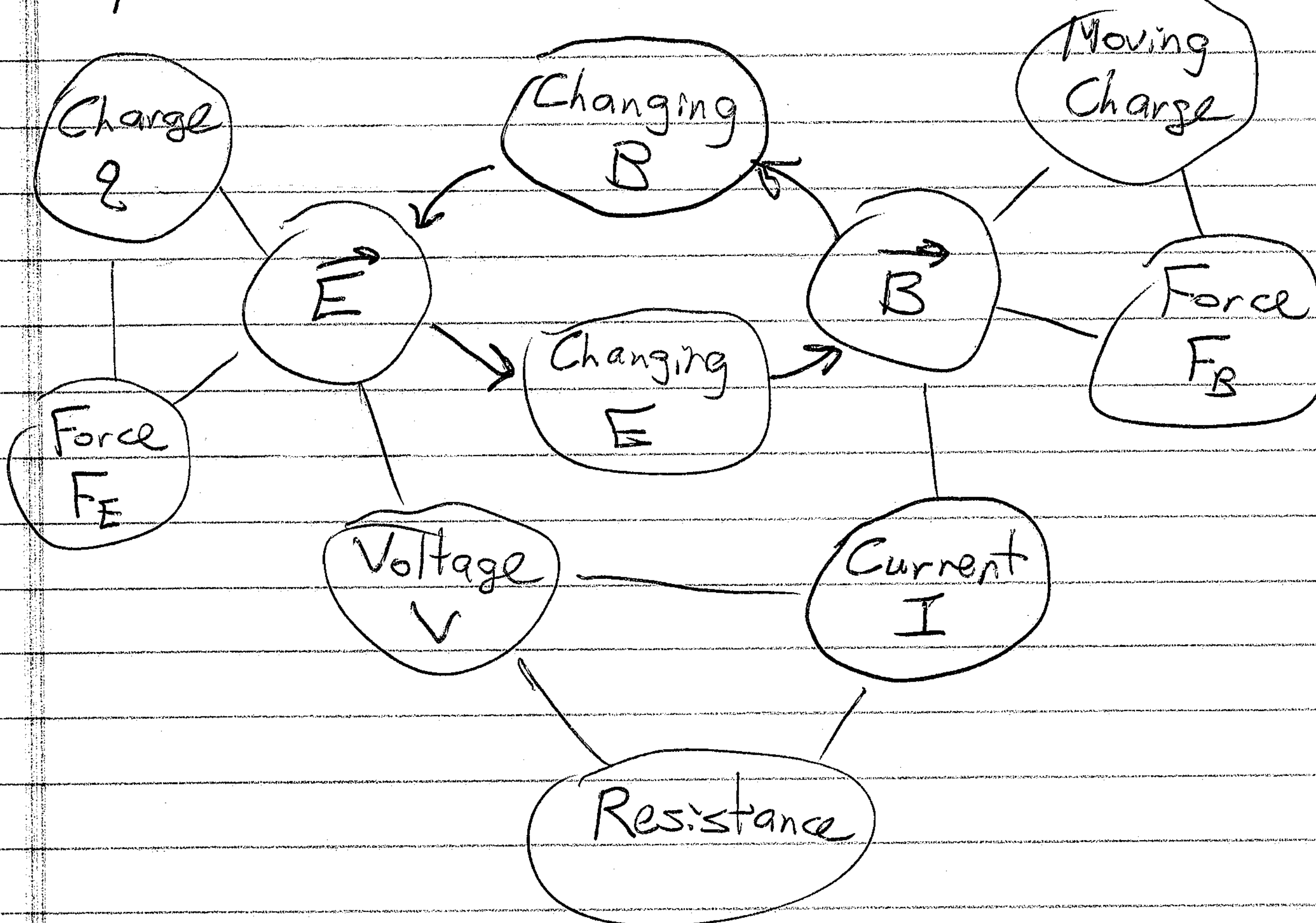
① Phys 1402 2017-07-19 Lec 10

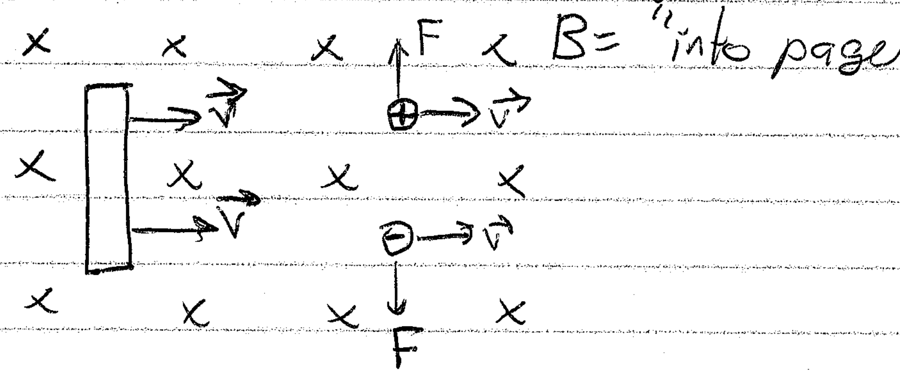


Details: • Maxwell's Addition to Ampere's Law
(Two causes of $\vec{B}$)

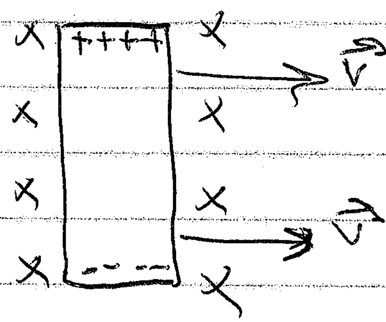
• Faraday's Law
(Second cause of $\vec{E}$)

Motional EMF – Voltage generated in a conductor moving thru $\vec{B}$.

Place a conductive bar in a magnetic field,



- ⊕ and ⊖ both moving w/ bar.
- Force on ⊕ is up.
  ... on ⊖ is down.
- Magnetic field is driving charges apart.



- Separated charges generate $\vec{E}$ and ΔV just like a capacitor,
- When the charges reach equilibrium, the remaining charges have zero force.

  $F_E = F_B \implies E = vB$
- Voltage is $\Delta V = E\ell = vB\ell$

③

Ex: Earth's $B \approx 50\ \mu T$

