Phy 4B 6/8

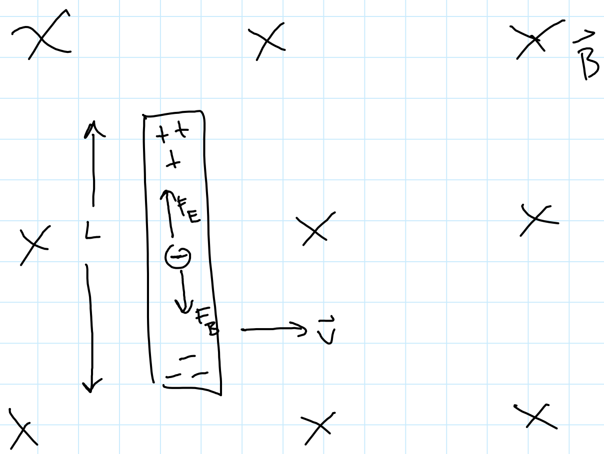
Thursday, June 8, 2017 3:54 PM

Goals for the Lecture:

1) Understand that a changing magnetic flux produces an EMF
2) Be able to use Faraday's Law to calculate the induced EMF from a changing magnetic flux
3) Understand Lenz's Law and be able to use it to determine the direction of the induced current
4) Understand how generators and motors work and that they are basically the same device
5) Understand Eddy currents

Motional EMF

A conductor moving in a magnetic field:



When $|\vec{F}_E| = |\vec{F}_B|$ we have No more moving charges (steady state)

