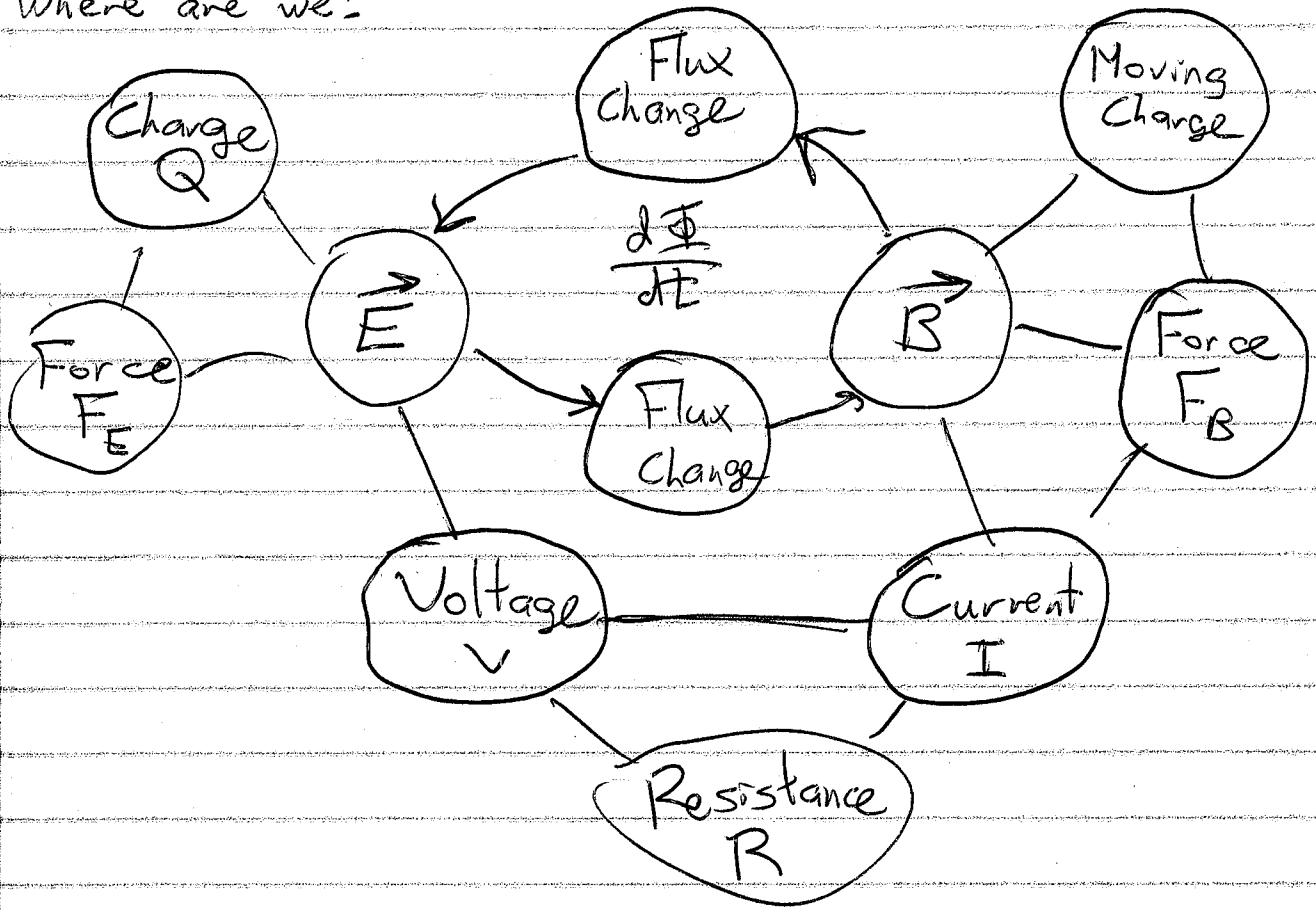
Where are we?



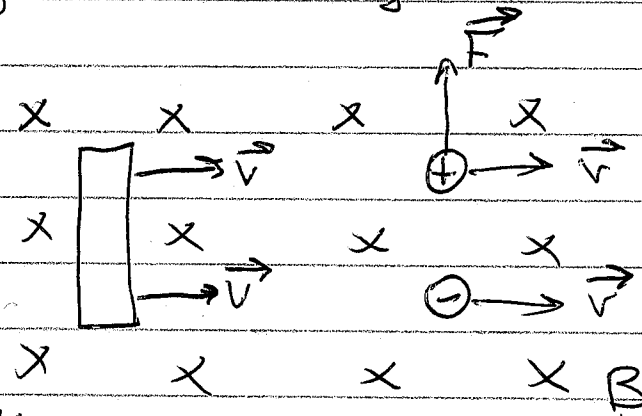
$\Phi_E = \iint \vec{E} \cdot d\vec{A}$ Usually EA

$\Phi_B = \iint \vec{B} \cdot d\vec{A}$ Usually $NBA\cos\theta$

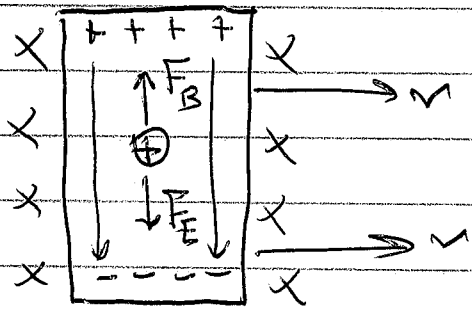
Details: Maxwell's Addition to Ampere's Law

Faraday's Law

Motional EMF – moving conductor going across $\vec{B}$ generates EMF,



- Both ⊕ and ⊖ moving with bar.
- Force on ⊕ is "up"
  ... on ⊖ is "down"
- Magnetic Field drives charges apart.



