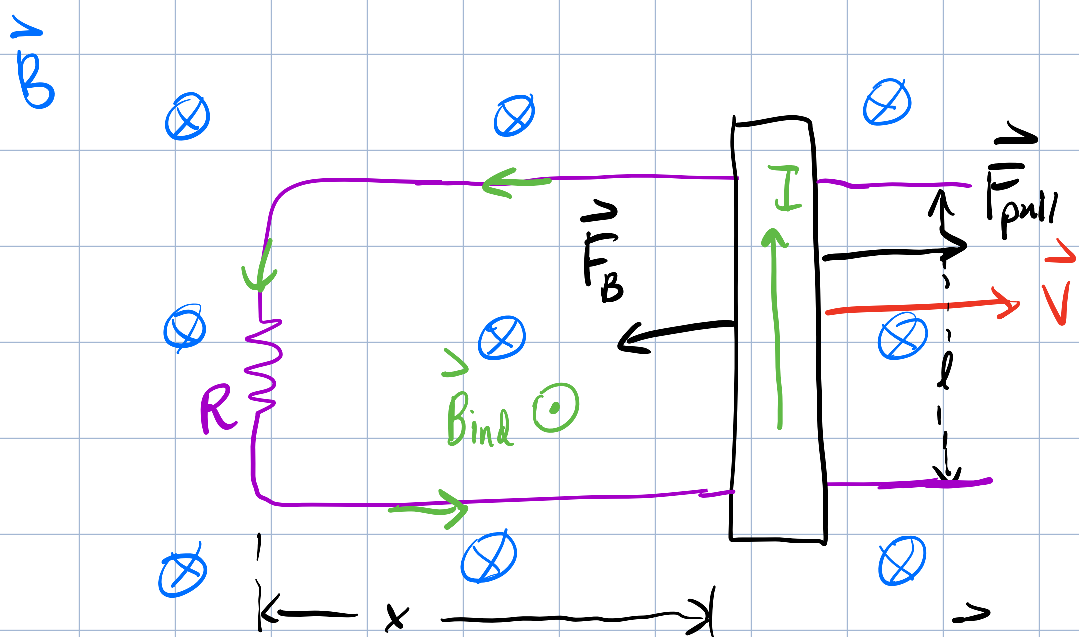
PHYS 121 April 5, 2024

- The last PrairieLearn HW is due Thur, Apr. 11 @ 23:59
- If completing the Hands-On bonus project, send me the link to your YouTube video today by @ 23:59.
- Complete end-of-term survey by 23:59 on Wed. Apr. 10 to receive 0.5 towards final grade. Link to Survey is on PHYS 121 Canvas home-page.
- Eclipse today. Peak ~11:30 am.

<u>Last Time</u>: Motional emf



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

$\mathcal{E} = vB\ell$; $I = \frac{vB\ell}{R}$; $P = \frac{(vB\ell)^2}{R}$; $F_B = I\ell B$

(2) ✓ (3) ✓ (4) ✓

↑ dissipated power by R

To maintain a const. speed of bar, must pull with a force $\vec{F}_{pull}$ that balances the magnetic force $\vec{F}_B$ acting on the current in the bar.

The work we do to pull the bar is

$$W = F_{pull}\, \Delta x$$

↙ displacement.

The Power input into the system is

$$P_{in} = \frac{W}{\Delta t} = F_{pull} \frac{\Delta x}{\Delta t} = F_{pull}\, v$$

