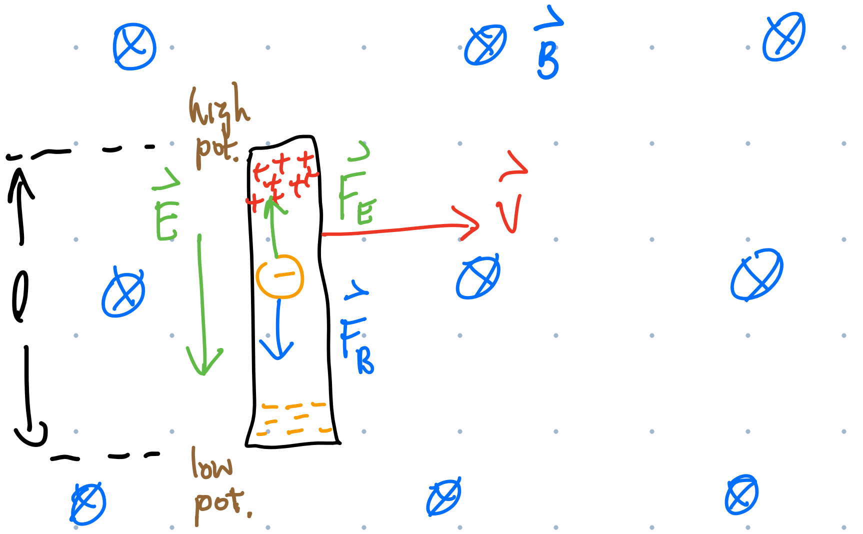
PHYS 121 April 2, 2025

- Next PrairieLearn HW due Tues. Apr. 8
- Labs are done
- Last tutorial this week
- See course website for final exam details (including formula sheet)

- If participating in the hands-on bonus project, send me a link to your YouTube video by 23:59 on April 7.

- Complete the end-of-term survey by 23:59 on April 8 for 0.5 marks towards your final grade. A link to the survey has been provided in Canvas.

