SELF-INDUCTANCE

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References: Griffiths, David J. (2007), Introduction to Electrodynamics, 3rd Edition; Pearson Education - Problem 7.22.

In addition to mutual inductance between two different circuits, a single circuit also has *self-inductance*, or just *inductance*. The flux through a circuit is

$$\Phi = \int \mathbf{B} \cdot d\mathbf{a} \tag{0.1}$$

and for a steady current I, this is proportional to I:

$$\Phi = LI \tag{0.2}$$

where L is the inductance of the circuit. The emf induced in a circuit by changing the current in that circuit is then

$$\mathscr{E} = -\frac{d\Phi}{dt} = -L\dot{I} \tag{0.3}$$

The inductance (and mutual inductance) are measured in a unit called the *henry*, named after Joseph Henry, who is generally acknowledged to be a co-discoverer of inductance around the same time as Michael Faraday (Faraday, of course, has been immortalized in the farad, the unit of capacitance).

As a simple example, let's work out the inductance of a long solenoid with n turns per unit length. The magnetic field of an infinite solenoid is

$$B = \mu_0 nI \tag{0.4}$$

so the flux through each turn of the solenoid is, if the solenoid's radius is R

$$\Phi_1 = \pi R^2 \mu_0 nI \tag{0.5}$$

The inductance per turn is thus

$$L_1 = \pi R^2 \mu_0 n \tag{0.6}$$

and the inductance per unit length is

$$L = \pi R^2 \mu_0 n^2 \tag{0.7}$$

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