

## 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

$$(1) \quad \Phi = \int \mathbf{B} \cdot d\mathbf{a}$$

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

$$(2) \quad \Phi = LI$$

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

$$(3) \quad \mathcal{E} = -\frac{d\Phi}{dt} = -L\dot{I}$$

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

$$(4) \quad B = \mu_0 n I$$

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

$$(5) \quad \Phi_1 = \pi R^2 \mu_0 n I$$

The inductance per turn is thus

$$(6) \quad L_1 = \pi R^2 \mu_0 n$$

and the inductance per unit length is

$$(7) \quad L = \pi R^2 \mu_0 n^2$$

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