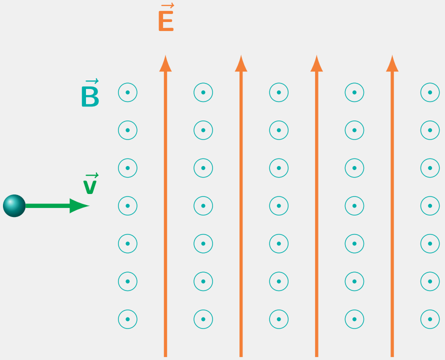
Announcements

- Webwork 16 due tonight!
- I'm still working my way through the VHW backlog. I'm trying!
- Your Test 2 is due on Friday at midnight
  - I got a pdf of all the learning objectives together on Campuswire
  - Email me with two separate pdfs
    - The test questions themselves
    - The test solutions and your objective explanation.
- No lecture on Friday!
- Nothing due on Monday!
- Polling: `rembold-class.ddns.net`

Warm Up Question

A negative charge enters the region shown to the right. In what direction do the different field forces point?

A) F_E up, F_B up
B) F_E up, F_B down
C) F_E down, F_B down
D) F_E down, F_B up



Hall Implications

- What can we do with it?

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  - Based on the sign of the voltage, we can determine the principle charge carriers!
    - Electrons would still feel a magnetic force in the same direction
    - Would charge the top of the wire *negative*
    - Flips the sign of our voltage measurement!

An Effective Example

Say we have a square wire which measured 1 mm per side and had a current of 3 A flowing horizontally through it. When we place it in a 1 T magnetic field, we measure a potential difference of 0.3 μV across the top of the wire to the bottom of the wire. What is the charge density of the wire?

Suppose we have a metal bar moving through space where a magnetic field exists.

Getting Motional

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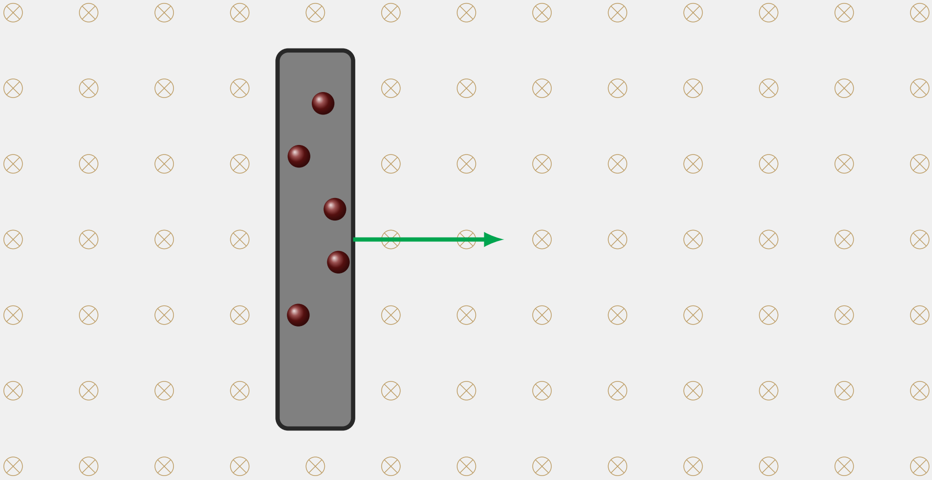

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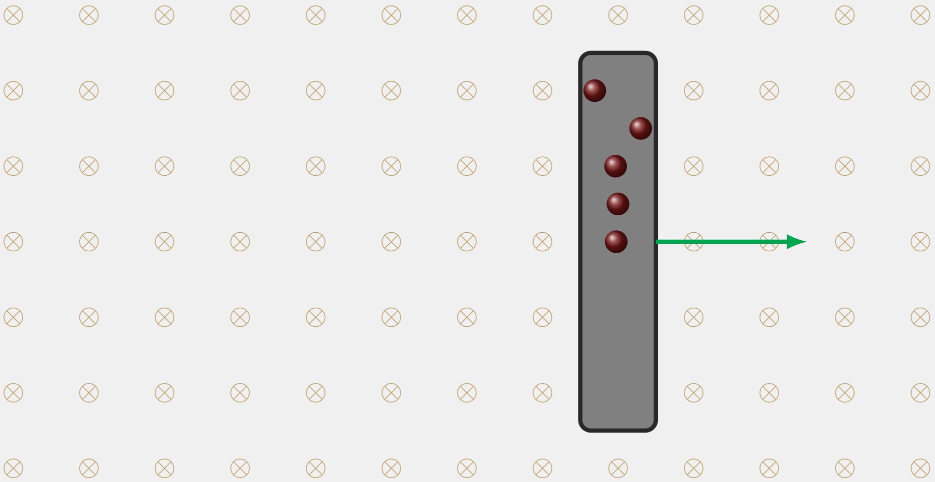

