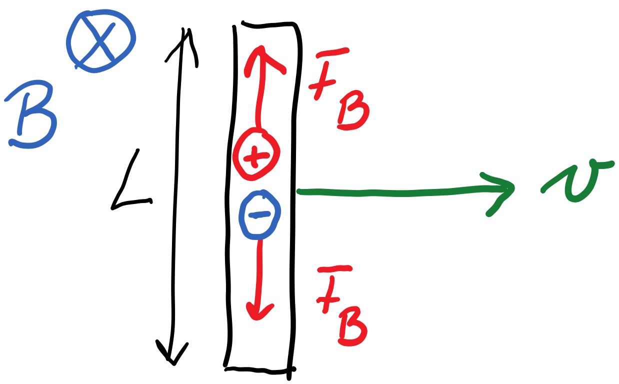
Lecture 28: Electromagnetic Induction

Motional emf



Conductor moves with speed v through magnetic field

Force on charged particles

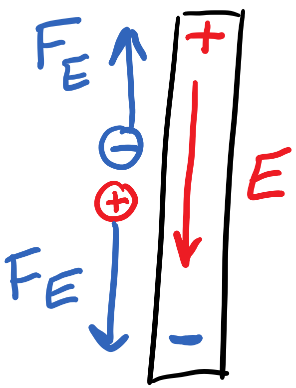
$$F_B = qvB$$

Charge separation

Electric field

Electric force $F_E = qE$

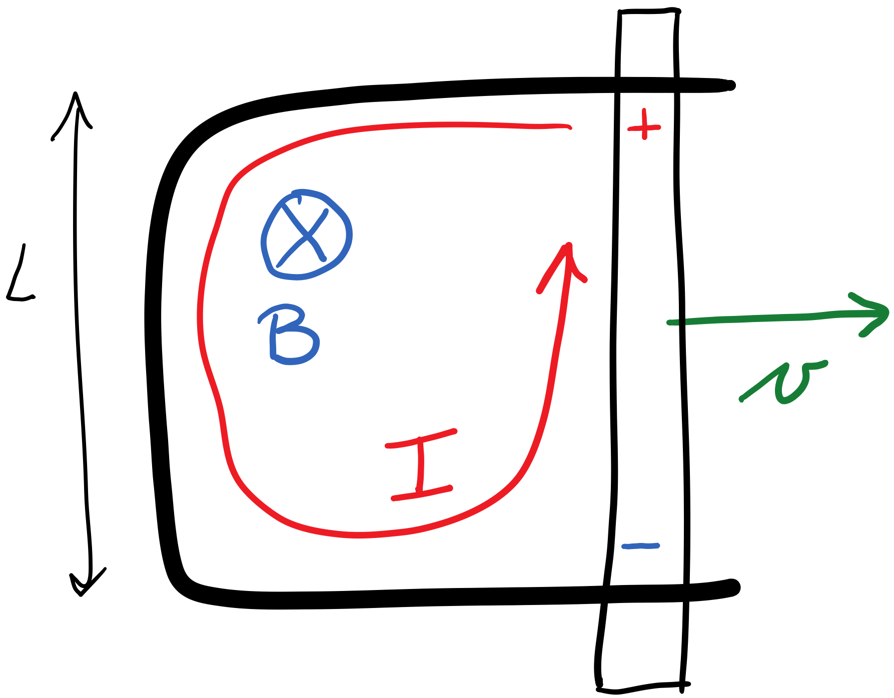
Until $F_E = F_B$



$E = vB$

$\Delta V = vLB$ motional emf

Induced current in a circuit

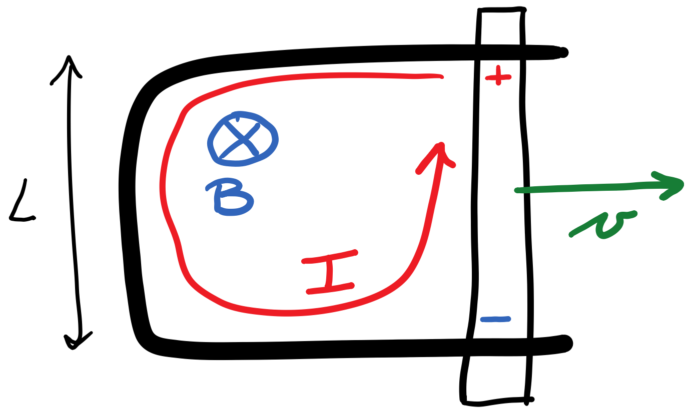


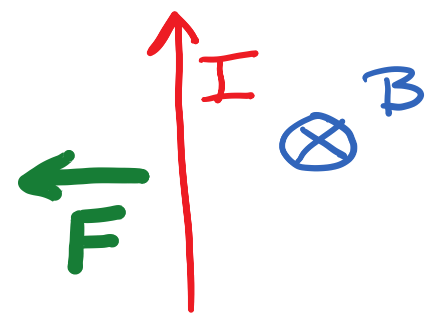
Moving conductor in previous example had emf, but could not sustain a current.
Resistance of circuit R

$$\Delta V = vLB$$

$$I = \frac{vLB}{R}$$

Force on current





