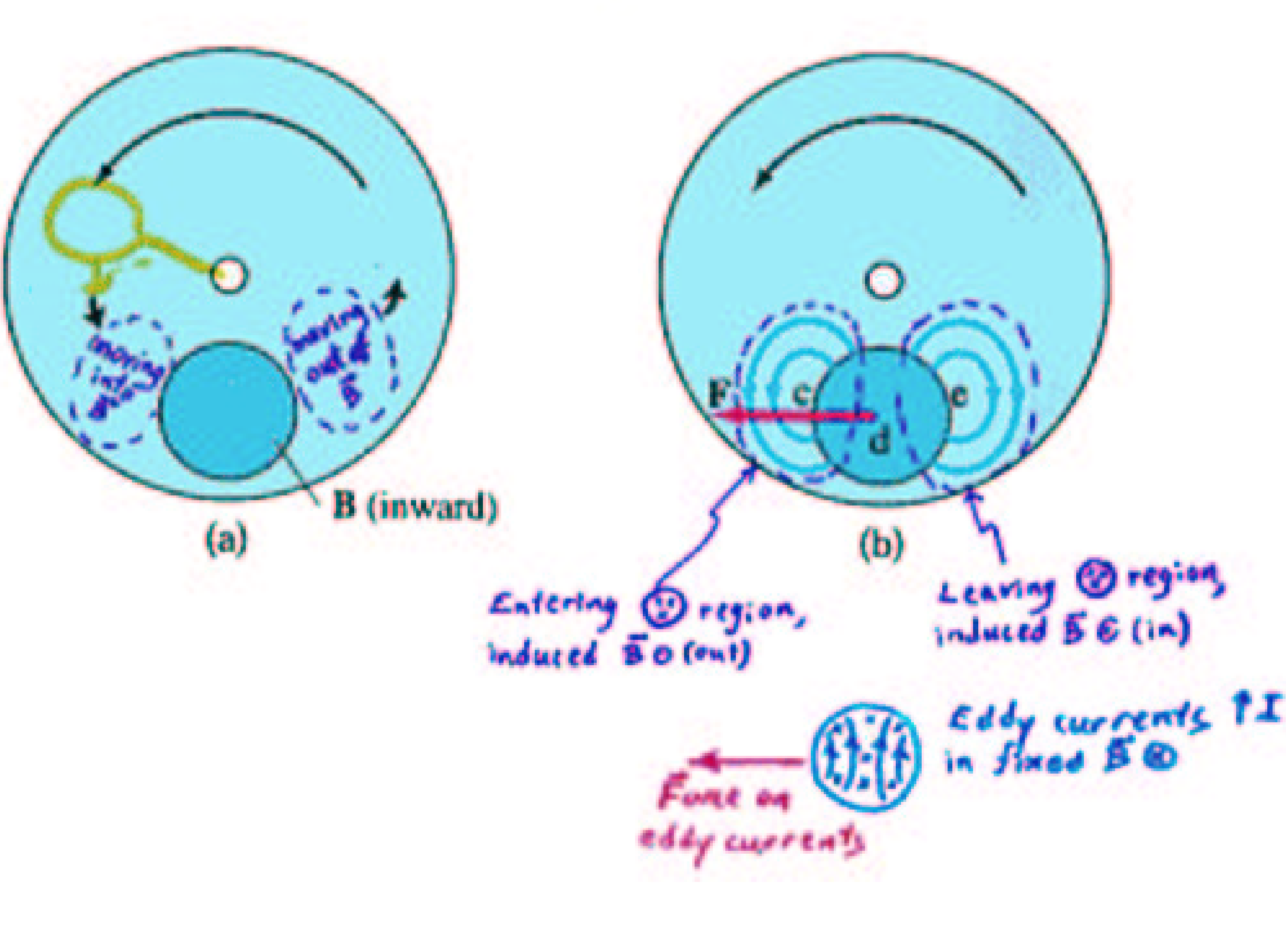
Lecture Notes #10T — *Tue 19 March 2002*

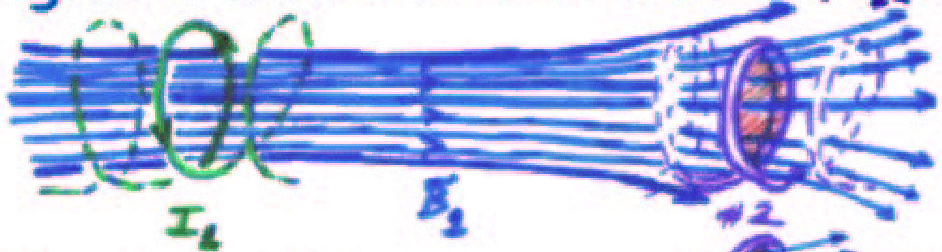
Inductance, Inductors, Magnetic Energy Storage, Eddy Currents, & Transformers

FIG. 21-19 Eddy currents in a rotating wheel



Mutual Inductance M

Each loop of current I_1 produces magnetic field $\vec{B}_1$ near each loop #2:



Flux Φ_1 of $\vec{B}_1$ through #2:

$\Phi_1 \propto B_1 \propto I_1$

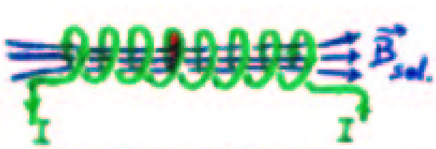
$\Longrightarrow$ (Faraday's Law) EMF induced in #2 from $\Delta\Phi_1$:

$$\mathcal{E}_2 = -\frac{\Delta\Phi_1}{\Delta t} \propto -\frac{\Delta B_1}{\Delta t}\,(\text{at } \#2) \propto -\frac{\Delta I_1}{\Delta t}$$

$$\Rightarrow \boxed{\mathcal{E}_2 = -M_{21}\frac{\Delta I_1}{\Delta t}} \ldots \ \& \ \boxed{\mathcal{E}_1 = -M_{12}\frac{\Delta I_2}{\Delta t}}$$

