

Toroid Permeability Experiment Analysis

Setup & Procedure:

This experiment was used to prove our original experiment plan that yielded strange, unexpected results. In order to prove the developed system, a toroid with known permeability was acquired.

The toroid with known permeability, of $6250 \text{ nH/T}^2 \pm 25\%$, was measured using calipers, then the cross sectional area was calculated. A wire was wrapped around the toroid 10 times, then was attached to a function generator feeding 5V at 1kHz signal and current clamp with amplifier. The output signal of the current clamp was displayed on the oscilloscope with a BNC cable. Once the setup for the experiment was complete, the slope of the current signal was plugged into equation (3) to get the permeability. Equation (3) was derived with the combination of Equation (1) & Equation (2). Equation (3) was also divided by 0.0254 in order to achieve the desired units of $[H/m]$ for permeability.

After the permeability of the known toroid was proven, the same experiment was performed on three different toroids with unknown percentages of iron labeled 3, 6, 9 & a known percentage of 30%.

$$\text{Equation (1)} \quad L = \frac{\mu N^2 A}{2\pi r} \qquad \text{Equation (2)} \quad V = L \frac{dI}{dt}$$

$$\text{Equation (3)} \quad \mu = \frac{V \left(\frac{t_2 - t_1}{i_2 - i_1} \right) l}{AN^2}$$

Results:

Using Equation (3) a reference permeability between 57.56×10^{-6} and 95.94×10^{-6} was found with a median of 76.75×10^{-6} . If our experiment is correct then it will result in a permeability within this range. After applying the 5V signal a permeability of 76.12×10^{-6} was calculated therefore proving our experiment to be accurate.

Reference Toroid Measurements:

$$\begin{aligned} r_o &= 2.14 \text{ [in]} & r_i &= 1.275 \text{ [in]} & h &= 1.01 \text{ [in]} & \Delta T &= 40 \text{ [ns]} \\ A &= (r_o - r_i)h = 0.874 \text{ [in}^2\text{]} & & & & & \Delta A &= 175 \text{ [mA]} \end{aligned}$$

Plugging into Equation (3) yielded a result of $\mu \equiv \underline{76.12} \times 10^{-6}$ fitting within the given parameters and therefore proving experiment method for permeabilities much greater than air.

Test Toroid Experiments:

$$r_o = 1.49 \text{ [in]} \quad r_i = 0.8165 \text{ [in]} \quad h = 0.5 \text{ [in]}$$

$$A = (r_o - r_i)h = 0.537 \text{ [in}^2\text{]}$$

Toroid	Calculated \mathcal{U}
3	1.14E-05
6	1.46E-05
9	1.52E-05
30%	2.02E-05

Overview:

From the testing done we can conclude our experiment will provide accurate results, although not for small permeabilities close to that of air. We also concluded that the permeabilities calculated are reasonable.