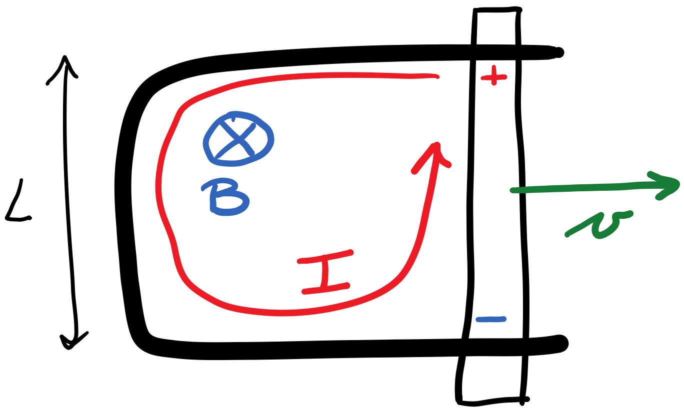
$$\Delta V = vLB$$

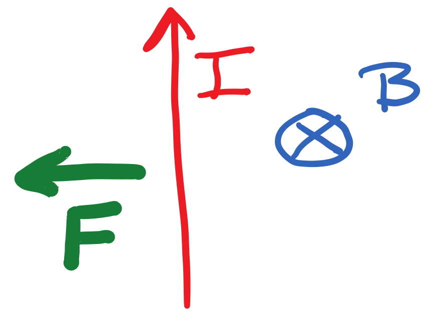
$$I = \frac{vLB}{R}$$

$$F_B = ILB = \left(\frac{vLB}{R}\right) LB = \frac{vL^2B^2}{R}$$

To move with const. speed, need to pull with the same force $F_p = F_B$.

Energy





$$F_B = F_P = \frac{vL^2B^2}{R}$$

Power dissipated:

$$P = IV = \left(\frac{vLB}{R}\right)(vLB) = \frac{(vLB)^2}{R}$$

Rate at which energy is added by pulling force:

$$P = F \cdot v = \frac{(vLB)^2}{R}$$

Same!
Energy Conservation

Magnetic Flux

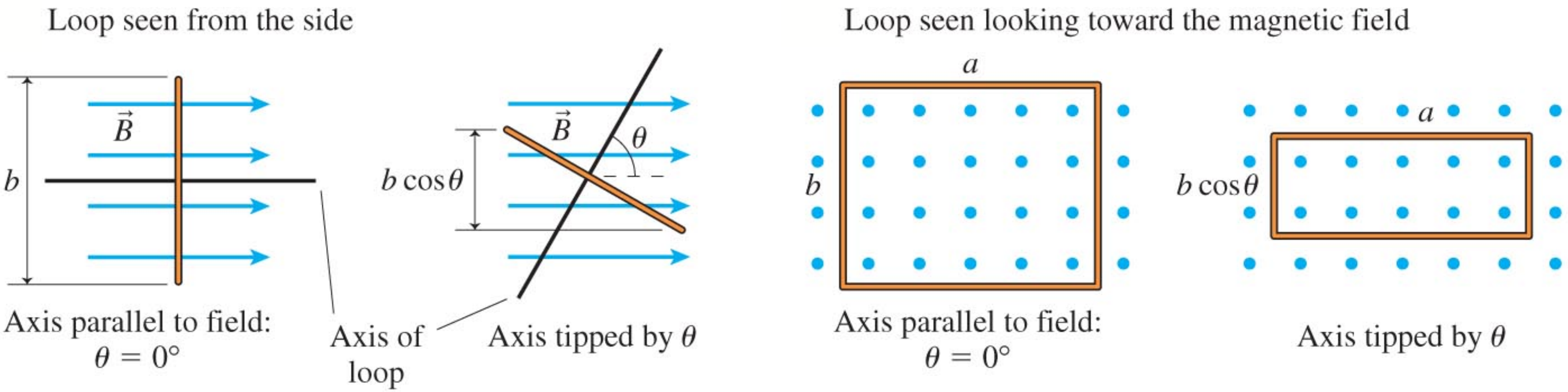
If the magnetic field passing through a coil of wire is changing, a current is created (=induced) in the coil.