$$qE = qvB$$

$$E = vB$$

Since $\Delta V = -Ed$

$$|\Delta V| = EL$$

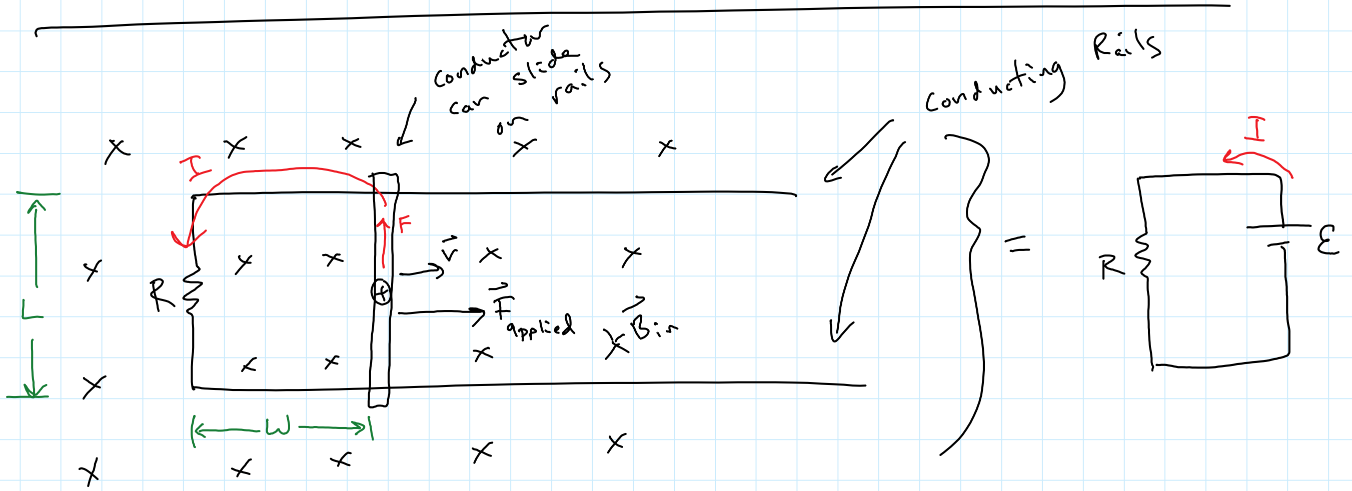
$$E = \frac{\Delta V}{L}$$

$$\frac{\Delta V}{L} = vB$$

$$\Delta V = BLv$$

↗ potential difference across the Conductor

↖ Velocity of the conductor



1) Forces : "+" charges in conductor feel force ↑

so, current is CCW ↶

2) Lenz's Law: Φ_B is increasing into page

so, I is created so its B field decreases the flux ↶ CCW

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

3) Faraday's Law:
$$\mathcal{E} = -N \frac{d\Phi_B}{dt}$$

$$|\mathcal{E}| = \left| N \frac{d\Phi_B}{dt} \right|$$

$$= (1) \frac{d}{dt}\left(\int \vec{B} \cdot d\vec{A} \right)$$

$$= \frac{d}{dt}(BA)$$

B d A

$$dt$$

$$= B \frac{dA}{dt}$$

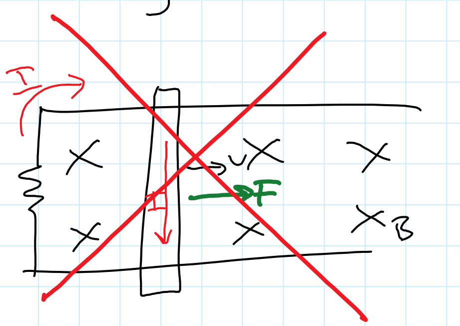
$$= B \frac{d}{dt}(LW)$$