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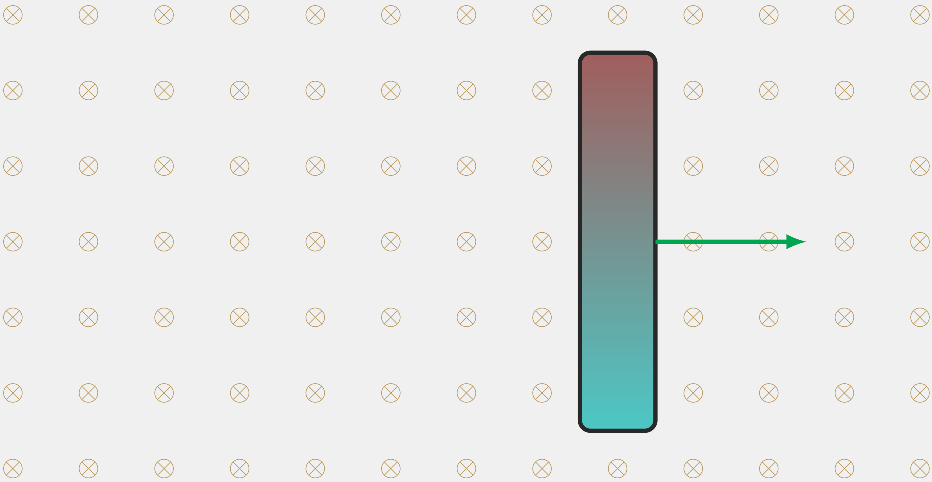

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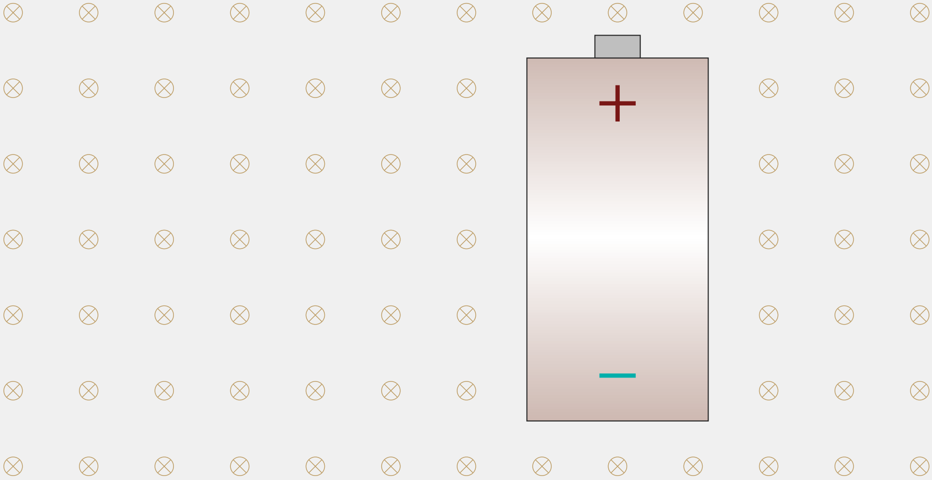
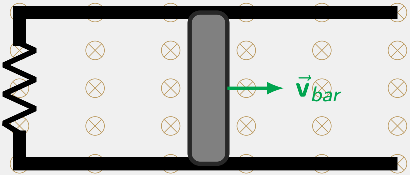


Put it in a circuit!

- Motion of the bar creates a charge separation just like a battery
- Can hook into a circuit and treat just like a battery!
- Need to answer some important qualitative questions though:
  - Is there a maximum charge build up that can occur? (What is the “battery” emf?)
  - What speed or force is necessary to move the bar to achieve this?



Determining the $\mathcal{E}$

- As charges accumulate, future charges will be harder to push upwards due to electrostatic repulsion
- Will reach a max when the downward force of the electric field equals the upward force of the magnetic field

$$\begin{aligned} \vec{\mathbf{F}}_E &= \vec{\mathbf{F}}_B \\ qE &= qv_{bar}B \\ E &= v_{bar}B \end{aligned}$$

- To go from one end to the other of the length L bar then would mean that

$$|\Delta V_{bat}| = \mathcal{E} = \int \vec{\mathbf{E}} \cdot \mathrm{d}\ell = v_{bar}BL$$

How hard to push

- The force that separates the charge means the charges are also moving upwards (or down)
- Means we also have a component of force pointing to the left, against the current

$$\vec{\mathbf{F}}_{opposing} = \mathrm{I}\vec{\mathbf{L}} \times \vec{\mathbf{B}} \quad \text{or} \quad \left|\vec{\mathbf{F}}_{opposing}\right| = ILB$$

- Must press with this much force to keep velocity constant, *which is needed for a steady state current*!
- Energy is still conserved
    - Energy in equals energy out

$$\frac{W}{\Delta t} = \frac{F\Delta x}{\Delta t} = \vec{\mathbf{F}}v_{bar} = ILBv_{bar} = I\mathcal{E}$$

    - Energy added by pushing the bar is dissipated by the resistor
    - Forms a simple generator

Understanding Check

Suppose I wanted to power a 10 W lightbulb which had a resistance of 2 mΩ. How fast would I need to move a 10 cm bar to drive a motional current through the bulb and light it up? You are moving the bar through a typical low magnetic field situation, where $B = 1\,\mathrm{mT}$.

