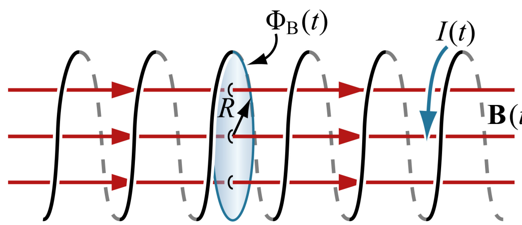
Inductors

Changing current through a loop induces a non-electrostatic electric force, and, thus, emf, that opposes the change in current.

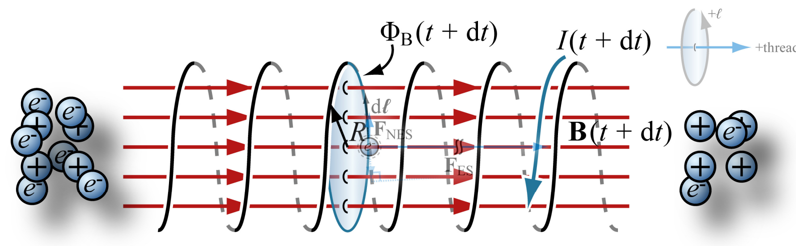
Initial: Time t



$$B(t) = \mu_0 \frac{N}{\ell} I(t)$$

$$\Phi_{\text{EACH LOOP}}(t) = \left[\mu_0 \frac{N}{\ell} I(t)\right] \cdot \pi R^2$$

Final: Time $t + \mathrm{d}t$



$$B(t + \mathrm{d}t) = \mu_0 \frac{N}{\ell} I(t + \mathrm{d}t)$$

$$\Phi_{\text{EACH LOOP}}(t + \mathrm{d}t) = \left[\mu_0 \frac{N}{\ell} I(t + \mathrm{d}t)\right] \cdot \pi R^2$$

$$\left(\int_{\substack{\text{SINGLE}\\\text{TURN}}} \vec{\mathbf{F}}_{\substack{\text{N.E.S.}\\\text{ON } q}} \cdot \mathrm{d}\vec{\boldsymbol{\ell}}\right)\Big/ q = -\frac{\mathrm{d}\Phi_{\mathrm{B}}}{\mathrm{d}t} = -\frac{\mu_0 \frac{N}{\ell} I(t + \mathrm{d}t) \cdot \pi R^2 - \mu_0 \frac{N}{\ell} I(t) \cdot \pi R^2}{\mathrm{d}t}$$

$$\left(\int_{N \text{ TURNS}} \vec{\mathbf{F}}_{\substack{\text{N.E.S.}\\\text{ON } q}} \cdot \mathrm{d}\vec{\boldsymbol{\ell}}\right)\Big/ q = -\underbrace{N \cdot \mu_0 \frac{N}{\ell} \cdot \pi R^2}_{\text{"self inductance" } L} \frac{\mathrm{d}I}{\mathrm{d}t}$$

The relationship between the strength of the induced emf and the rate of change of the current over time depends on the geometry of the coil.

$$\mathcal{E}_{\text{BACK}} = -L \frac{\mathrm{d}I}{\mathrm{d}t} \qquad [L] = \mathrm{H} \qquad \Delta U_{\mathrm{L}} = \frac{1}{2} L I^2$$