Length of wingspan ≈ 60 m

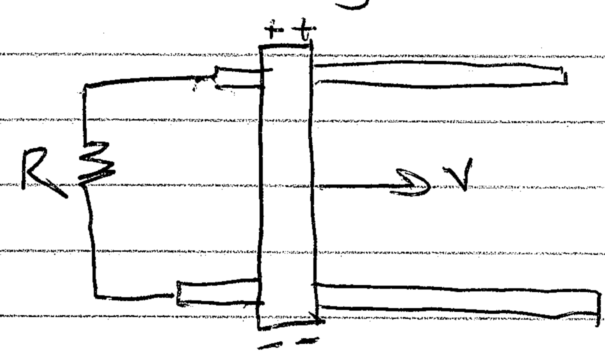
speed ≈ 270 m/s

$$\Delta V = vBl = (270\ m/s)(50 \times 10^{-6}\ T)(60\ m)$$
$$= 0.81\ V$$

This voltage isn't useful because any wires connected to the wings would also have generated voltage.

To extract energy, need stationary wires.

Ex: Bar sliding on rails.



$\Delta V = vBl$ in bar

$I = \frac{\Delta V}{R}$ in resistor

Ex: $B = 1.0$ T
$v = 10$ m/s
$l = 0.03$ m
} $\Delta V = 0.3$ V

$R = 5\ \Omega$ $\quad I = \frac{0.3 V}{5 \Omega} = 0.06\ A = 60\ mA$

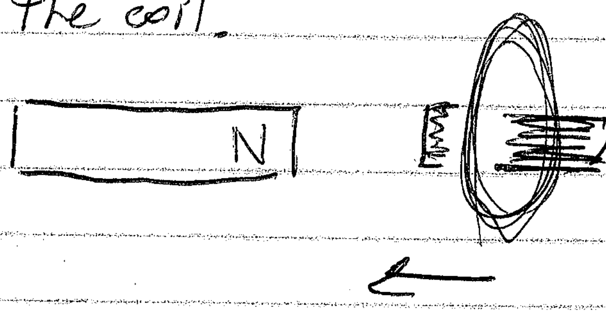
$P = VI = (0.3 V)(0.06 A) = 0.018\ W$

Drag Force: $F_B = IlB = (0.06 A)(0.03 m)(1.0 T)$
$= 0.0018\ N$

Mechanical Power $P = F \cdot v = 0.0018 \cdot 10 = 0.018\ W$

How else could we extract the energy?