$$= BL \underbrace{\frac{dW}{dt}}_{\vec{v}\ \text{velocity}}$$

$$= BLv$$

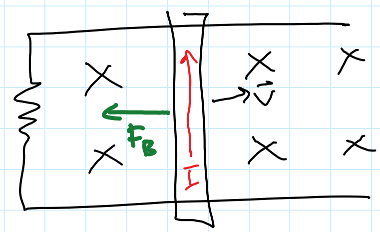
4) Magnetic Force on Conductor

Let's say I is CW ↷

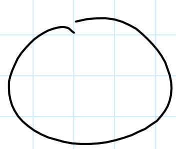


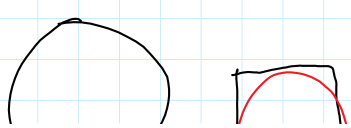
current in a magnetic field feels a force

Let's say I is CCW ↶

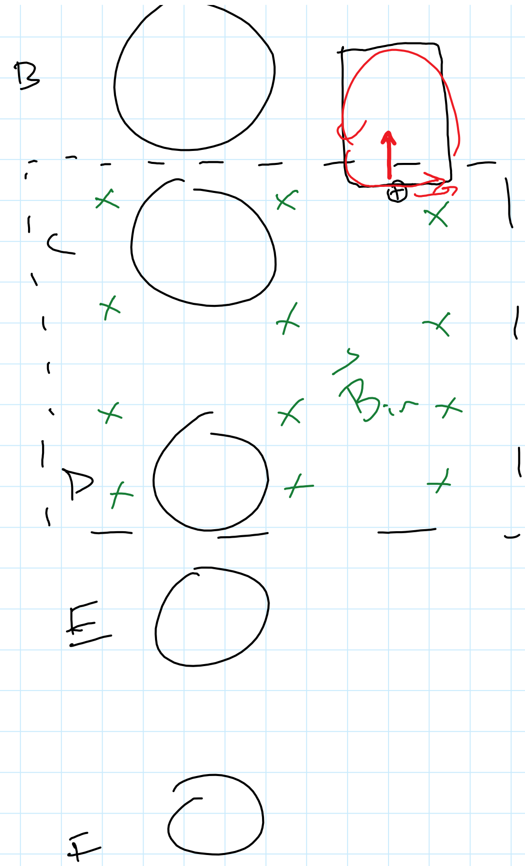


Just give it a little push & it generates its own energy → violates conservation of energy

A 

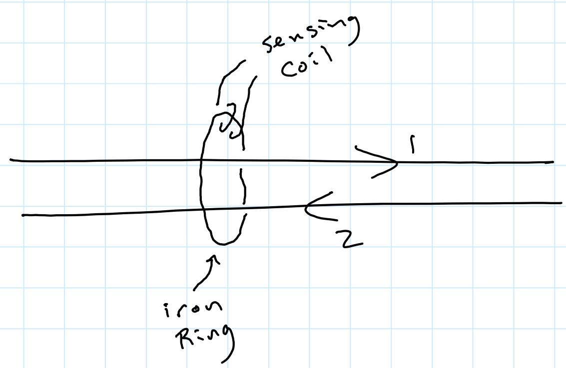
B 

As the loop moves from	current induced
A → B	None



A → B	None
B → C	CCW ↶
C → D	None
D → E	CW ↷
E → F	None

GFIC – Ground fault Interrupt Circuit

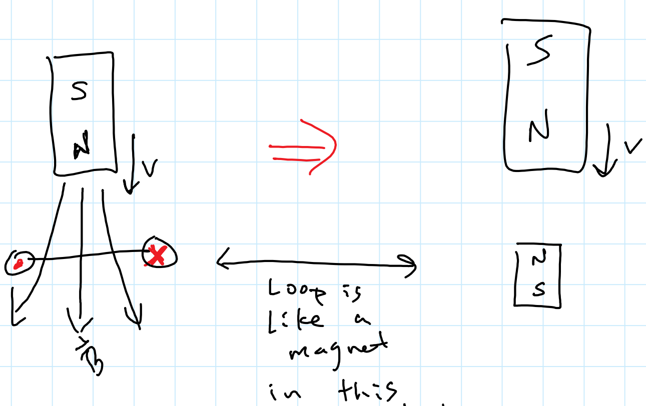


if all is well: $I_1 = I_2$

Net flux = 0 (in sensing coil)

if current finds another path to ground: $I_2 < I_1$

Net flux ≠ 0 (in coil)

