International Journal of Recent Engineering Research and Development (IJRERD)
Volume No. 01 – Issue No. 03, ISSN: 2455-8761
www.ijrerd.com, PP. 27-31

Measurement of Magnetic Permeability of Matters Using Inductive Coil

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Abstract: In this work an inductive coil was used to measure the value of magnetic permeability of matter by means of alternation current. The permeability of air, aluminum, copper and iron were measured. The results found agreed with the standard ones.

Introduction

In electromagnetism, **permeability** is the measure of the ability of a material to support the formation of a magnetic field within itself. Hence, it is the degree of magnetization that a material obtains in response to an applied magnetic field. Magnetic permeability is typically represented by the (italicized) Greek letter μ. The term was coined in September 1885 by Oliver Heaviside. The reciprocal of magnetic permeability is *magnetic reluctivity*[1,2,3]

In SI units, permeability is measured in henries per meter (H/m or $H\cdot m^{-1}$), or newtons per ampere squared ($N\cdot A^{-2}$). The permeability constant (μ_0), also known as the magnetic constant or the permeability of free space, is a measure of the amount of resistance encountered when forming a magnetic field in a classical vacuum. The magnetic constant has the exact (defined)[1] value ($\mu_0 = 4\pi \times 10^{-7}\ H\cdot m^{-1} \approx 1.2566370614\ldots\times 10^{-6}\ H\cdot m^{-1}$ or $N\cdot A^{-2}$)[4,5]. A closely related property of materials is magnetic susceptibility, which is a dimensionless proportionality factor that indicates the degree of magnetization of a material in response to an applied magnetic field [6, 7].

Experimental Setup

Materials

The equipments used in this work were:

AC/DC Power supply

$I_{min} = 0$ $I_{max} = 5$ Am $V_{min} = 0$ $V_{max} = 15$ Volt

Coil

N = 250 turns A = 1.5 mm, R = 0.6 Ω I max = 5 Am

Microvoltmeter

$V_{min} = 1$ mirovolt $V_{max} = 1000$Volt
Ammeter
$I_{min} = 0$ $I_{max} = 20$ Am

Rheostat

R = 27.5Ω I = 5.2 Am
Connecting wires

Method

The circuit was connected in series; the coil at the first readings was air coil then the core of the coil was filled with aluminum, copper and iron respectively, the reading were taken by changing the rheostat continuously.

Results

Table (1) Voltage vs. Current (Air core Coil)

Voltage (mV)	Current (μA)
0.74296	0.3228
0.73188	0.29824
0.7219	0.27544
0.71248	0.25007
0.70445	0.2333
0.69389	0.20784
0.68476	0.18585
0.6781	0.16891
0.66784	0.1368
0.65786	0.114

Table (2) Voltage vs. Current (Al core Coil)

Voltage (mV)	Current (μA)
0.52	0.099
0.51144	0.09152
0.50521	0.08721
0.49921	0.08239
0.49	0.07654
0.48225	0.07047
0.47403	0.06438
0.46804	0.06031
0.46354	0.05727
0.4598	0.05448
0.45506	0.05094
0.45231	0.04865
0.44982	0.04636

Table (3) Voltage vs. Current (Copper core Coil)

Voltage (mV)	Current (μA)
0.81	0.034
0.7952	0.0327
0.77965	0.03151
0.76957	0.03053
0.75707	0.02958
0.74763	0.02864
0.73419	0.02755
0.72261	0.02671
0.715	0.026

Table (4) Voltage vs. Current (Iron core Coil)

Voltage (mV)	Current (μA)
2.75091	0.0217
2.7323	0.02128
2.68031	0.02032
2.62946	0.01936