require $F_{pull} = F_B = I\ell B$

sub (3) for I

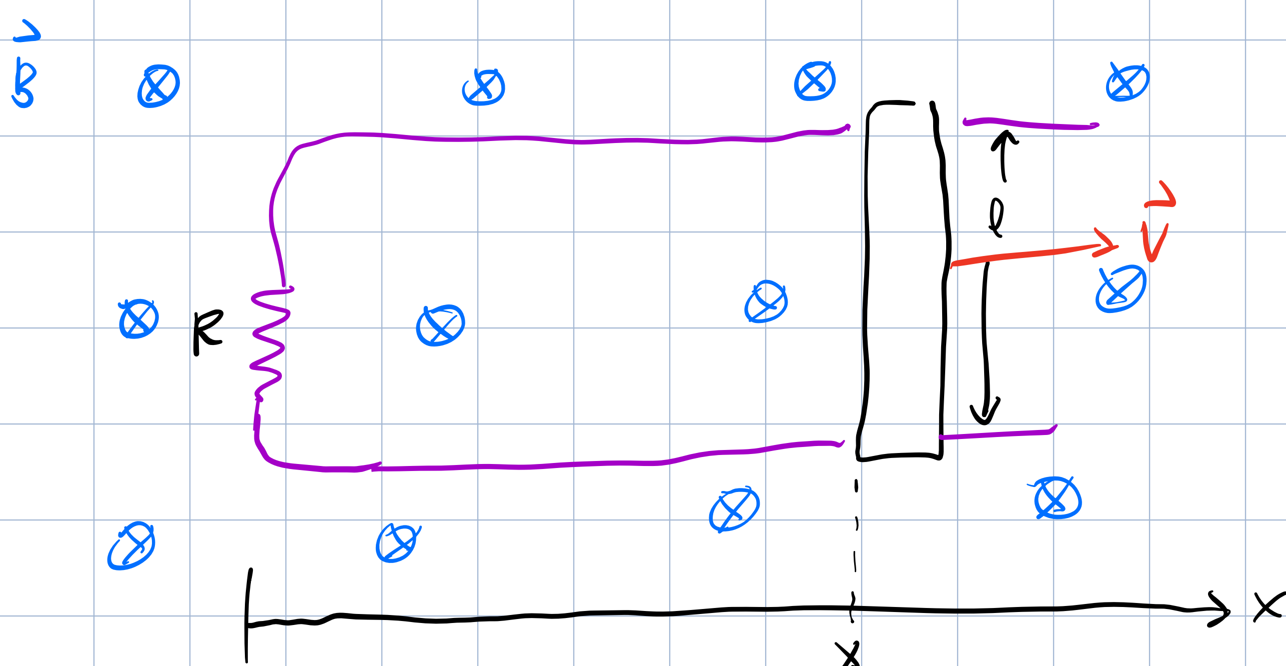
$$F_{pull} = \left(\frac{vB\ell}{R}\right)\ell B$$

$$\therefore P_{in} = \underbrace{\left[\left(\frac{vB\ell}{R}\right)\ell B\right]}_{F_{pull}} v = \frac{(vB\ell)^2}{R}$$ Power put into the system,

Note that $P_{in} = P$ ← power dissipated by the resistor.

→ Conservation of energy.

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



Calculate the magnetic flux through the circuit loop of area $A = \ell x$.

In general, the magnetic flux is given by:

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

For a const $\vec{B}$ w/ $\vec{B} \perp$ area, $\Phi_B = BA$
$= B\ell x$

Let's consider $\frac{d\Phi_B}{dt} = \frac{d}{dt}(B\ell x)$

Since B & ℓ are const in the current problem

$$\frac{d\Phi_B}{dt} = B\ell \underbrace{\frac{dx}{dt}}_{v} = vB\ell = \mathcal{E}$$

It is generally true that the induced emf in a circuit is equal to the time derivative of the magnetic flux:

$$\mathcal{E} = \left| \frac{d\Phi_B}{dt} \right| \qquad \text{Faraday's Law}$$

We can change magnetic flux Φ_B through a loop in 3 different ways:

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

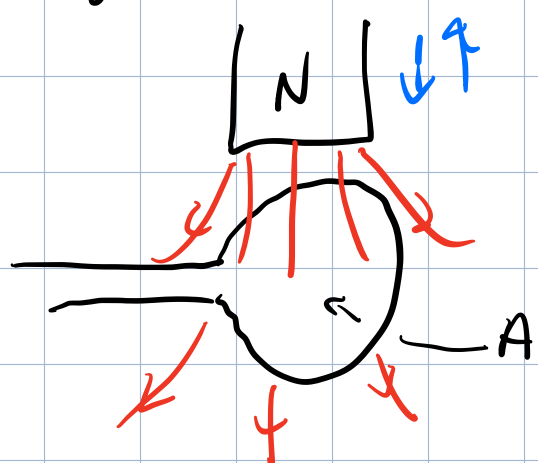
1. Change the angle between $\vec{B}$ & the area $d\vec{a}$

side view

edge of a loop

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

2. Change the strength of the magnetic field.



If we move the bar magnet towards or away from the loop, change magnetic flux & get induce emf & current.