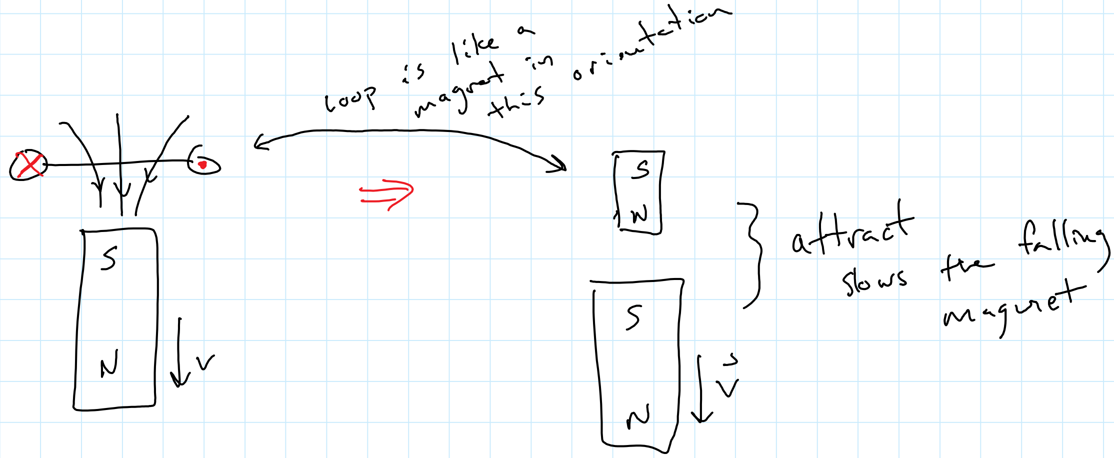


Repel

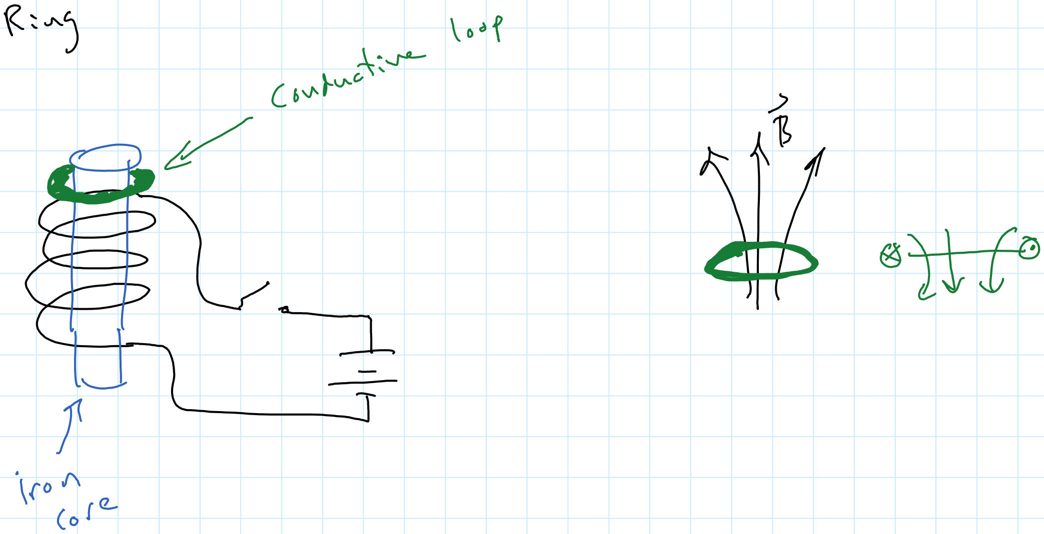
slows the falling magnet

orientation

Now,



Jumping Ring

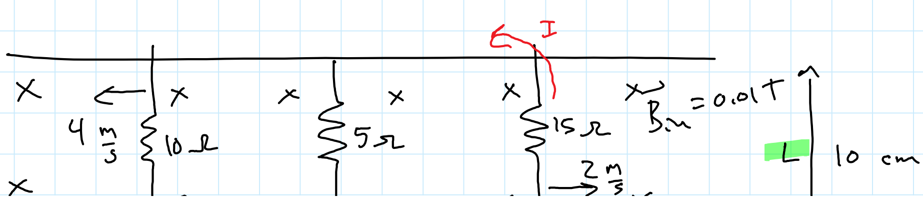


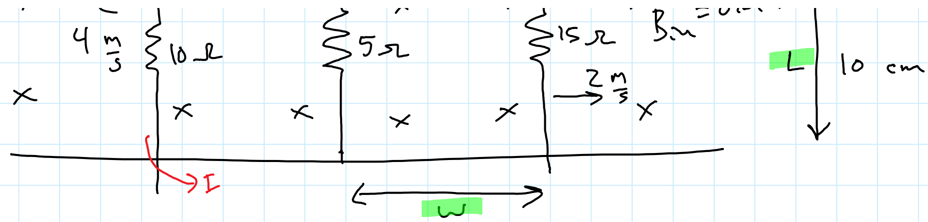
Applications:

- wireless phone chargers
- electric toothbrush charging
- hybrid car (regenerative braking)
- GFIC in bathrooms and kitchens
- Motors
- Generators
- Roller coaster brakes

} see below

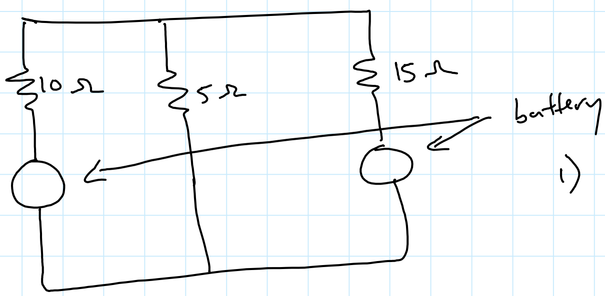
Problem:





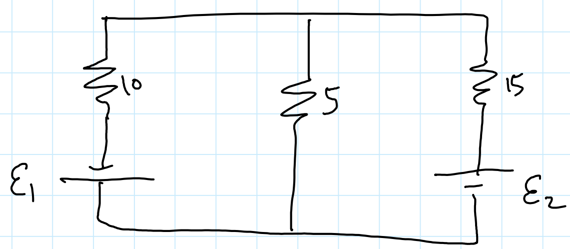
Find I in the 5 Ω resistor.

Like this circuit



1) use Lenz's Law to find orientation of batteries

2) use Faraday's Law to find emf of batteries



$$\mathcal{E} = N \frac{d\Phi_B}{dt} = (1) \frac{d}{dt}\left[\int \vec{B}\cdot d\vec{A}\right]$$

