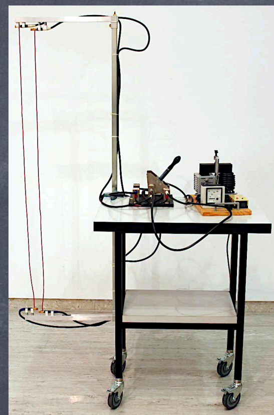

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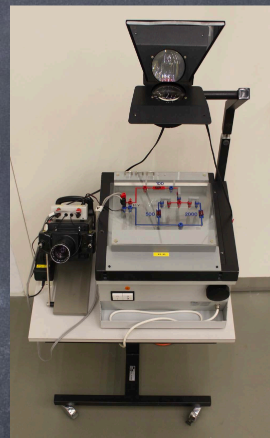

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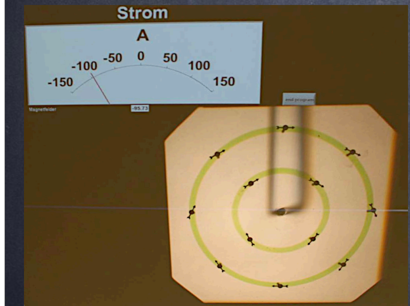

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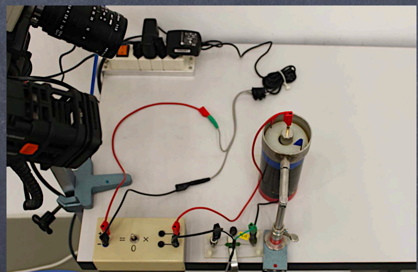

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