INDUCTION

- energy in our world is not generated by a battery but by another source (GPE, hydroelectric, geothermal, etc.). These convert energy via induction

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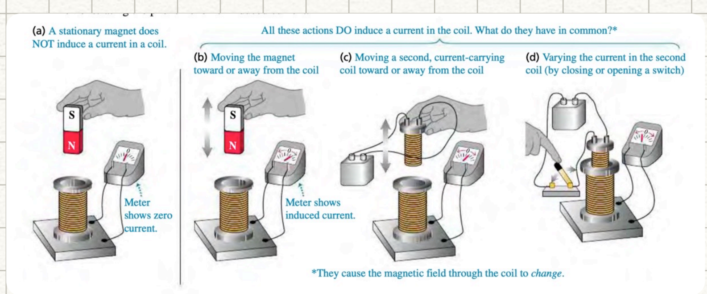
Experiments by Faraday & Henry show that changing $\vec{B}$ induces current.



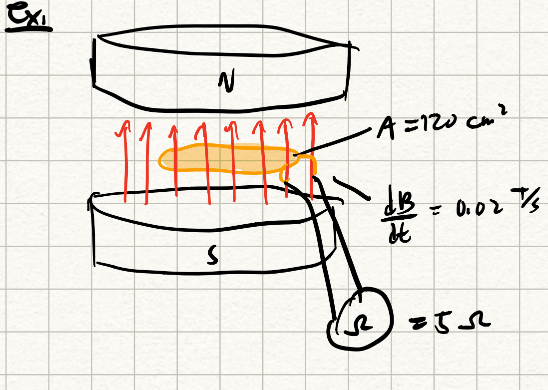
FARADAY'S LAW

$$\boxed{\varepsilon = -\frac{d\Phi_B}{dt}}$$

or

$$\boxed{\varepsilon = -N\frac{d\Phi_B}{dt} \quad \text{(solenoid)}}$$

Ex.



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

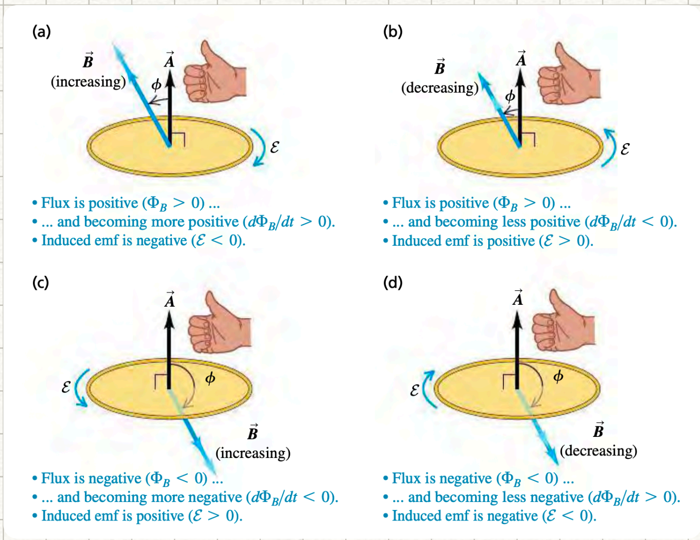
$$\varepsilon = -\frac{d\Phi_B}{dt} = -A \cdot \frac{d\vec{B}}{dt} = -(0.012)(0.02)$$

$$\varepsilon = -0.24 \text{ mV}$$

$$I_{ind} = \frac{\varepsilon}{R} = \frac{0.24\times10^{-3}}{5} = 0.048 \text{ mA}$$

* replacing loop w/ insulator makes current 0 but EMF constant.

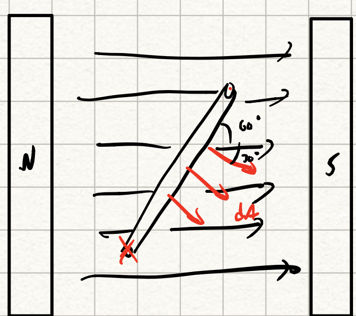
determining direction of $\mathcal{E}$:



- point thumb in dir. of $\vec{A}$
  - ↳ if $\mathcal{E}$ positive, w/ fingers
    if $\mathcal{E}$ negative, against fingers

ex: 500-loop circular wire coil w/ $r = 0.04$ m.