$$= \frac{d}{dt}\left[B \int dA\right]$$

$$= \frac{d}{dt}(BA)$$

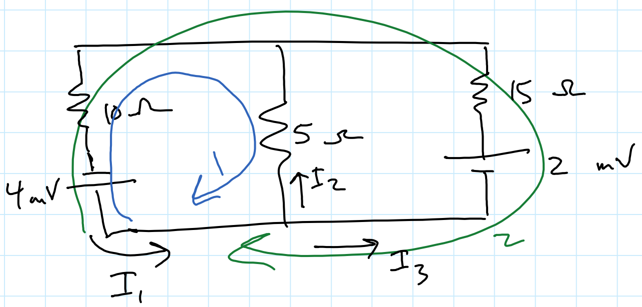
$$= B \frac{d}{dt}(LW)$$

$$= BL \frac{dW}{}$$

dt

$= BLV$ ← velocity

$\mathcal{E}_1 = 4\,mV$ $\mathcal{E}_2 = 2\,mV$

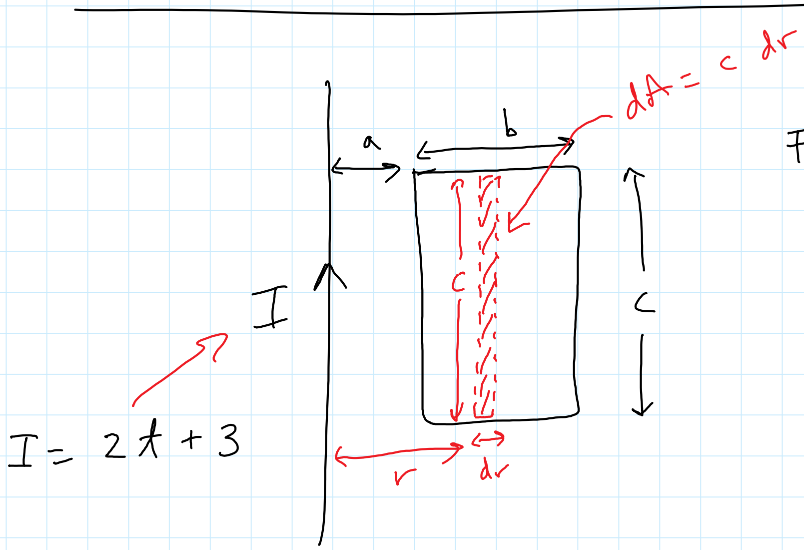


junction: $I_1 = I_2 + I_3$

Loop 1: $-4\,mV + I_1(10) + I_2 5 = 0$

Loop 2: $-4\,mV + I_1(10) + I_3(15) - 2\,mV = 0$

Solve for I_2



Find $\mathcal{E}$ in loop at $t = 0$

$$\mathcal{E} = N \frac{d\Phi_B}{dt} \quad (N = 1)$$

$$= \frac{d}{dt}\left[\int \vec{B} \cdot d\vec{A}\right]$$

Find B: $B = \frac{\mu_0 I}{2\pi r}$ (using Amperes Law)

$$\mathcal{E} = \frac{d}{dt}\left(\int^{a+b} \frac{\mu_0 I}{2\pi r}\, c\, dr\right)$$

$$\mathcal{E} = \frac{d}{dt}\left(\int_a^{a+b} \frac{\mu_0 I}{2\pi r}\, c\, dr\right)$$

$$= \frac{d}{dt}\left[\frac{\mu_0 I c}{2\pi} \int_a^{a+b} \frac{1}{r}\, dr\right]$$

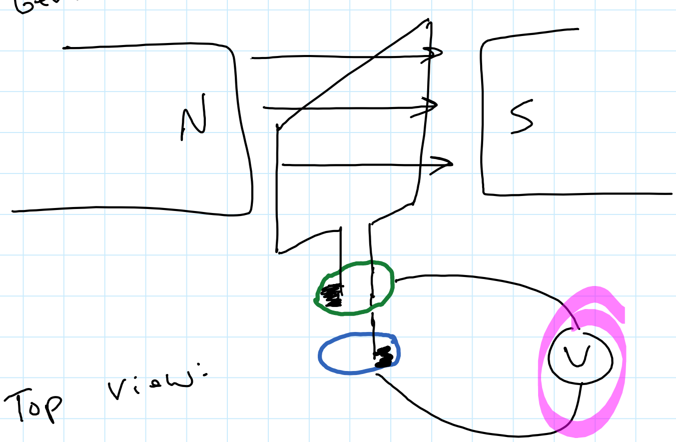
$$= \frac{d}{dt}\left[\frac{\mu_0 I c}{2\pi} \ln\left(\frac{a+b}{a}\right)\right]$$

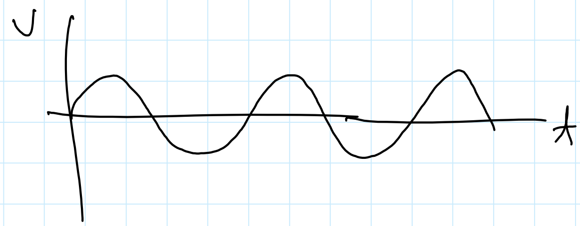
$$= \frac{\mu_0 c}{2\pi} \ln\left(\frac{a+b}{a}\right) \underbrace{\left(\frac{d}{dt} I\right)}_{\underbrace{\frac{d}{dt}(2t+3)}_{2}}$$

