Consider a solenoid with $N$ turns:

The current $i(t)$ flowing in the wire will produce a time-varying magnetic flux density within the solenoid. This time-varying magnetic flux density will induce a voltage $v(t)$ across the solenoid.

This voltage can be determined using Faraday's Law:

$$-\oint_{C_1} \mathbf{E}(\mathbf{r}) \cdot d\ell = \frac{\partial}{\partial t} \int_{S_1} \mathbf{B}(\mathbf{r}) \cdot d\mathbf{s}$$
Just like we determined for the ideal transformer, we find that:

$$-\oint_{\partial S} \mathbf{E}(\mathbf{r}) \cdot d\mathbf{l} = v(t)$$

and that:

$$\frac{\partial}{\partial t} \iint_{S_0} \mathbf{B}(\mathbf{r}) \cdot d\mathbf{s} = \frac{\partial}{\partial t} N \iint_{S_0} \mathbf{B}(\mathbf{r}) \cdot d\mathbf{s} = N \frac{\partial \Phi(t)}{\partial t}$$

where $S_0$ is the surface area of one loop.

Therefore, just as we determined for a transformer, Faraday’s Law says that:

$$v(t) = N \frac{\partial \Phi(t)}{\partial t}$$

Now, let’s define the product $N \Phi(t)$ as:

$$N \Phi(t) \equiv \Lambda(t) = \text{flux linkages} \quad [\text{Webers}]$$
A: A magnetic flux of $\Phi(t)$ Webers passes through each and every one of the \(N\) loops of the solenoid. We say therefore that each loop surrounds, or “links” $\Phi(t)$ Webers of flux. If there are \(N\) loops, then the solenoid links a total of $N \Phi(t)$ Webers of flux. We call therefore $N \Phi(t)$ the total flux linkages surrounded by the solenoid.

Thus we can state our induced solenoid voltage as the time derivative of the flux linked by the solenoid:

$$v(t) = \frac{\partial \Lambda(t)}{\partial t}$$

Now, recall that current $i(t)$ produced the magnetic flux density and thus the magnetic flux. As a result, we find that the current $i(t)$ is directly proportional to the total flux linkages of the solenoid:

$$i(t) \propto \Lambda(t)$$

Lets define the proportionality constant as $L$, so that we can say:

$$\Lambda(t) = L \: i(t)$$

Since $i(t)$ has units of amps and $\Lambda(t)$ the units of Webers, the constant $L$ must have units of Webers/Amp.

Taking the time derivative we thus find:
\[
\frac{\partial \Lambda(t)}{\partial t} = L \frac{\partial i(t)}{\partial t}
\]

Note we can now write the induced voltage as:

\[
v(t) = L \frac{\partial i(t)}{\partial t}
\]

**Q:** Look familiar?

**A:** Of course, \( L \) is inductance!

Inductance is therefore defined as the ratio of current \( i \) to the total flux linkages it creates!

\[
L \equiv \frac{\Lambda}{i} = \text{inductance} \left[ \frac{\text{Webers}}{\text{Amp}} \right]
\]

Inductance is obviously dependent on the structure of the device (e.g., number of loops, diameter, length).

By the way, we have another name for Webers/Amp—Henries!

\[
\text{Henries} \equiv \frac{\text{Webers}}{\text{Ampere}}
\]