Understanding Electromagnetic Induction: Faraday and Lenz's Laws

Technical Blog

July 28, 2025

Introduction to Electromagnetic Induction

Electromagnetic induction explains how electric currents are generated by changing magnetic fields. This principle is the foundation of devices like transformers and generators.

Magnetic Flux (Φ)

Magnetic flux is the total magnetic field passing through a surface:

$$\Phi = \int \mathbf{B} \cdot d\mathbf{A}$$

For uniform B perpendicular to area A:

$$\Phi = BA$$

If at angle θ:

$$\Phi = BA\cos\theta$$

Measured in Webers (Wb).

Faraday's Law

The induced electromotive force (emf) is:

$$\mathcal{E} = -\frac{d\Phi}{dt}$$

For N turns:

$$\mathcal{E} = -N\frac{d\Phi}{dt}$$

Lenz's Law

The induced current opposes the change in magnetic flux, ensuring energy conservation.

Examples

Problem 1

A loop of area $0.05\,m^2$ in $0.2\,T$ field reduced to zero in $0.1\,s$.

$$\Phi_i = 0.2 \times 0.05 = 0.01\,Wb$$

$$\Delta\Phi = -0.01\,Wb, \quad \frac{d\Phi}{dt} = -0.1\,Wb/s$$

$$\mathcal{E} = 0.1\,V$$

Problem 2

$N = 50$, $A = 0.01\,m^2$, B from 0.5 T to 0 in 0.05 s.

$$\Delta\Phi = -0.005\,Wb, \quad N\Delta\Phi = -0.25\,Wb$$

$$\frac{d\Phi}{dt} = -5\,Wb/s, \quad \mathcal{E} = 5\,V$$

Problem 3

Rectangular coil $0.2 \times 0.1\,m$, $N = 100$, $\omega = 50\,rad/s$, $B = 0.3\,T$.

$$\mathcal{E}_{max} = N\omega BA = 30\,V$$

Problem 4

Coil with $N = 200$, $A = 0.02\,m^2$, $B(t) = 0.4\sin(100t)$:

$$\mathcal{E}(t) = -NA\frac{dB}{dt} = -160\cos(100t)\,V$$

Problem 5

Solenoid $N = 500$, length $0.5\,m$, radius $0.05\,m$, $dI/dt = 2\,A/s$.

$$n = \frac{500}{0.5} = 1000\,turns/m$$

$$\frac{dB}{dt} = \mu_0 n\frac{dI}{dt} = 2.51 \times 10^{-3} T/s$$

$$A = \pi(0.05)^2 = 7.85 \times 10^{-3} m^2$$

$$\mathcal{E} = A\frac{dB}{dt} = 1.97 \times 10^{-5} V$$

Problem 6

Coil $N = 200$, dimensions $0.3 \times 0.1\,m$, moving out of $0.6\,T$ field in 0.02 s.

$$\Phi_i = 0.018\,Wb, \quad \Delta\Phi = -3.6\,Wb$$

$$\mathcal{E} = \frac{3.6}{0.02} = 180\,V$$

Conclusion

Faraday's and Lenz's laws govern electromagnetic induction, crucial for electrical engineering and physics.