PhysicsTutor

Induction

Giambattista 20.46-47

Problem:

- A solenoid of length 2.8 cm and diameter 0.75 cm is wound with 160 turns/cm, and carries current of 0.2 A. What is the flux through one of the windings?
- The current is now decreasing at a rate of 35 A/s, what is the induced EMF in one winding?
- What is the induced EMF in the entire solenoid?

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$$B_{sol} = N\frac{\mu_0 I}{\ell} = \mu_0 I \frac{N}{\ell}$$

ℓ = length of solenoid

magnetic field strength inside solenoid (derived from Ampère's law)

n = number of windings / length $= \frac{N}{\ell}$

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- The current loops create a magnetic field. This field permeates each loop, ie, there is magnetic flux through each loop.

$$\Phi_M^{\text{one loop}} = B_{sol} \cdot A_{loop} \left(\cdot \cos(0) \right)$$

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- The current loops create a magnetic field. This field permeates each loop, ie, there is magnetic flux through each loop.
- EMF is generated when the flux changes. In this way the solenoid counteracts rapid changes: electromagnets display inertia.

magnetic flux from N-turn solenoid changes in one turn

→ EMF / turn, then add them in series

→ self inductance $L \sim N^2$!

Equations associated with ideas:

$$B_{sol} = N \frac{\mu_0 I}{\ell}$$

$$\phi_M^{(1)} = N \frac{\mu_0 I}{\ell} \pi \left(\frac{d}{2}\right)^2 \text{ in one turn}$$

$$\mathcal{E} = - \frac{\Delta \Phi_M}{\Delta t}$$

caused by $\frac{\Delta I}{\Delta t}$

$$\phi_M^{(1)} = \frac{L I}{N} \quad \text{(one turn)}$$

$\therefore$ $L = \frac{N^2}{\ell} \mu_0 \pi \left(\frac{d}{2}\right)^2$ (no iron core)

self inductance in Henry

Flux for entire solenoid $\phi_M = L I = N \phi_M^{(1)}$

Solenoid-EMF: $\mathcal{E}_{sol} = - \frac{\Delta \Phi_M}{\Delta t} = -L \frac{\Delta I}{\Delta t}$

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- Calculate the rate of change of the flux from the rate of change for the current, deduce the EMF for one turn. Sum EMF from N windings.

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- $\Phi_M^{sol} = N\,\Phi_M^{(1)} = 7.9 \times 10^{-5}\,Wb$ $\therefore L = \frac{\Phi_M^{sol}}{I} = 0.4\,mH$

$$\frac{\Delta \Phi_M^{sol}}{\Delta t} = L \frac{\Delta I}{\Delta t} = 0.4 \times 10^{-3} H \cdot \left(-\frac{35A}{s}\right) \quad \therefore \mathcal{E} = 0.014\,V = 14\,mV$$