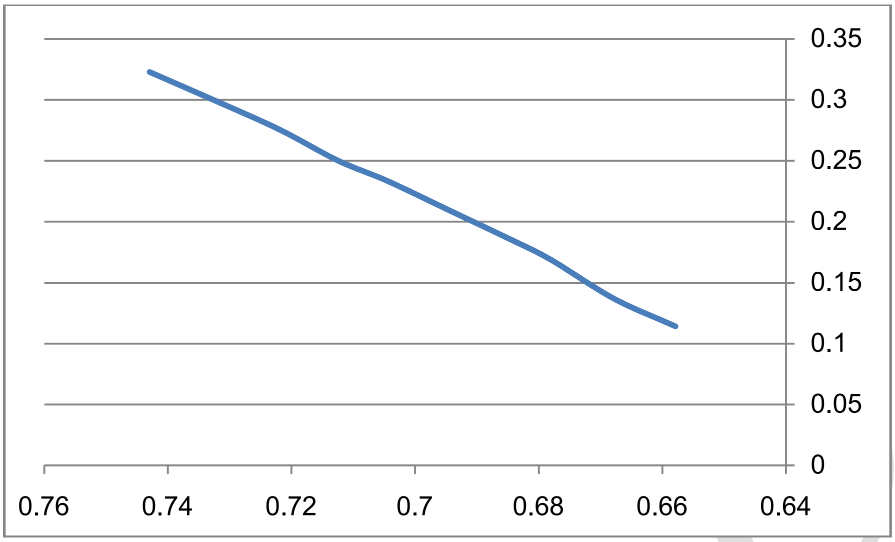

Fig (1) for table (1)
Finding the magnetic permeability μ for air:
L = AμN
μ = L/AN
Where:
A = cross sectional area = 1.5 mm
N = number of turns = 250
L = self-inductance of the coil
From the graph, since;
V/I = slop = $2\pi f$L
f = frequency of the supply
L = 1/$2\pi f$ X slope = 7.961 X10^{-6} Henry
μ = L/AN = 7.961X10^{-6}/1.5 X10^{-3} X 250 = 2.123 X 10^{-5} H/m

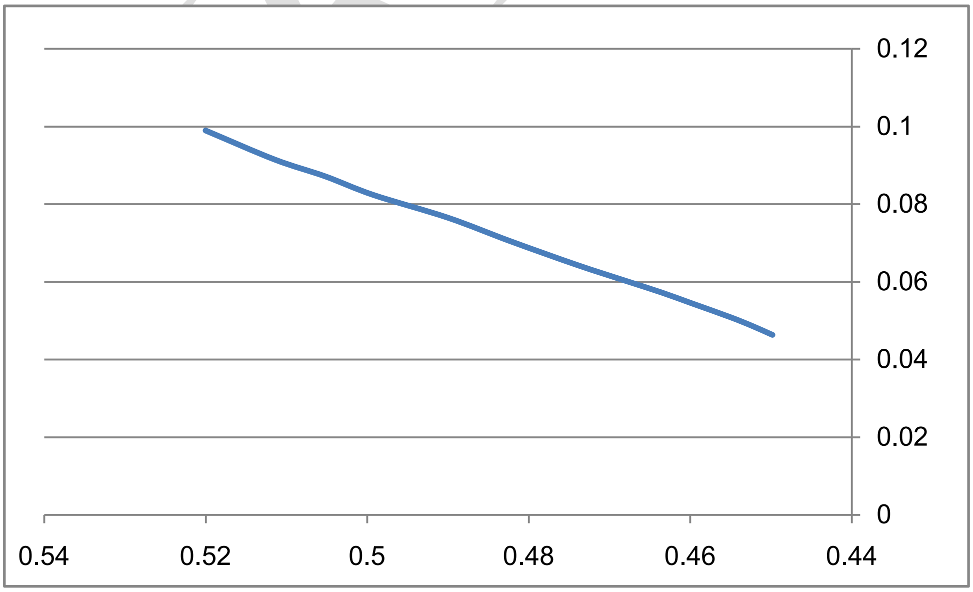

Fig (2) for table (2)
Finding the magnetic permeability μ for Al :
L = 1/$2\pi f$ X slope = 2.296 X10^{-6} Henry
μ = L/AN = 2.296 X 10^{-6}/1.5 X10^{-3} X 250 = 6.123 X 10^{-6} H/m