$M_{21} = M_{12}!$ $\propto N_1 N_2$

[Self-] Inductance L



$\leftarrow$ length ℓ $\rightarrow$

N turns

Area A

$B_{sol.} = \mu_0 I N/\ell$

$$\mathcal{E}_{own} = -\frac{\Delta\Phi_{own}}{\Delta t} \propto -\frac{\Delta B_{own}}{\Delta t} \propto -\frac{\Delta I_{own}}{\Delta t}$$

$$\Rightarrow \boxed{\mathcal{E} = -L\frac{\Delta I}{\Delta t}}$$

Ex/ $$\mathcal{E}_{sol.} = -N\frac{\Delta(B_{sol.}A)}{\Delta t} = -NA\frac{\Delta(\mu_0 I N/\ell)}{\Delta t} = -\underbrace{\boxed{\mu_0 \frac{A}{\ell} N^2}}_{= L_{sol.}}\frac{\Delta I}{\Delta t}$$

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INDUCTORS vs CAPACITORS

Work done to put ch. Q on a capacitor C creates $\vec{E}$ → ENERGY "stored" in $\vec{E}$.

- Work done to establish current I in an inductor L creates $\vec{B}$ → ENERGY "stored" in $\vec{B}$.

INDUCTOR vs **CAPACITOR**

Voltage Drop:
(L→R)

$$\mathcal{E} = -L\frac{\Delta I}{\Delta t} \qquad \mathcal{E} = -\frac{1}{C}Q$$

Energy Stored:

$$U_L = \frac{1}{2}LI^2 \qquad U_C = \frac{1}{2}\frac{1}{C}Q^2$$

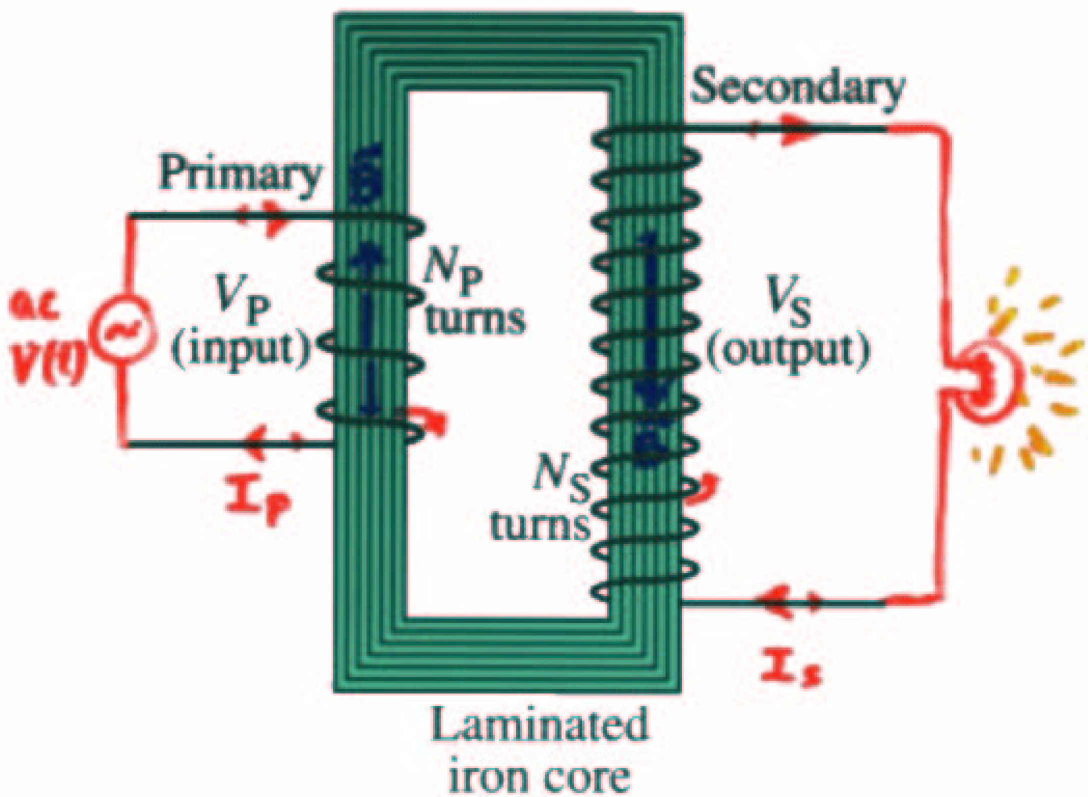
Energy per volume (en. density) of Field:

$$u_B = \frac{1}{2}\frac{1}{\mu_0}B^2 \qquad u_E = \frac{1}{2}\epsilon_0 E^2$$

$$L_{solenoid} = \mu_0\frac{A}{l}N^2 \qquad C_{ll\text{-}plate} = \epsilon_0\frac{A}{d}$$

T-192 FIG. 21-21 Step-up transformer

ENERGY CONSERV.: $P_P = P_S$ *



$\Delta\Phi_P = \Delta\Phi_S$ (for each "link")

$$V(t) \longleftrightarrow V_P = N_P \frac{\Delta\Phi_P}{\Delta t}, \quad V_S = N_S \frac{\Delta\Phi_S}{\Delta t}$$

$$\Rightarrow \boxed{\frac{V_S}{V_P} = \frac{N_S}{N_P}}$$

$$* \; I_P V_P = I_S V_S \Rightarrow \boxed{\frac{I_S}{I_P} = \frac{N_P}{N_S}}$$