Electromagnetic Induction

Lenz's Law: direction

1) Direction of external flux Φ_0

2) Increasing, decreasing, or constant?

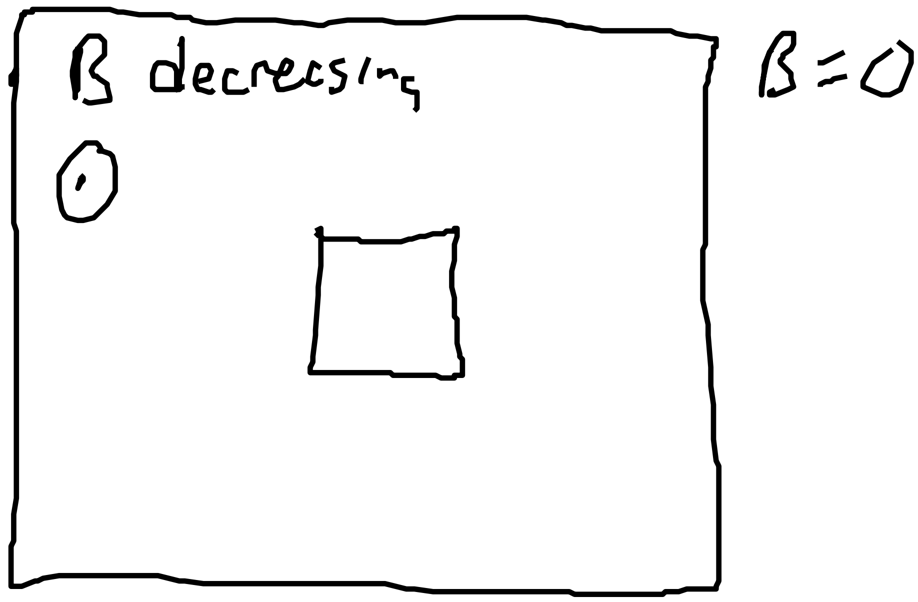
3) If #2 constant, no induction

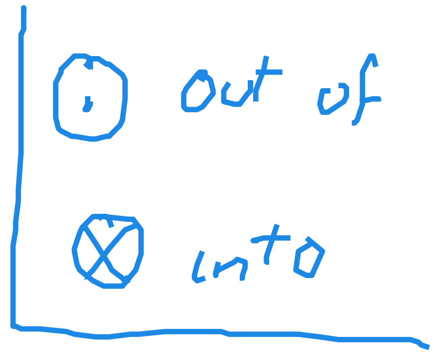
   If #2 increasing, Φ_{ind} opposite Φ_0

   If #2 decreasing, Φ_{ind} same as Φ_0

4) RHR thumb: Φ_{ind}

   fingers: I_{ind}



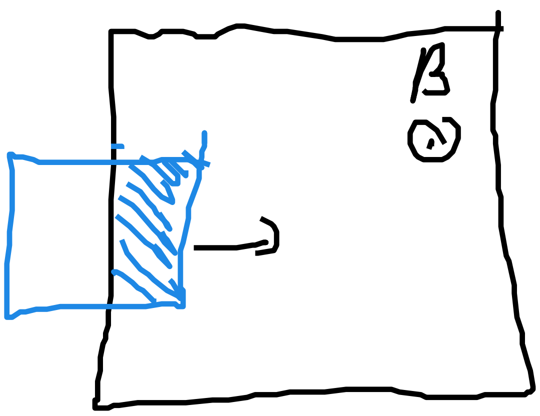


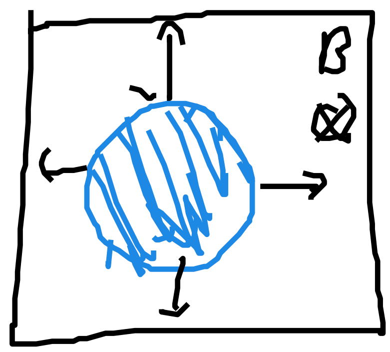
1) Φ_0: $\odot$
2) change: decreasing
3) Φ_{ind}: $\odot$
4) I_{ind}: $\circlearrowleft$ CCW

How Φ_0 can change!