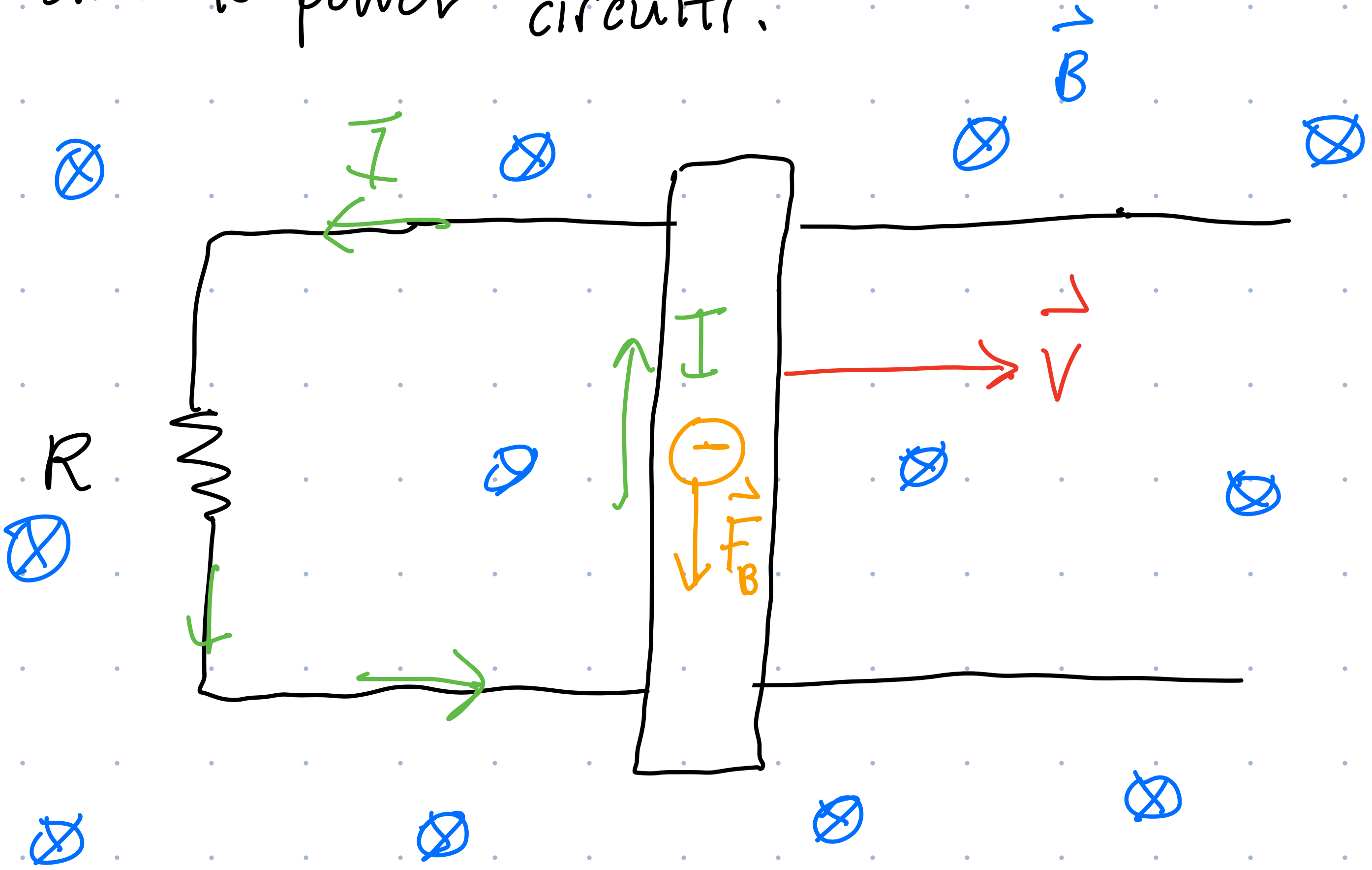
Last Time: Motional Emf



$$\Delta V = \mathcal{E} = vB\ell$$

Induced voltage due to motion of rod through $\vec{B}$.

We can use the voltage due to motional emf to power circuits.



Rod slides on a pair of conducting tracks/wires that are joined on one end by a resistor R.

e^- flow CW around out circuit which corresponds to a CCW current.

$$\boxed{I = \frac{\Delta V}{R} = \frac{vBl}{R}}$$ ③

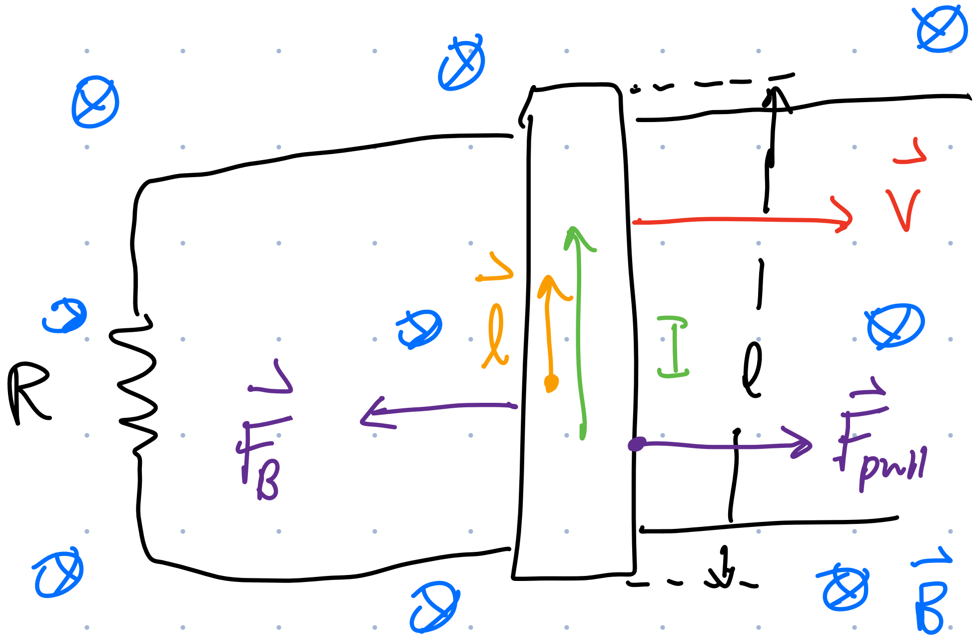
Power dissipated by resistor is:

