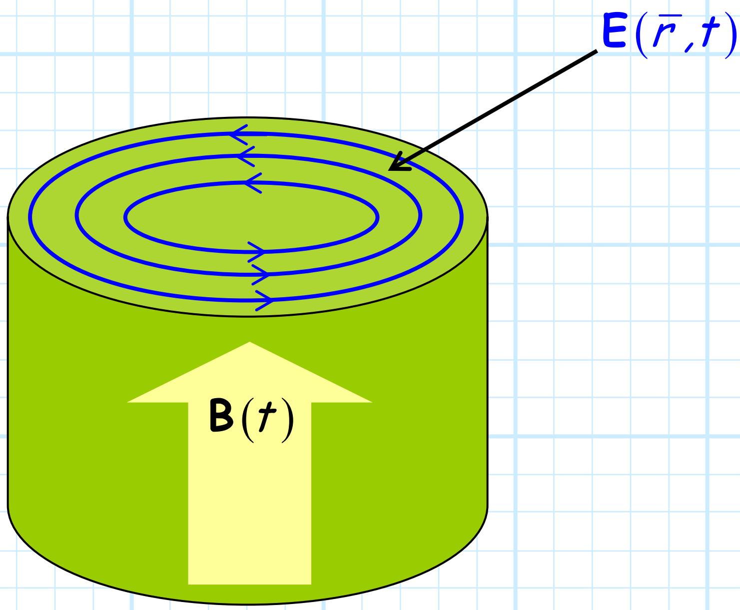
Eddy Currents

From **Faraday's Law**, we know that a **time-varying** magnetic flux density $\mathbf{B}(t)$ will **induce** electric fields $\mathbf{E}(\bar{r},t)$. Consider what happens if this time-varying magnetic flux density occurs **within** some **material**, say the **magnetic core** of some solenoid.

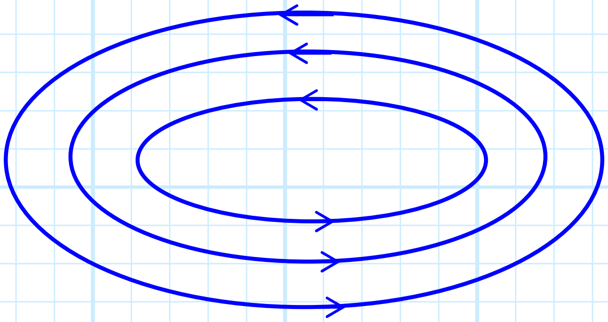


If the material is **non-conducting** (i.e., $\sigma = 0$), then these induced electric fields essentially cause **no** problems. But consider what happens if the material **is** conducting. In this case, we apply Ohm's Law and find that **current** $\mathbf{J}(\bar{r})$ is the result:

$$\mathbf{J}(\bar{r}) = \sigma(\bar{r})\,\mathbf{E}(\bar{r})$$

We find that these currents **swirl** around in the media in a **solenoidal** manner (i.e., $\nabla \cdot \mathbf{J}(\bar{r}) = 0$ and $\nabla \times \mathbf{J}(\bar{r}) \neq 0$).

We call these currents **Eddy Currents.**



Eddy currents are **problematic** in the magnetic cores of transformers, generators, and inductors, as they result in **Ohmic Losses**. These losses in power can be determined from Joules Law as:

$$\begin{aligned} P_{loss} &= \iiint_V \mathbf{E}(\bar{r}) \cdot \mathbf{J}(\bar{r})\, dv \\ &= \iiint_V \sigma \left|\mathbf{E}(\bar{r})\right|^2 dv \qquad [\mathrm{W}] \end{aligned}$$

where V is the volume of the magnetic core. The "lost" power is of course simply transferred to **heat**.

It is evident that if conductivity is **low** (i.e., $\sigma \approx 0$), the eddy currents and their resulting losses will be **small**. Ideally, then, we seek a magnetic material that has **very high** permeability and **very low** conductivity.

Oh, it also should be **inexpensive**!

Finding a material with these three attributes is **very** difficult!