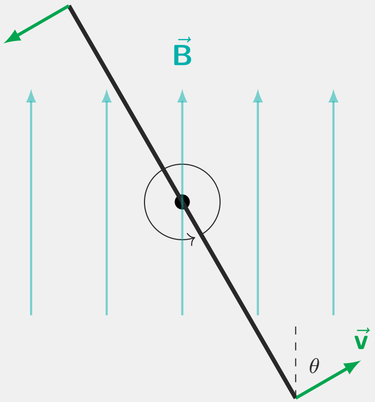
A) 0.051 m/s

B) 58 m/s

C) 202 m/s

D) 1415 m/s

Compacting to Circles



Side View

- Sliding bars are hard to upscale to make effective generators
  - Also tend to be hard to limit friction losses
- Most generators instead rely on spinning motion

$$F_B = qvB\sin\theta$$

- If width of loop is a, then:

$$W_B = qvB\sin\theta \cdot a$$
$$\Rightarrow \mathcal{E} = avB\sin\theta$$

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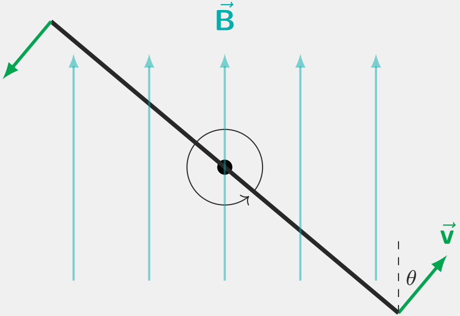

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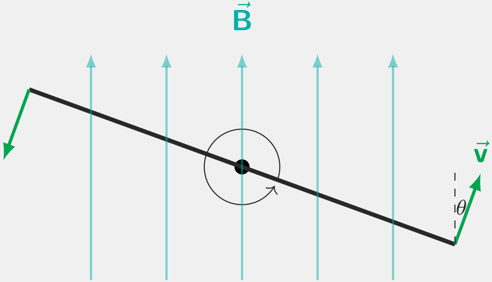

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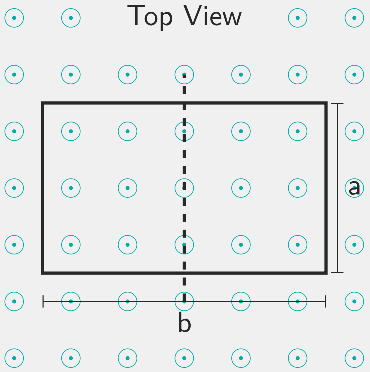
Onward to $\mathcal{E}$!

- We have two parts of the circuit creating an $\mathcal{E}$, so

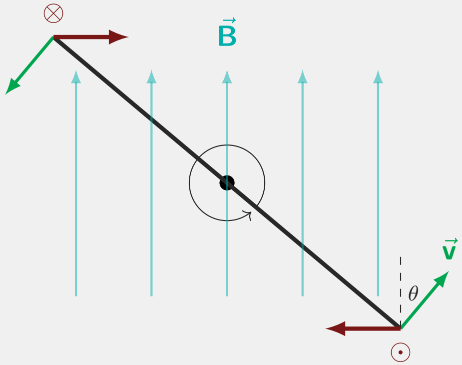
$$\mathcal{E}_{tot} = 2avB\sin\theta$$

- Usually we'd know the rotation speed, so we can write everything in terms of ω:

$$\begin{aligned}\mathcal{E}_{tot} &= 2a\left(\omega\frac{b}{2}\right)B\sin(\omega t)\\ &= AB\omega\sin(\omega t)\end{aligned}$$



Energy to Keep Spinning?



- Current implies new forces
- Those forces will exert a torque against the motion of the loop

$$
\begin{aligned}
\vec{\tau} &= \vec{\mathbf{r}} \times \vec{\mathbf{F}} \\
&= \frac{b}{2} F \sin\theta \\
&= \frac{b}{2} \mathrm{I} a B \sin\theta \\
\vec{\tau}_{tot} &= BA\mathrm{I} \sin\theta \\
&= \vec{\mu} \times \vec{\mathbf{B}}
\end{aligned}
$$

Mechanical to Electric

- Any force could supply the needed torque
  - A stream turning a water wheel
  - A turbine in a dam
- Converts mechanical energy to electric
- Note in this spinning situation that the $\mathcal{E}$ depends on a trig term
  - Results in what we call AC or alternating current
  - Circuits in general behave a little differently in AC than they do in DC
- Can use the same ideas to also convert electric energy into mechanical energy
  - Need to be a little clever to get full circular motion
  - Results in motors! (And your Tesla. . .)