$$P = I^2 R = \underbrace{\left(\frac{vBl}{R}\right)^2}_{\text{from ③}} R$$

$$\boxed{\therefore P = \frac{(vBl)^2}{R}} \quad ④$$

Notice that we now have a current in our rod & currents in magnetic fields experience a force.

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



By RHR, force on I in sliding bar is to the left.

To keep the bar moving at a const. speed, need to apply an external force $\vec{F}_{pull}$ to the right to offset $\vec{F}_B$.

As we pull the bar to the right, we do work on the system (put energy into the system).

$$W = \underset{\text{force}}{\underset{\nearrow}{F_{pull}}} \cdot \underset{\text{displacement}}{\underset{\uparrow}{\Delta x}}$$

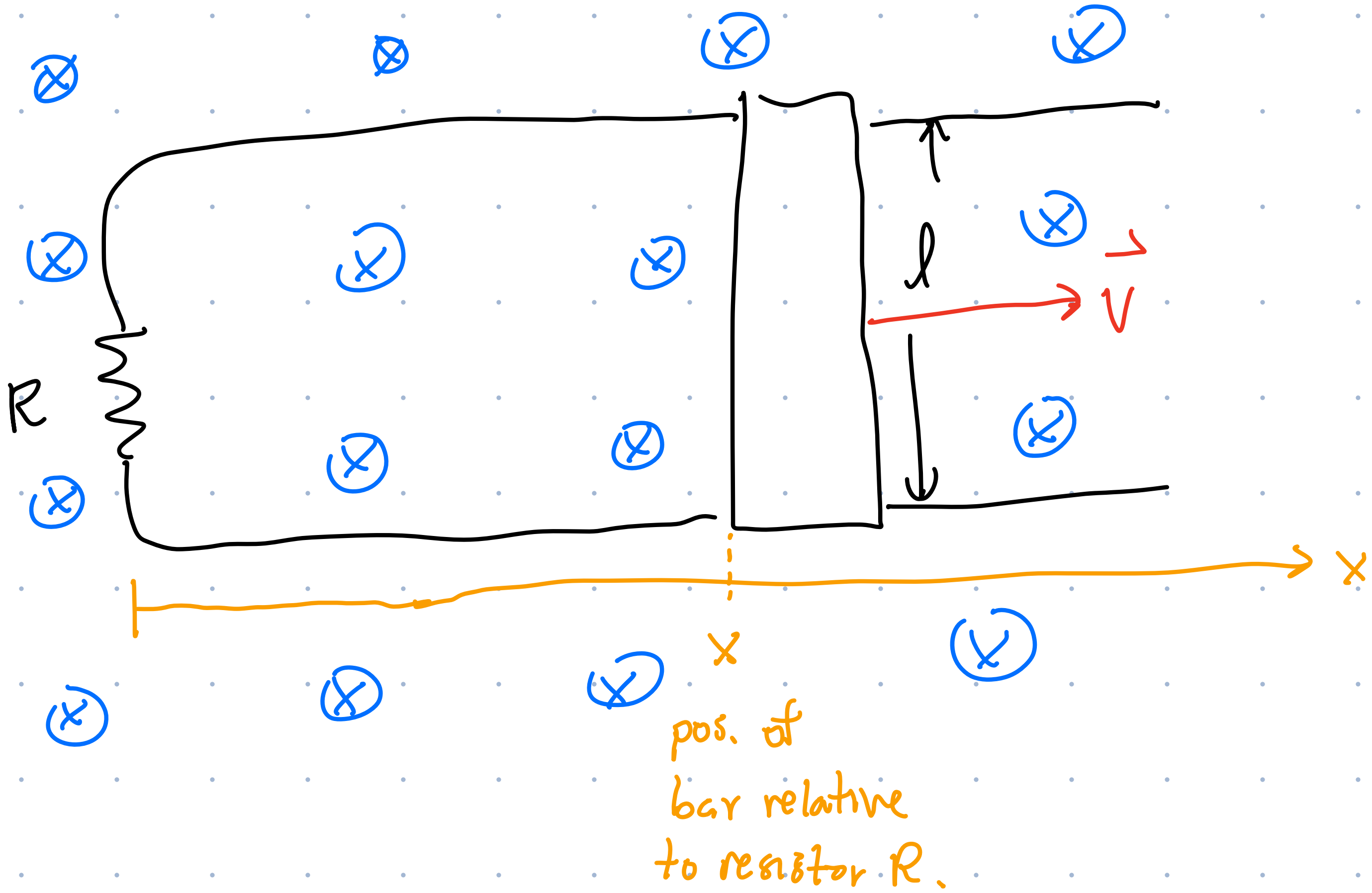
power into sys.: $$P_{in} = \frac{W}{\Delta t} = F_{pull}\frac{\Delta x}{\Delta t} = F_{pull}\, v$$