Magnetic Flux:

$$\Phi = A_{eff}B = AB\cos\theta$$

Unit:

$Tm^2 = Wb$ Weber



Lenz's Law

Current is induced in a loop of wire when the magnetic flux through the loop changes.
The direction of the induced current is such that the induced magnetic field opposes the change in flux.

Loop "wants" to keep the flux the way it was before the change.

$$\Phi = A_{eff}B = AB\cos\theta$$

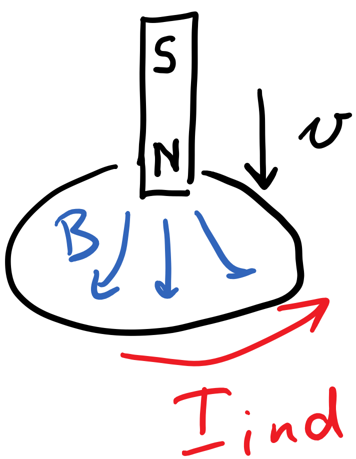
Changes in flux:

- B changes (increases/decreases)
- Loop changes area or angle
- Loop moves in or out of magnetic field

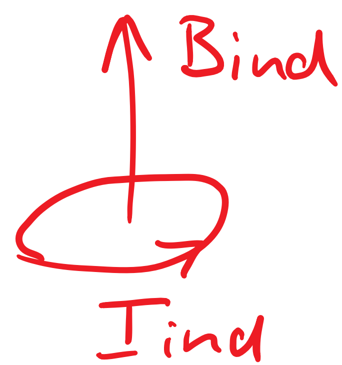
Examples

Current is induced in a loop of wire when the magnetic flux through the loop changes. The direction of the induced current is such that the induced magnetic field opposes the change in flux.

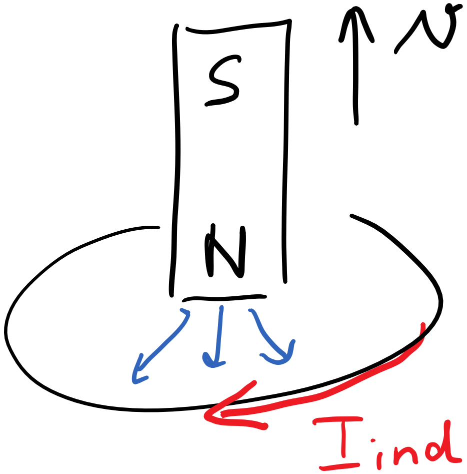
$$\Phi = A_{eff}B = AB\cos\theta$$

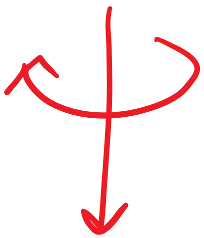


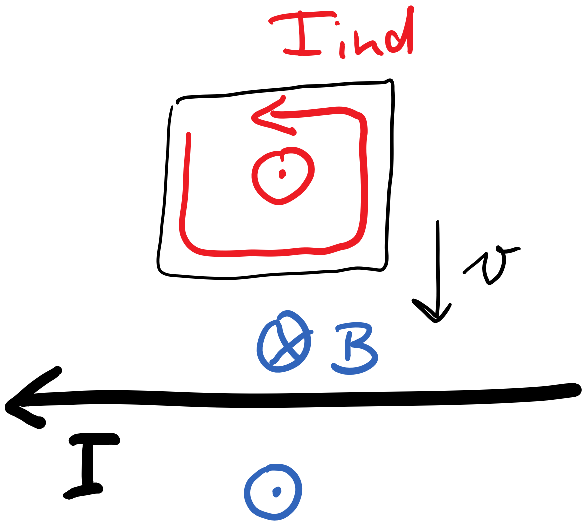
$\vec{B}$ down
flux increases
Loop makes $\vec{B}$
to counteract



$\vec{B}$ down, decreases







Closer to current

B increases ⊗

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Loop makes B ⊙