1) $\vec{B}$ can increase or decrease

2) Area of overlap between loop and field can change



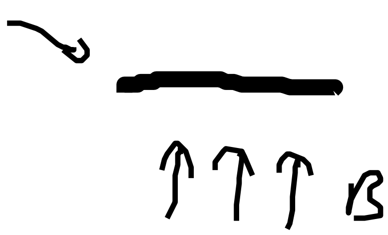


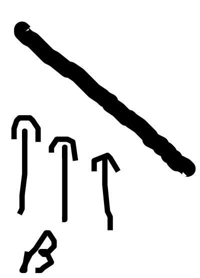
$A_{overlap}$ increasing

Φ_0 increasing

3) Field & loop change orientation with respect to each other

loop seen edge on





less flux because fewer field lines get thru

Define area vector $\vec{A}$

of loop $|\vec{A}|$ = area

$\vec{A}$ is perpendicular to loop

points in direction of

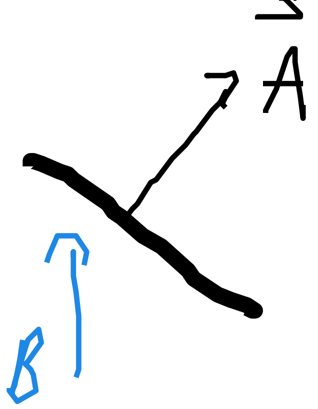
positive flux $\Phi > 0$

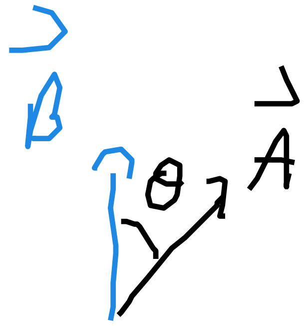
(arbitrary choice)

In simplest case

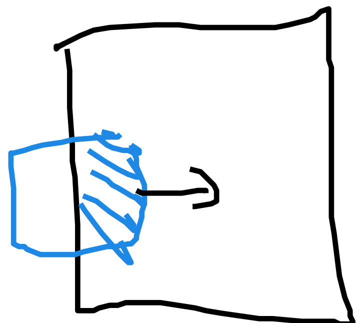
- $\vec{B}$ is uniform
- loop is flat

$$\Phi = \vec{B} \cdot \vec{A} = BA\cos\theta$$





If some of the loop is in uniform $\vec{B}$ and some is in $\vec{B}=0$ region



$$\boxed{\begin{aligned}\Phi &= \vec{B}\cdot\vec{A}_{overlap}\\ &= B A_{overlap}\cos\theta\end{aligned}}$$

Most generally,

$$\Phi = \int_{surface} \vec{B}\cdot d\vec{A}$$

Faraday's Law

magnitude of I_{ind}

$$I_{ind} \sim \frac{d\Phi_o}{dt}$$

Units of $\frac{d\Phi}{dt}$ are $\frac{BA}{t} = \frac{Tm^2}{s}$

$$1\,T = \frac{N}{Am}$$

$$\frac{Tm^2}{s} = \frac{N m^2}{A m s} = \frac{\overbrace{Nm}^{J}}{As}$$

$$= \underbrace{\frac{J}{As}}_{W} = \frac{W}{A} = \text{Volts} \qquad \frac{P}{I}$$