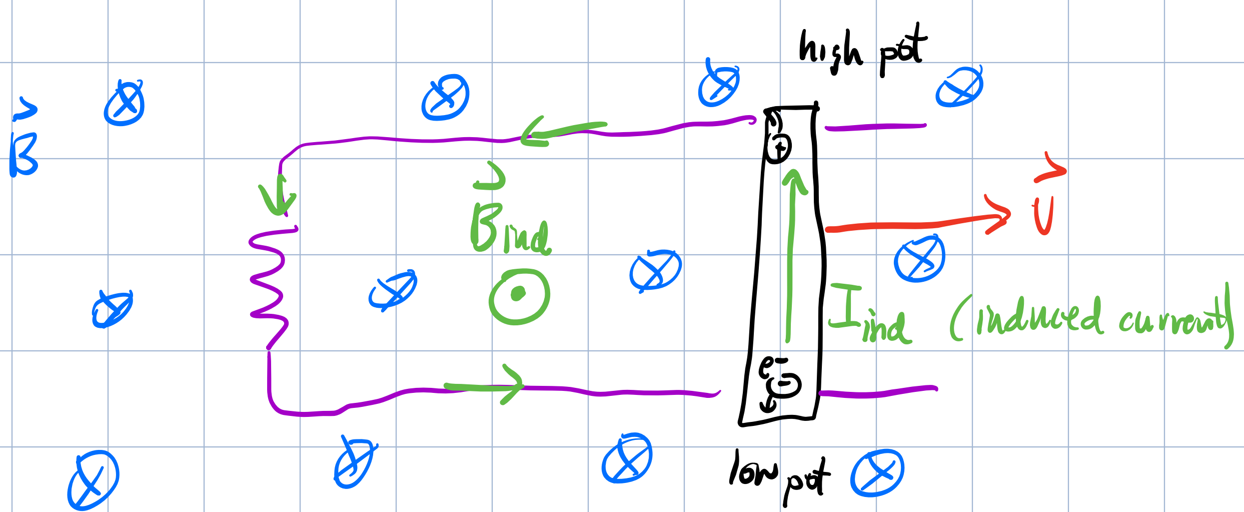
3. Change the area of the loop.

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

Motional emf is an example of induced emf due to a changing loop area.

Consider the dir'n of induced emf & current.

CASE I Increase flux Φ_B through a loop.

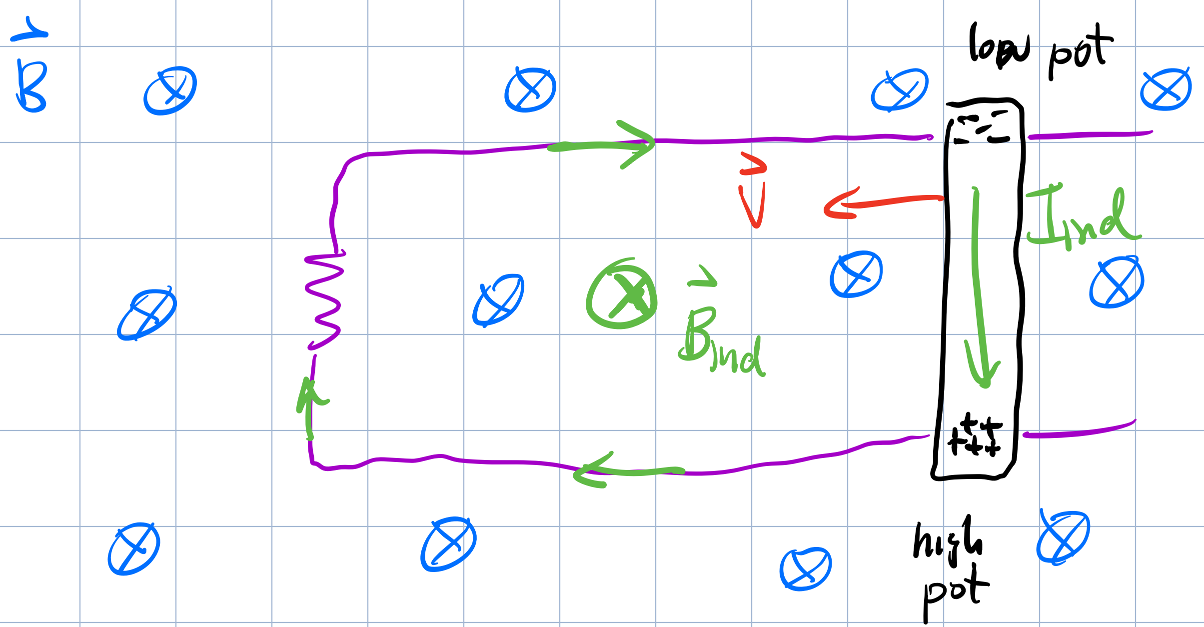


By RHR, induced current in this case is CCW.

The induced current creates its own induced magnetic field $\vec{B}_{ind}$.

When we <u>increase</u> Φ_B through a loop, the induced magnetic field $\vec{B}_{ind}$ opposes this change in flux by having a dir'n that is opposite to the dir'n of the original field.

CASE II – decrease Φ_B through loop.



In this case, the shrinking area cause a change in Φ_B that induces a CW current. The CW current establishes a induce mag.

field $\vec{B}_{ind}$ that is into the screen (same dir'n a original (blue) magnetic field).