**Experiment No : ** EM9

**Experiment Name:** Inductance of Solenoids

**Objective:** To determine the inductance of solenoids by using an LC circuit. To observe the length, cross sectional area, and number of winding dependence of inductance of solenoids.

**Keywords:** Faraday's law of induction, Lenz's law, self and mutual inductance, $LC$ oscillatory circuit,

## Theoretical Information:

According to Britannica, inductance is defined as *a property of a conductor (often in the shape of a coil) that is measured by the size of the electromotive force, or voltage, induced in it, compared with the rate of change of the electric current that produces the voltage.*

If the inductance does not depend on the current, this definition can be written in a mathematical language as,

$$V = L\frac{dI}{dt} \tag{9.1}$$

There are also some equivalent definitions of inductance. If we integrate the above equation with assumption $L = const$ and remember Faraday's law of induction we would take,

$$\Phi = LI \tag{9.2}$$

where $\Phi$ is the magnetic flux through the circuit. Thus, inductance can be seen as a measure of inductive property of a substance.

The SI unit of inductance is called the *henry* and is defined as the inductance of a conductor in which a current of 1A flowing through it produces a flux linkage of 1Wb*.

In the Gaussian system of units, the inductance has the dimension of length. Accordingly, the unit of inductance in this system is called *centimeter*. A loop with which a flux of 1 $Mx$ ($10^{-8}$ Wb) is linked to a current of 1 $cgsm_I$ (= 10 A) has an inductance of 1 cm

Inductor is considered also as a passive device and is characterized by its reaction to change in current flowing through the circuit, obeying Faraday's law. This device, at last analysis, is a coil. Therefore, a solenoid can be considered as an inductor in a circuit. We will discuss this point at the experimental part in detail.

Let's calculate the inductance of a solenoid, which is assumed to be long enough to ignore the end effects, with $n$ turns per unit length, cross sectional area $S$ and carrying a current $I$. As we know from Biot-Savart's law, magnetic induction inside this solenoid is constant and would be $B = \mu_0 \mu n I$. Here $\mu_0$ and $\mu$ are magnetic permeabilities of vacuum and the medium, respectively. By definition, flux through each turn is $BS$ and thus total magnetic flux linked with the solenoid is

* Wb: Weber, Mx: Maxwell

$$\Phi = NBS = \mu_0 \mu n^2 Sl \cdot I \tag{9.3}$$

from which the induction of the solenoid is found as,

$$L = \mu_0 \mu n^2 Sl \tag{9.4}$$

If we substitute $S = \pi r^2, n = N/l$ we would express $L$ in terms of directly measurable quantities:

$$L = \mu_0 \mu \pi \frac{N^2 r^2}{l} \tag{9.5}$$

This is the theoretical expression for induction of a cylindrical solenoid and it will become a reference point for your discussions.