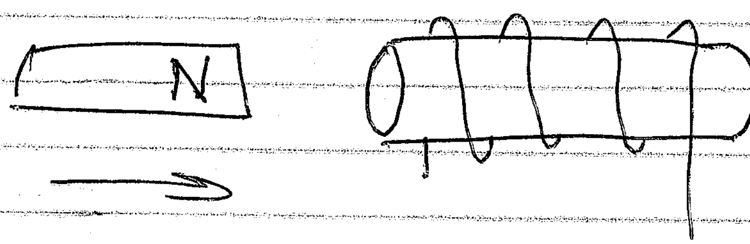
- Coil the conductor, Let resistor "ride" with the coil.



move coil near magnet

"Motional EMF" uses F_B and F_E to generate electricity.

Moving the magnet works, too.



- Spinning the magnet (or the coil) works.

(I)

Voltage in a rotating coil:

$$\mathcal{E} = NBA\,\omega$$

(Recall: $\tau = NBA\,I$)

ω = rotational speed in radians per second.

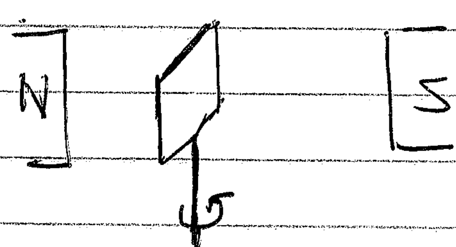
$$1 \text{ rpm} = \left(1 \frac{\text{rotation}}{\text{minute}}\right)\left(\frac{2\pi \text{ rad}}{1 \text{ rot}}\right)\left(\frac{1 \text{ min}}{60 \text{ s}}\right)$$

$$1 \text{ rot} = 2\pi \text{ rad}$$

$$1 \text{ rpm} = \frac{2\pi}{60} \text{ rad/s} = 0.105 \text{ rad/s}$$

1 rpm is <u>slower</u> than 1 rad/s

- We could Also rotate the coil.

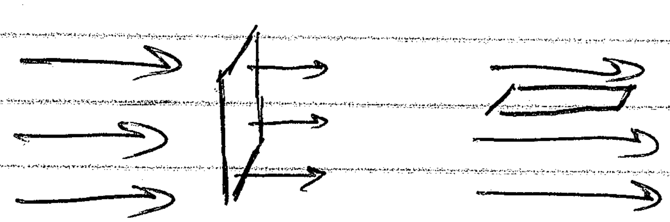


← Bearings w/ contacts so wire doesn't get twisted

(6)

All of the $\mathcal{E}$ generation techniques can be summarized by Faraday's Law

- Changing Magnetic Flux makes EMF.
- What is Flux? Amount of magnetic field going thru a coil.
    - How many compass arrows, and how strong are they?
    - How many B Field Lines go thru the coil?
    - Proportional to:
        - B
        - Area of coil
        - Number of loops
        - How directly B "strikes" the coil



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Electric Motor:

We cause I.
Motor generates torque. $\tau = NBA\,I$
Torque makes it spin.

Spinning generates "Back EMF"

$$\mathcal{E}_{input} - \mathcal{E}_{Back} = I R$$

$\mathcal{E}_{Back}$ reduces the current, which saves energy!
This happens most when the motor spins freely.

Generator:

We spin the generator: ω
It generates voltage $\mathcal{E} = NBA\,\omega$
Voltage pushes current: I

This causes drag torque: $\tau = NBA\,I$

This means we must exert torque
to maintain the rotation.