Lecture 34

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1 Magnetostatics

Example 1.1 (Transformers from a Magnetic Circuit Perspective)**.** Consider the coils and turns $N_1 i_1$ and $N_2 i_2$ respectively. Using Kirchoff's Voltage Law,

$$-N_1 i_i + R_C \Phi + N_2 i_2 = 0$$

We know that for ideal transformers,

$$\frac{i_1}{i_2} = \frac{N_2}{N_1}$$

and

$$\frac{V_1}{V_2} = \frac{N_1}{N_2}$$

This means $R\Phi = 0$, or $\mu_r \to \infty$.

Changes in magnetic flux can be due to

- Transformer emf: static loop with time-varying magnetic field
- Motional emf: moving loop with static magnetic field
- Combination of both

2 Eddy Currents

If a time-varying magnetic field is applied to a conducting material the result will be that ”eddy currents” will flow within this material.

Example 2.1. Consider the case where a lossy material ($\sigma \neq 0$) is exposed to a changing magnetic field

$$
\begin{aligned}
\vec{\nabla} \times \vec{E} &= -\frac{\partial \vec{B}}{\partial t} \\
\frac{1}{r}[\frac{\partial}{\partial r}(rE_\Phi) - \frac{\partial}{\partial \Phi}(E_r)]\hat{a}_z &= B_0 \sin \omega t \\
\frac{\partial}{\partial r}(rE_\Phi) &= rB_0 \sin \omega t \\
rE_\Phi &= \frac{r^2 B_0 \sin \omega t}{2} + C \\
E_\Phi &= \frac{rB_0}{\sin \omega t} 2 + \frac{C}{r} \\
&= \frac{rB_0}{\sin \omega t} 2
\end{aligned}
$$

Eddy currents can be used for braking, because by Lenz’ Law, a force is induced to oppose the change. These are great for contactless braking. However, braking force decreases with motion. They can also be used in induction stoves, where eddy currents in the coocking utensils produce heat through resistance, reducing heat loss. (Traditionally, heat energy is conducted from the stove to the cooking utensil.)