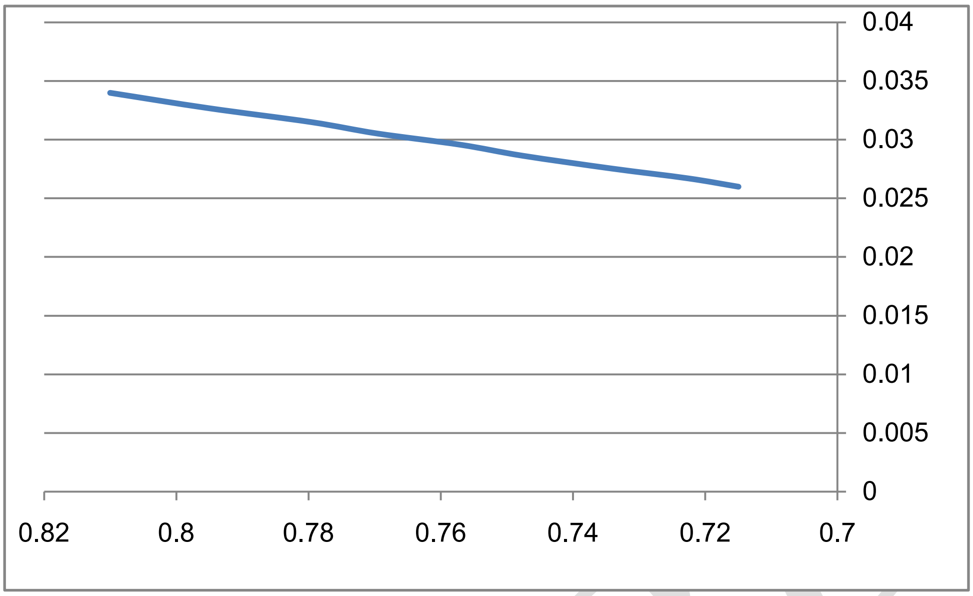

Fig (3) for table (3)
Finding the magnetic permeability μ for Cu:
$L = 1/2\pi f$ X slope = 2.675 X10^{-7} Henry
$\mu = L/AN = 2.675 \text{ X } 10^{-7}/1.5 \text{ X}10^{-3} \text{ X } 250 = 7.1 \text{ X } 10^{-7}$ H/m

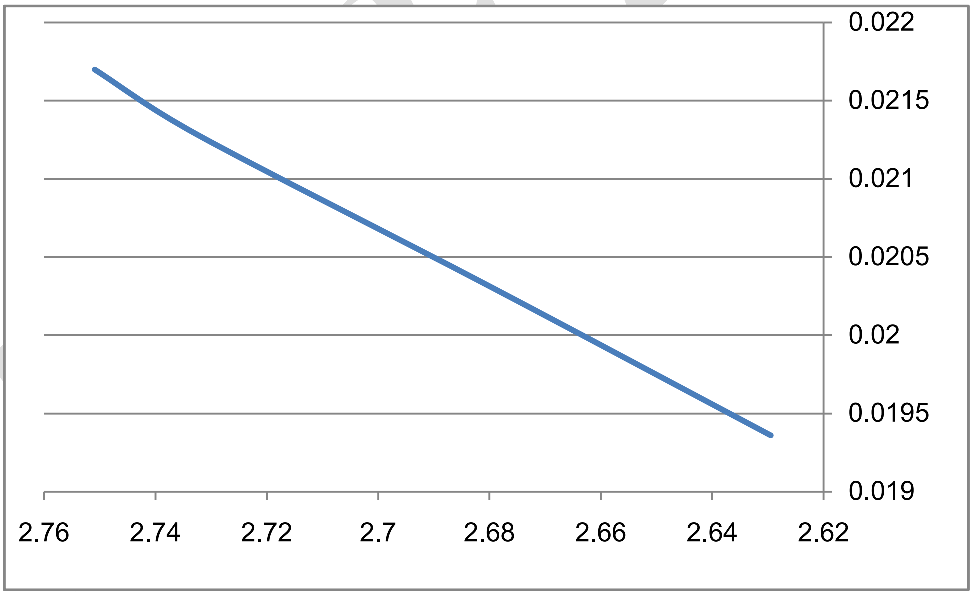

Fig (4) for table (4)
Finding the magnetic permeability μ For Fe:
$L = 1/2\pi f$ X slope = 6.003 X10^{-8} Henry
$\mu = L/AN = 6.003 \text{ X } 10^{-8}/1.5 \text{ X}10^{-3} \text{ X } 250 = 1.6 \text{ X } 10^{-4}$ H/m

Discussion

The magnetic Permeability of air, aluminum (Al), copper (Cu) and Iron (Fe) was found from figures (1, 2, 3 & 4) respectively to be:
2.123×10^{-5} H/m for air
6.123×10^{-6} H/m for Al
7.1×10^{-7} H/m for Cu
1.6×10^{-4} H/m for Fe
Comparing these values with the standard ones,
$1.25663753 \times 10^{-6}$ H/m for air
1.256665×10^{-6} H/m for Al
1.256629×10^{-6} for Cu
6.3×10^{-3} for Fe
It's clear that the values agree to a good degree of precision with the standard ones.

Conclusion

It was concluded that, it's very easy to find magnetic permeability for materials by using simple electric circuits.

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