but we require $$F_{pull} = F_B = I \ell B = \boxed{\left(\frac{vB\ell}{R}\right)\ell B}$$

$$\therefore P_{in} = \underbrace{\left[\left(\frac{vB\ell}{R}\right)\ell B\right]}_{F_{pull}} v = \boxed{\frac{(vB\ell)^2}{R} = P_{in}}$$

Notice that P_{in} is exactly equal the dissipated power given by ④. ⇒ Conservation of energy.

See if we can get the motional emf result $\mathcal{E} = vBl$ in another way.



Calculate the magnetic flux through the circuit loop of area $A = lx$

In general, the magnetic flux is given by:

$$\Phi_B = \int \vec{B} \cdot d\vec{a}$$

For a const. $\vec{B}$ w/ $\vec{B} \parallel d\vec{a}$, $\Phi_B = BA$

$\therefore$ In this case, $\Phi_B = Blx$

Let's consider $\frac{d\Phi_B}{dt} = \frac{d}{dt}(Blx)$

since B & l are constants,

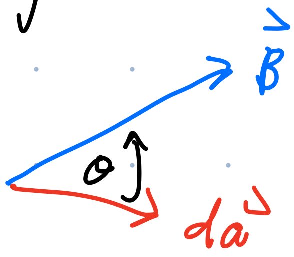
$$\frac{d\Phi_B}{dt} = Bl \underbrace{\frac{dx}{dt}}_{v} = \underbrace{Blv}_{\varepsilon \text{ motional emf that we previously calculated.}}$$

$$\boxed{\therefore \ \varepsilon = \left|\frac{d\Phi_B}{dt}\right|}$$ Faraday's Law

Faraday's law tells us that a change in magnetic flux through a circuit loop induces a voltage or emf $\mathcal{E} = \left| \frac{d\Phi_B}{dt} \right|$

In general, there are 3 ways to change Φ_B through a loop.

