Experiment Nr. 35

Inductance of coil - self-inductance and mutual inductance

Theory

The magnetic interaction is described in terms of a vector field, where each point in space (and time) is associated with a vector that determines what force a moving charge would experience at that point. The magnetic flux through some surface is proportional to the number of field lines passing through that surface. The magnetic flux Φ through some surface, in this simplified picture, is proportional to the number of field lines passing through that surface. In more advanced physics, the field line analogy is dropped and the magnetic flux is properly defined as the surface integral of the normal component of the magnetic field passing through a surface. If the magnetic field is constant, the magnetic flux passing through a surface of vector area S is

$$\Phi = \iint_S \vec{B} d\vec{S}$$

If an electric current passing through a circuit implicates the magnetic field, thus, the magnetic flux could be defined as

$$\Phi = LI$$

The linear parameter L is called **self-inductance**. Self-inductance of a conductor (or a coil) is proportional to its geometric properties exclusively. For an ideal coil, the self-inductance could be determined by following formula:

$$L = \mu_0 \frac{N^2 S}{l},$$

where μ_0 is the vacuum permeability, N is the coil number of turns, S is the coil cross-section area and l is the coil length.

If two conductors (or two coils) producing magnetic field could interact, then the electric current I_1 in the first conductor (coil) causes a magnetic flux Φ_{12} in the second coil. The interaction could be defined by a linear factor M_{12} called **mutual inductance**:

$$M_{12} = \frac{\Phi_{12}}{I_1}$$

If two conductors (coils) are connected in series, the total self-inductance is given by

$$L = L_1 + L_2 + 2|M_{12}|$$

The third equation term plays a role of mutual inductance rate. If no mutual inductance is present, then $M_{12} = 0$. The value M_{12} (positive or negative) is dependent on the mutual direction of electric current I flowing through the conductors (coils).

Measurement objectives

1. Determine the winding resistance of the coils.

2. Using to the circuit wiring diagram Nr. 1 (see Fig. 1) determine the self-inductance L_1 and L_2 of both coils. Use the series connection arrangement in the same wiring diagram and determine the total inductance of two coils L_{12} and L'_{12} (changing the current flow direction in one of the coils). Calculate the mutual inductances M_{12} and M'_{12}.

3. Using to the circuit wiring diagram Nr. 2 (see Fig. 2) determine the mutual inductances M_{12} and M_{21} from the induced voltage on the secondary coil. Compare the obtained values of the mutual inductances with the values M_{12} and M'_{12} calculated in the previous objective.

4. Determine the coil self-inductance L using the geometrical parameters and compare the results with the self-inductance L_1 and L_2 obtained on the objective Nr. 1.

Comments

Ad 2. The self-inductance measurement is based on the total coil impedance determination. Use the wiring diagram Nr. 1 (see the Fig. 1) and make the measurement of the current I and the voltage U for every coil. The self-induction L could be calculated from the formula

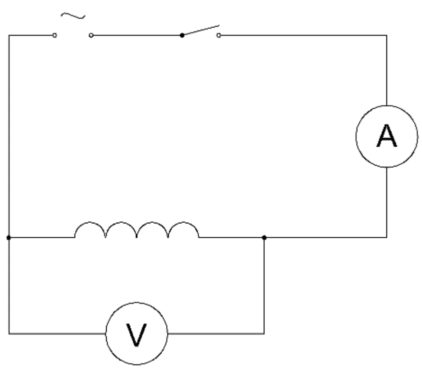

Fig. 1 The wiring diagram Nr. 1

$$L = \frac{\sqrt{\left(\frac{U}{I}\right)^2 - R^2}}{2\pi f},$$

where R is the winding resistance of the coil and f is the voltage frequency. Additionally, carry out the measurement in the series connection arrangement of both coils, change the current direction flow and calculate the mutual inductance using following formulas

$$M_{12} = \left|\frac{L_{12}-L_1-L_2}{2}\right| \text{ and } M'_{12} = \left|\frac{L'_{12}-L_1-L_2}{2}\right|.$$

Ad 3. The direct mutual inductance measurement is based on the induced voltage determination. Use the wiring diagram Nr. 2 (see the Fig. 2) and make the measurement of the current I_1 on the primary coil and of the voltage U_2 determined on the secondary coil. The mutual inductance could be calculated as

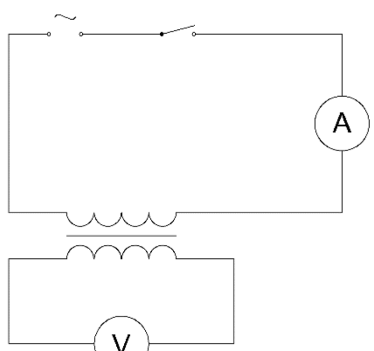

Fig. 2 The wiring diagram Nr. 2

$$|M_{12}| = \frac{1}{2\pi f}\frac{U_2}{I_1}$$

Compare the results of M_{12} and M_{21} with the values of the M_{12} and M'_{12} obtained in the previous objective. Keep in mind that the results will be comparable only on condition that the electric current in all the measurements was kept at the same level.