$\vec{B}$ makes angle of 60° with coil, $\frac{dB}{dt} = -0.2$ T/s.



$$\Phi_B = \int \vec{B} \cdot dA$$

$$= \vec{B} \cos 30° \int dA$$

$$= \vec{B} \left(\pi (0.04)^2 (\cos 30°) \right)$$

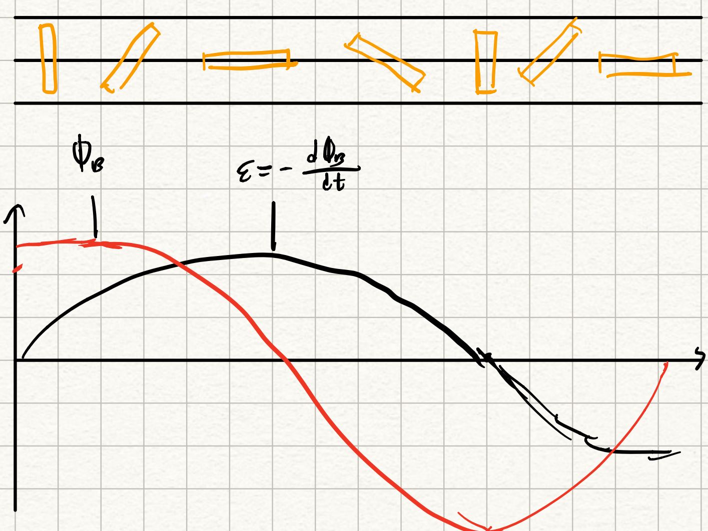
$$= 4.353 \times 10^{-3} \vec{B}$$

$$\mathcal{E} = -500 \frac{d\Phi_B}{dt} = -2.177 \frac{d\vec{B}}{dt} = 0.4353 \text{ V}$$

direction: ccw when thumb // dA.

ex:

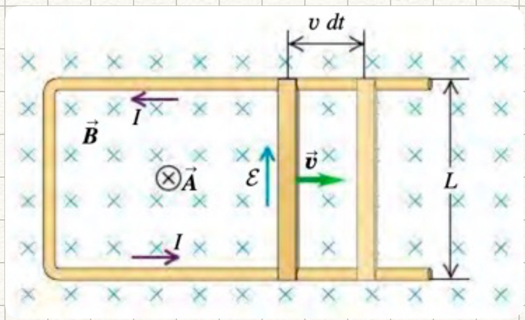
⇒



$$\Phi_B = BA\cdot\cos\phi = BA\cdot\cos(\omega t)$$

$$\mathcal{E} = -\frac{d\Phi_B}{dt} = -\frac{d}{dt}\left(BA\cos(\omega t)\right) = \omega\cdot BA\sin(\omega t)$$

Ex:



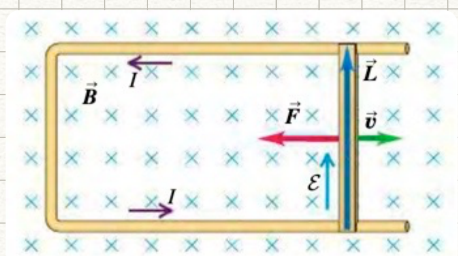
We slide a conducting bar across wire with speed v. Induced EMF, and power?

- $\vec{B}\uparrow$, so $\vec{B}_{ind}$ points out of the paper and I flows ccw.
- $\mathcal{E} = -\frac{d\Phi_B}{dt} = -\frac{d(B\cdot A)}{dt} = -B\frac{dA}{dt} = -B\frac{L(v\,dt)}{dt} = -BLv$

let resistance be R,

$$P_{dissipated} = I^2R = \left(\frac{BLv}{R}\right)^2 R = \frac{B^2L^2v^2}{R}$$

$$\vec{F} = I\vec{L}\times\vec{B}$$

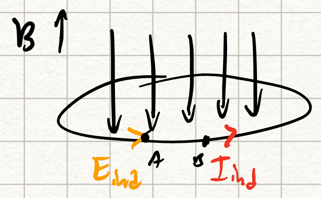


Since $L\perp B$, $\vec{F} = ILB = \frac{BLv}{R}\cdot LB = \frac{B^2L^2v}{R}$

$$P_{app} = Fv = \frac{B^2L^2v^2}{R}$$

notice that $P_{app} = P_{diss}$

relation to electric field



- current is driven by an induced electric field.
- $\oint \vec{E} \cdot d\vec{l} \neq 0$!! Usually, going around closed loop means no change in voltage.
  - ↳ Voltage will change here!

$$\oint \vec{E} \cdot \vec{dl} = -\frac{d\Phi_B}{dt} = -\frac{d}{dt}\iint_S \vec{B} \cdot \vec{ds}$$