Project 3. Inductor Design, Fabrication, and Analyses

Notes on project:

1. This is a group project. Each group may consist of either two or three students. Each group shall submit a single report in pdf format.
2. Experimental measurements may be done in our laboratories or using other resources as in the case of the first project.
3. Deadline of the report submission: June 11, 2023, 23:59.

General Task: Fabricating and testing inductors while analyzing hypothetical scenarios using mathematical tools.

Part 1. Fabrication of cylindrical inductors.

Using insulator-coated conductive wires, prepare two cylindrical inductors (i.e., solenoids) having a length of at least 1 cm and diameter of at least 3 mm. Wind one of the inductors around a dielectric material of your choice and the other one around a ferromagnetic material. In your report, present a photo of your inductor and add the information on winding number, length, diameter, and relative permeability of the core material (if you do not know the exact nature of your material, make an educated guess).

Part 2. Fabrication of toroidal inductors.

Using insulator-coated conductive wires, prepare two toroidal inductors having a diameter of at least 5 mm. Wind one of the inductors around a dielectric material of your choice and the other one around a ferromagnetic material. In your report, present a photo of your inductor and add the information on winding number, length, diameter, and relative permeability of the core material (if you do not know the exact nature of your material, make an educated guess).

Part 3. Develop a test procedure.

A) Design a circuit such that you can measure the current passing through both inductors. Measure the current in your circuit and report it.

B) Design a circuit such that you can measure the inductance values of your solenoids and toroids. Report the inductance values you measured.

Part 4. Comparison with theory.

Using the formulae of inductance for solenoids and toroids, calculate the theoretical inductances of your fabricated components. Compare your theoretical and experimental results and discuss the potential sources of differences if there are any.

Part 5. Hypothetical inductors.

A. You are given a solenoid of length L and diameter or d. This solenoid is wound around a material whose relative magnetic permeability is a function of space and time such that $\mu_r(z,t) = 4t + 5z$. Furthermore, the density of the wires around the core material also depends on space and time according to $N(z,t) = 2z$.

a. Calculate the total inductance of the solenoid as a function time.
b. If the current passing through this circuit is $i(t) = 3\cos(2t)$, what is the voltage on the inductor?

c. Calculate the voltage at an arbitrary point on the inductor as a function *z* and *t*. Analyze its critical points as the functions of z and t.

B. Consider the finite solenoid (see Fig.) with the current *I*, radius *R*, and *N* turns of wire tightly wound over a length *L*. Compute the magnetic field **B** along the central axis *y* of the solenoid (i.e. at the point *P*), if the angles $\theta 1$ and $\theta 2$ are given. At which point the field has maximum?