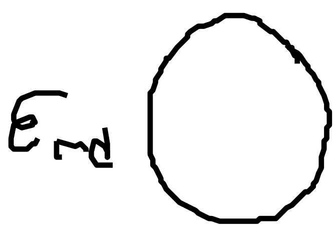
$$P = I \Delta V$$

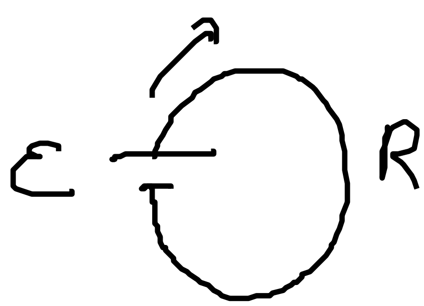
$\frac{d\Phi}{dt}$ has units of volts

induced emf $\mathcal{E}_{ind}$

$$\boxed{\mathcal{E}_{ind} = \left|\frac{d\Phi_o}{dt}\right|}$$

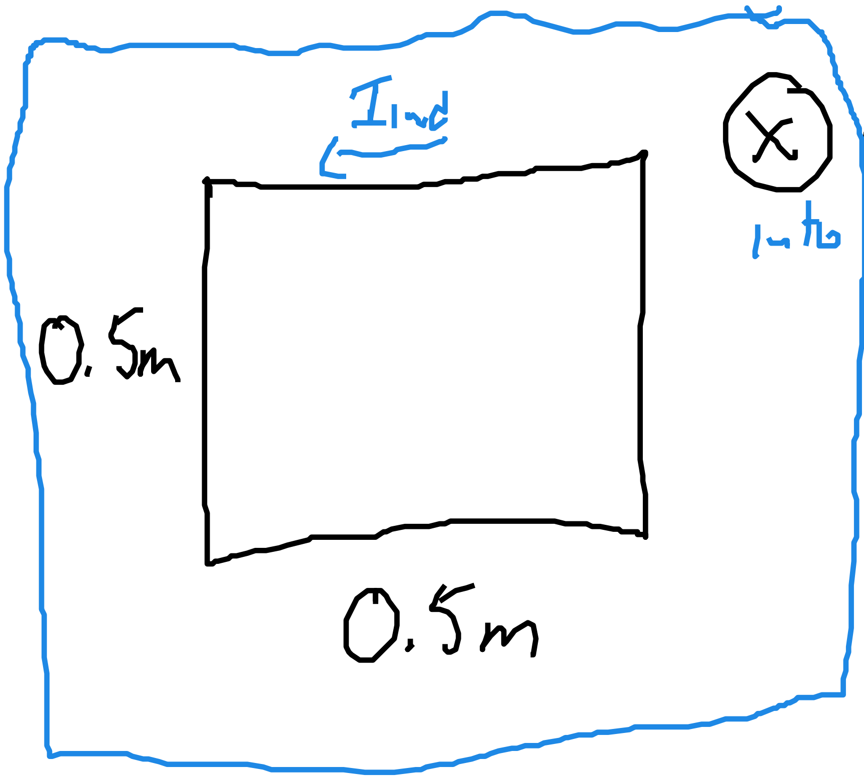
Faraday's Law





$I = \frac{\mathcal{E}}{R}$

$$\boxed{I_{ind} = \frac{\mathcal{E}_{ind}}{R}}$$



$B(t) = (5t)\ mT$

$\left(5\frac{mT}{s}\right)t$

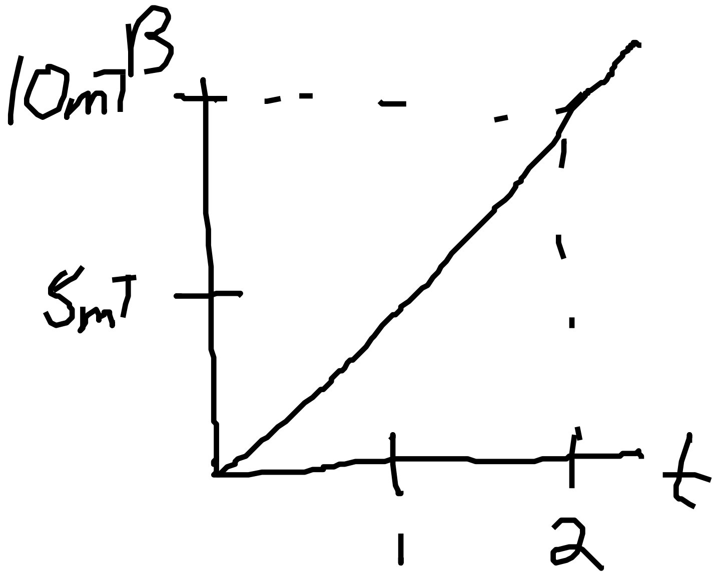
Lenz's Law

1) Φ_0 ⊗

2) change increasing

3) Φ_{ind} ⊙ out of

4) I_{ind}



$\vec{A}$ ⊗

$$\Phi_0^{(t)} = \vec{B}\cdot\vec{A}_{overlap}$$

$$= (5\times10^{-3}t)(0.5)^2\cos 0^\circ$$

$$= 0.00125t$$

$$\mathcal{E}_{ind} = \left| \frac{d\Phi}{dt} \right|$$

$$= \frac{d}{dt}(0.00125\,t)$$

$$= 0.00125 \text{ V}$$

$$= 1.25 \text{ mV}$$

If $R = 0.01\,\Omega$ in loop

$$I_{ind} = \frac{1.25\text{ mV}}{0.01\,\Omega} = 125\text{ mA}$$