Note that $\Phi_B = \int \vec{B} \cdot d\vec{a} = \int B \cos\theta \, da$

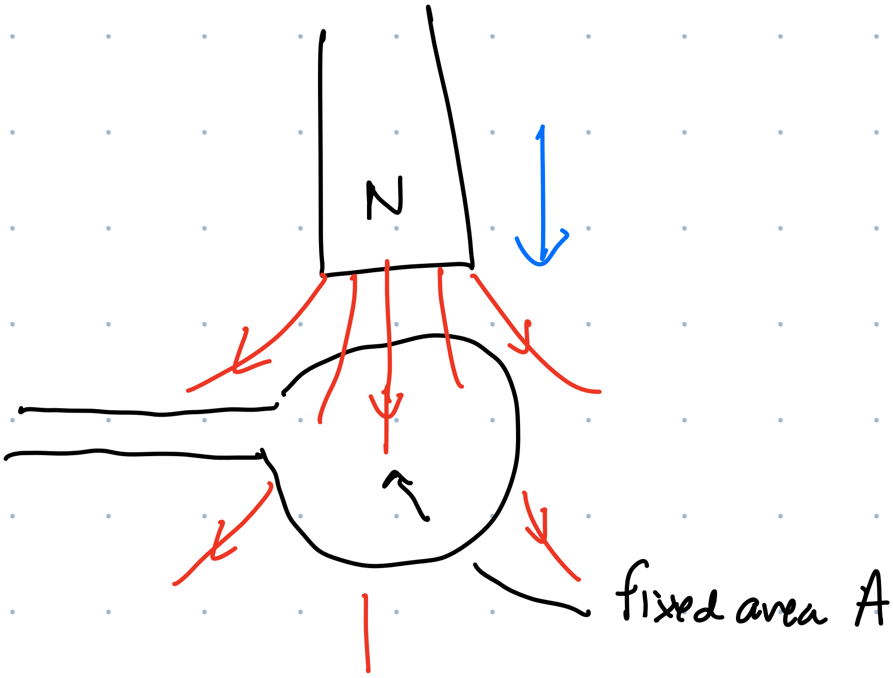


1. We can change the area of the circuit loop.

If $\Phi_B = BA\cos\theta$ & we change A, then the resulting change in Φ_B creates an induced emf & current.

Motional emf is an example of this case.

2. Change the strength of the magnetic field.



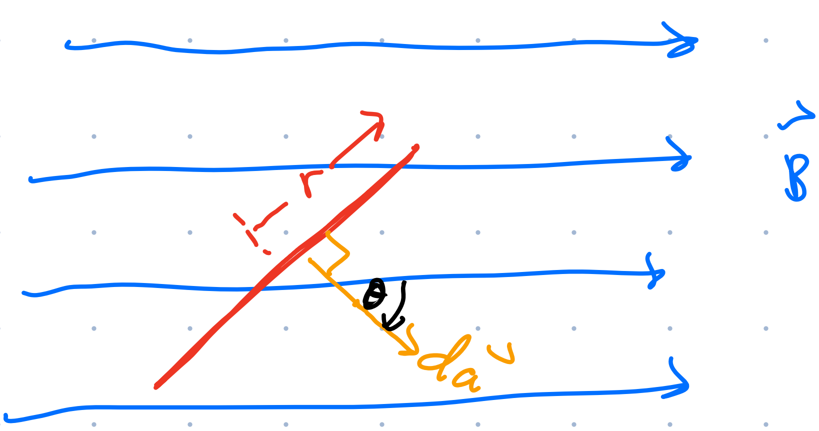
If bar magnet is stationary, Φ_B through the loop is const. ⇒ no induced emf or current.

If a move the magnet towards or away from the loop, the strength of the field at the loop changes ⇒ changing magnetic flux & an induced emf & current.

The magnetic braking lab was an example of this case.

3. Change the angle between $\vec{B}$ & the area vector $d\vec{a}$

Side View of a circular loop of wire of radius r in a uniform magnetic field $\vec{B}$.



If we rotate the loop so that θ changes, we create a change in Φ_B through the loop & we get an induce emf / current.

* Electric generator are examples of this case.