$$\mathcal{E} = \frac{\mu_0 c}{2\pi} \ln\left(\frac{a+b}{a}\right) (2)$$

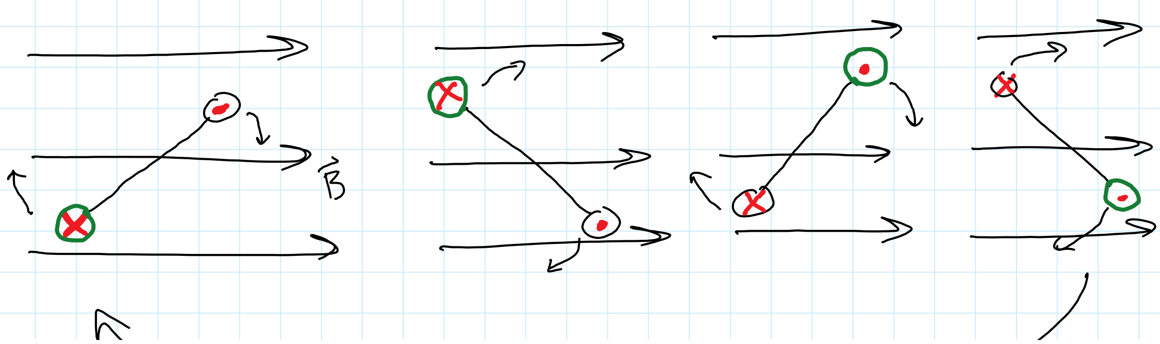
Motors and Generators

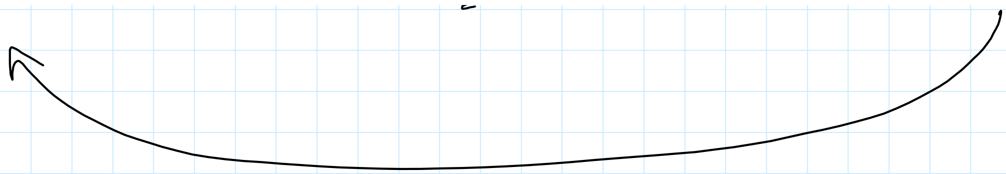
AC Generator

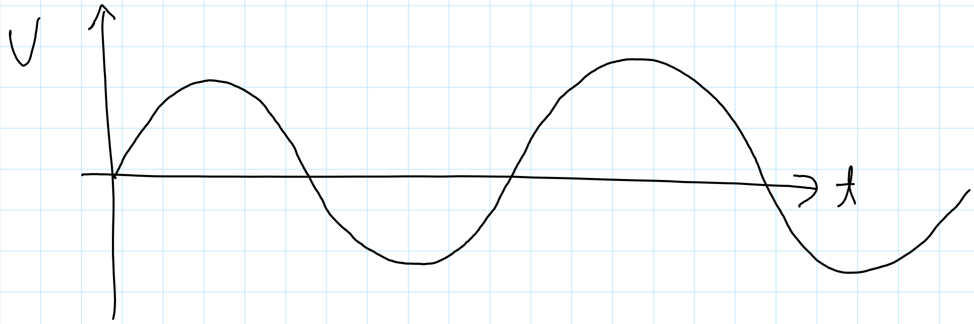




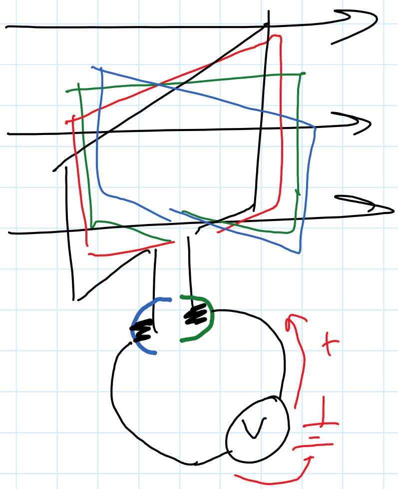
Top view:

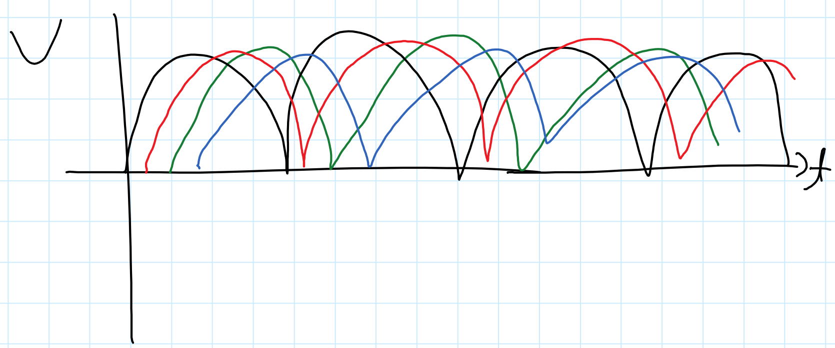


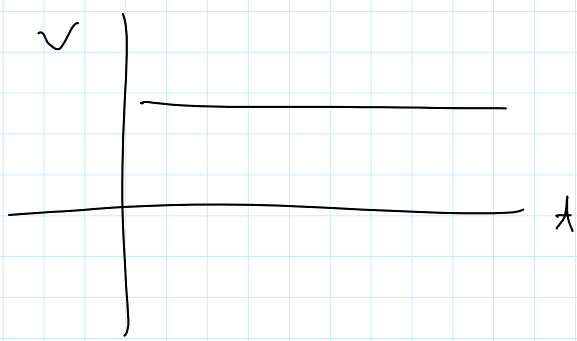




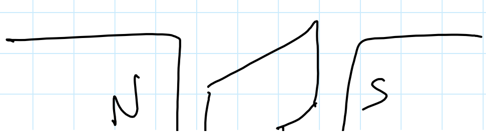
DC Generator:

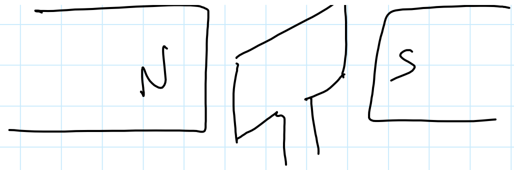




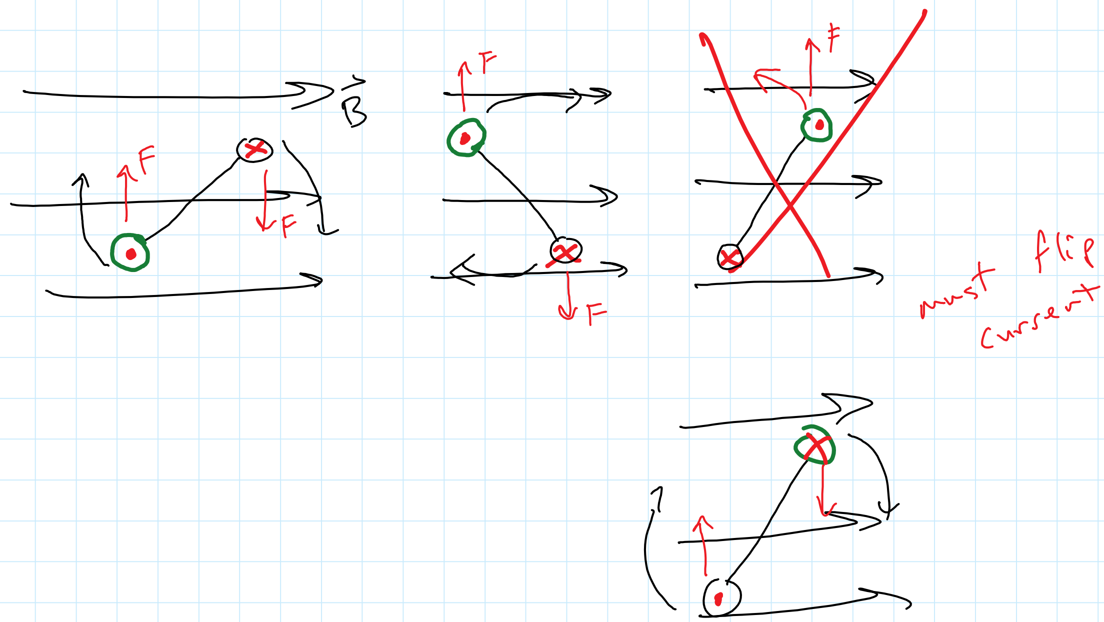


Motor





Top View



worksheet
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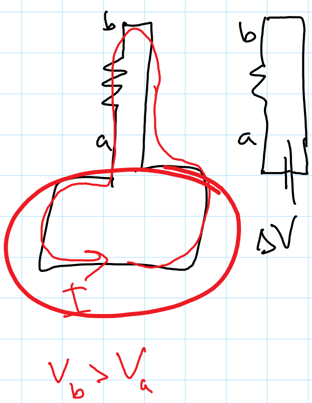
