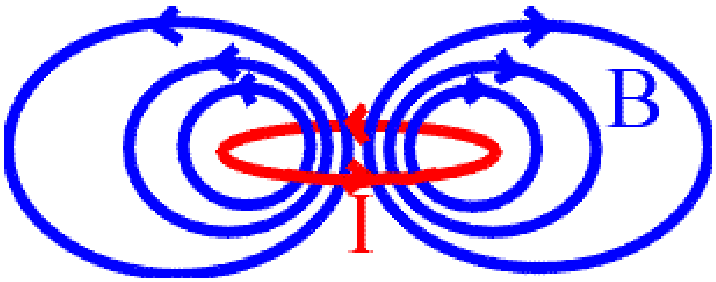
Homework 21.

Inductance

As we know, electrical current is a source of magnetic field. If we take a wire loop and pass electrical current through the wire, magnetic field appears. Magnetic field lines of a circular current loop are shown in the Figure below.



As we can see, the magnetic field lines "flow" into the loop. In spite that the magnetic field is nonuniform, it is possible to calculate magnetic flux Φ through the loop. Since the magnetic field, created by electrical current is proportional to the current magnitude $\boldsymbol{I}$, it is natural to assume that total magnetic flux is also proportional to the current in the loop. So we can write

$$\Phi = L \cdot I \quad (1)$$

Here L is the coefficient called ***inductance***. This coefficient is entirely determined by the geometry of the loop. The unit of inductance in the international system of units is called "henry" (H). 1H=1Wb/A.

This unit is named after Joseph Henry, an American scientist who discovered the effect of self-inductance described below.

Joseph Henry (1797-1878)

As we try to change the current in the loop, the magnetic flux in the loop will be changing as well. According to the Faraday's induction law, this will lead to appearance of an additional current in the loop. This additional current is always directed "to resist the change". For example if you are increasing the current, the additional current will be directed against the original current, if you are decreasing the current, the induced current will "support" the original one. This effect is called self-inductance. We can write:

$$|\mathcal{E}| = \left|\frac{\Delta\Phi}{\Delta t}\right| = \left|L \cdot \frac{\Delta I}{\Delta t}\right| \quad (2)$$

Here $\boldsymbol{\mathcal{E}}$ is an additional e.m.f. induced in the loop. It is also called a self-inductance e.m.f. To obtain the additional current we have to divide $\boldsymbol{\mathcal{E}}$ by the resistance of the loop $\boldsymbol{R}$. I would like to stress that *here we have no external magnetic field*. The magnetic flux is created entirely by the current in the loop, and the magnetic flux changes due to change of the current. The higher is the speed of the current change, the more additional current is. It looks like the self-inductance provides inertia of the electrical circuit with respect to the current change.

Problems:

1. As we changed the current through the wire loop from 4A to 20A, the magnetic flux through the loop changed for 2Wb. Find the inductance of the loop.

2. The current in the loop was changed from 10A to 5A in 5 seconds. Find the loop's inductance if self-inductance e.m.f. is 5V.