??

$$\vec{v} = \frac{\vec{E} \otimes \vec{B}}{B^2}$$

Poynting Vector

- Separated charges generate E and ΔV, just like in a capacitor.
- @ Equilibrium, remaining charges have $F_E = F_B$
- In the metal, $E = vB$
- Voltage is $\Delta V = El = vBl$

③

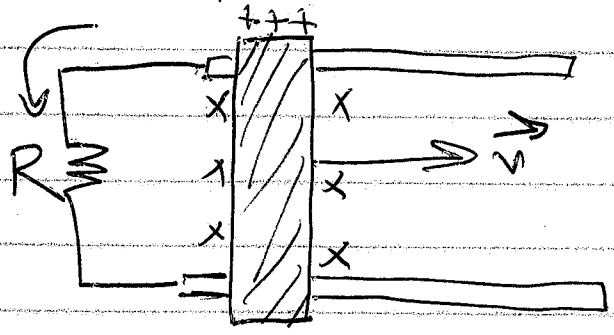
Ex: 747 Jet: $B = 50\ \mu T$

$v = 270\ m/s$

$\ell = 60\ m$

$\mathcal{E} = 0.81\ V$

Extract energy? Rails



Ex: $B = 1.0\ T$, $v = 25\ m/s$, $\ell = 0.1\ m$ } $\Delta V = vB\ell = 2.5\ V$

Connect to $R = 5\ \Omega$

$$I = \frac{V}{R} = 0.5\ A$$

Power used $P = IV = 1.25\ W$

Drag Force: $F = I \ell_\perp B$

$= (0.5\ A)(0.1\ m)(1.0\ T)$

$= 0.05\ N$

Mechanical Power $P = Fv$ $\quad \vec{F} \cdot \vec{v}$

$= (0.05\ N)(25\ m/s)$

$= 1.25\ W$

How was that related to flux?

$\Phi_B = NBA\cos\theta$ (1, 1, i)

$\frac{d\Phi_B}{dt} = B\frac{dA}{dt} + A\frac{dB}{dt}$ (dB/dt: 0)

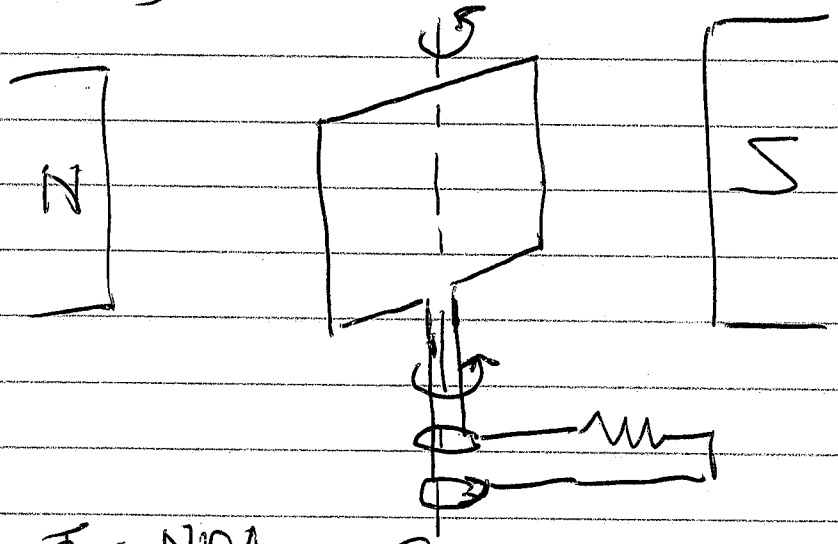
$A = lw$ $\quad \frac{dA}{dt} = l\frac{dw}{dt} + w\frac{dl}{dt}$ (dl/dt: 0)

$= lv$

$\frac{d\Phi_B}{dt} = Blv$

Faraday's Law $\quad \mathcal{E} = -\frac{d\Phi_B}{dt}$

Rotating Coil



$\Phi = NBA\cos\theta$

Time Derivative → $\dot{\Phi} = NBA(-\sin\theta)\omega$

(3)

ω = rotational speed in rad/s

Engine idle

$$750 \text{ rpm} = \left(750 \frac{\text{rotations}}{\text{minute}}\right)\left(\frac{2\pi \text{ rad}}{1 \text{ rot}}\right)\left(\frac{1 \text{ min}}{60 \text{ s}}\right)$$
$$= 79 \text{ rad/s}$$

Motor	Generator
Apply V_0, causes I	Spin @ ω, requires τ_0
$\tau = NBA\, I$	$\mathcal{E} = NBA\, \omega$
Torque makes it spin = output	$\mathcal{E}$ drives current = output
Side-effects:	
Spinning makes Back-EMF.	Current causes drag.
$\mathcal{E} = NBA\, \omega$	$\tau = NBA\, I$
$V_0 - \mathcal{E} = IR$	Our input τ must match this.
Bigger $\mathcal{E} \rightarrow$ Lower I, Startup I is without $\mathcal{E}$! Less I = easier when running.	Use generator = more I = more τ