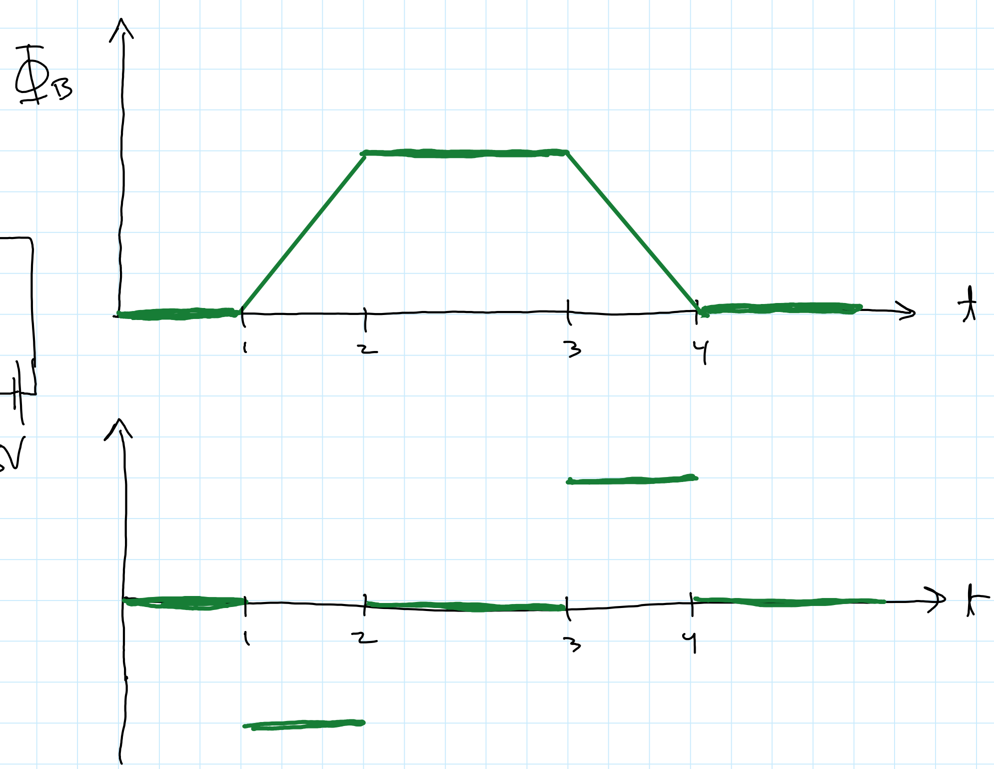
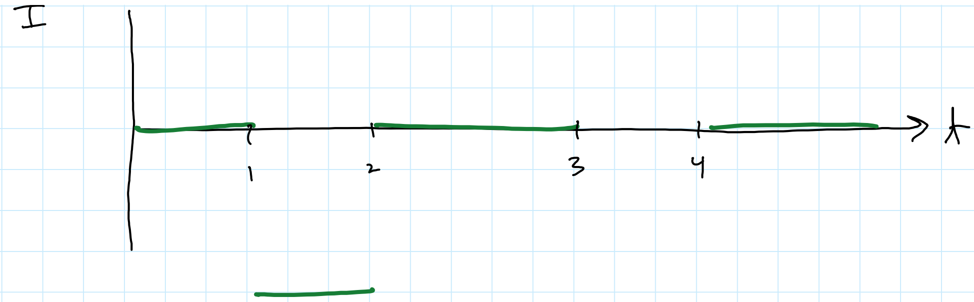
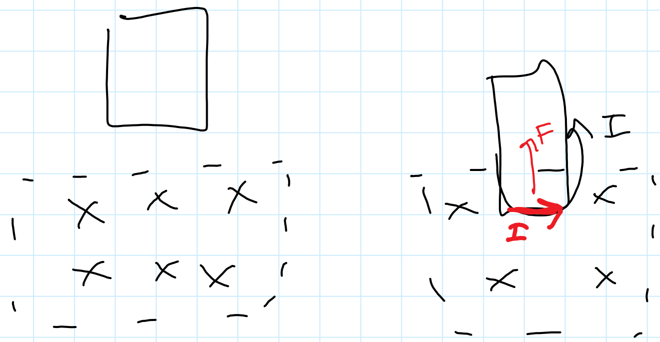
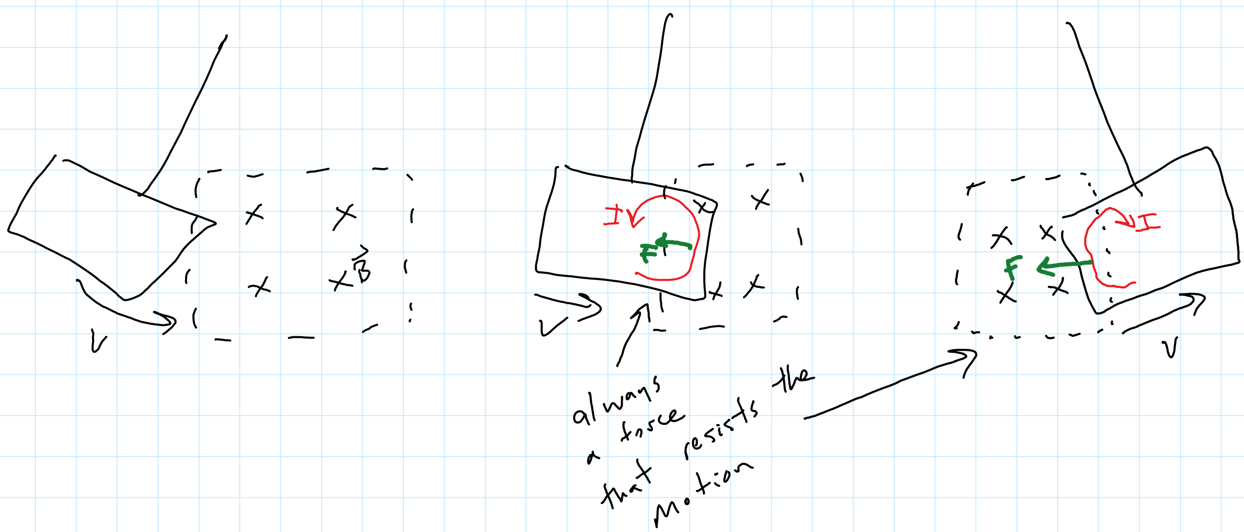






Eddy Currents





Some roller coasters use eddy current brakes