

UNIVERSITY OF NORTH CAROLINA AT CHARLOTTE

Department of Electrical Engineering

Experiment No. _____ Magnetic Properties of a Small
TransformerINTRODUCTION

A wire carrying current produces a magnetic field around itself that is directly proportional to the current and varies inversely as the distance from the wire.

$$B = \frac{\mu i}{2\pi D} \quad (1)$$

where,

B - magnetic flux density
 μ - permeability of the medium
 i - current
 D - radial distance from the wire

The magnetic field intensity is related to the flux density as shown.

$$H = B/\mu \quad (2)$$

The line integral of field intensity around a closed path just equals the current it encloses.

$$\oint H \cdot dL = i$$

If the line integral encircles a number of turns of wire, then,

$$\oint H \cdot dL = Ni = F \quad (3)$$

where,

F - magnetomotive force.

For a ferromagnetic core,

$$\phi = BA = \frac{\mu ANi}{l} \quad (4)$$

where,

Φ - flux

A - cross-sectional area of core

l - center circumference of core.

Also,

$$F = Hl = Ni = \frac{l\phi}{\mu A} = R\phi \quad (5)$$

where,

R - reluctance of the core (magnetic resistance)

The relationship between flux density and flux intensity is often shown graphically for various mediums such as iron, steel, etc. Such a curve is shown in Figure 1. A great deal of research has gone into developing core materials with various B-H characteristics. The permeability of these materials can be on the order of ten thousand times that of air. This means that a large amount of flux can be produced in these cores as compared with air cores for a given amount of ampere-turns (Ni). Also, observe from the figure that the core will start saturating at some level of flux density. Air cores, of course, would not saturate.

The energy stored in a magnetic core per unit volume can be expressed as follows;

$$W = \int HdB \quad \frac{\text{watt-sec}}{\text{meter}^3\text{-cycle}} \quad (6)$$

The energy lost in the core in the form of heat is represented by the area enclosed by the hysteresis curve such as shown in Figure 2.

Faraday's law states that the voltage produced across a coil is equal to the number of turns in the coil times the rate-of-change of flux with time linking the coil.

$$e(t) = \frac{Nd\phi}{dt} \quad (7)$$

If equation (4) is substituted into the above equation, then,

$$e(t) = \left(\frac{\mu AN^2}{l} \right) \frac{di}{dt} = \frac{Ldi}{dt} \quad (8)$$

where, L , is defined as the inductance of the coil. If the flux of one coil magnetically links a second coil, the electrical relationship between the two coils would be,

$$e(t)_2 = \frac{N_2 d\phi_{12}}{dt} = \frac{M_{12} di_1}{dt} \quad (9)$$

and vice versus,

$$e(t)_1 = \frac{N_1 d\phi_{21}}{dt} = \frac{M_{21} di_2}{dt} \quad (10)$$

where,

$M_{12} = M_{21}$ - mutual inductance.

It is the purpose of this experiment to obtain a B-H curve for a transformer core and determine its characteristics.

PRELIMINARY

P-1. Determine the voltage across the 1-microfarad capacitor of Figure 3 in terms of the output voltage of the transformer assuming that for 60 Hertz the impedance of the capacitor is much less than the 1-megohm resistor ($1/SC \ll R$). Relate this voltage to the magnetic flux density, B .

P-2. Relate the voltage across the 1-ohm resistor to the magnetic flux intensity, H .

P-3. Rewrite the equation (6) above in terms of voltage and current.

(INSTRUCTOR'S SIGNATURE_____DATE_____)

Suggested References

1) Electric Machines and Transformers (chapter 3)

Leonard R.Anderson

2) Electric Machinery (5th edition) (chapters 1 & 2)

A.E. Fitzgerald, Charles Kingley Jr, Stephen D.Umans

3) Physics of Technology Series : vol 27.

Title- The Transformer : a module on magnetic properties of matter and AC currents

Arnold A.Strassenburg , Malcolm Goldberg

Call number : QC33.P47.vol 27

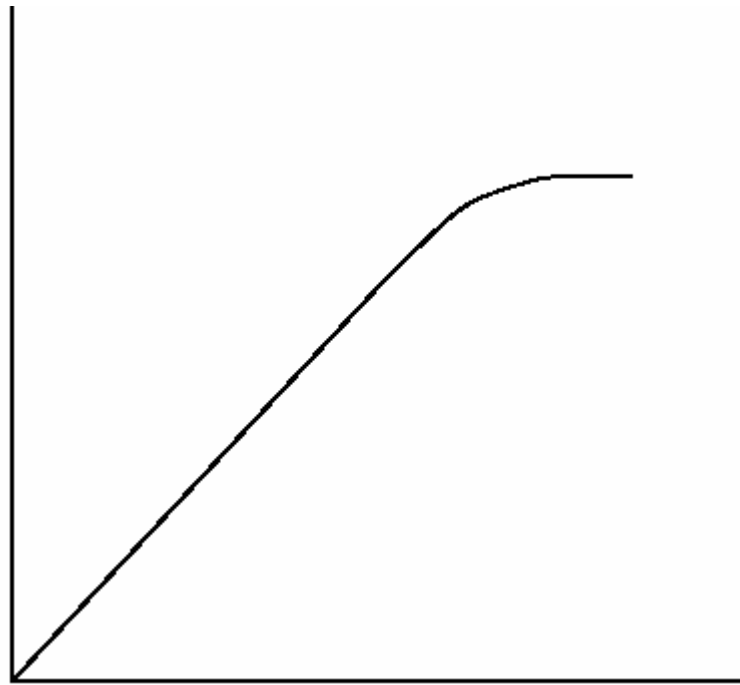
PROCEDURE

- F-1. Connect the circuit of Figure 3.
CAUTION: DO NOT MAKE CHANGES IN THE CIRCUIT UNLESS THE AC SUPPLY IS TURNED ALL THE WAY DOWN!
- F-2. Increase the voltage of the AC supply until the core just begins to saturate (about one ampere input to the transformer). Adjust the oscilloscope settings to give a well-proportioned hysteresis curve. Make a sketch of the curve and take enough data to plot a more accurate curve later.
- F-3. Change the Y-input from the oscilloscope to the input of the transformer. Place the oscilloscope in time-sweep and carefully sketch the current and voltage waveforms showing the relative phase. Take data to plot a more accurate curve of voltage and current later.
- F-4. Record the wattmeter reading as well as the RMS voltage across and the RMS current into the transformer.
- F-5. Be sure to measure the DC resistance on the 5 VAC side of the transformer and the exact resistance of the 1-Ohm resistor.

REPORT

- R-1. Draw an accurate B-H curve for the core.
- R-2. Draw an accurate voltage and current versus time plot on the same axes showing relative phase.
- R-3. Determine the apparent power, S , and reactive power, Q , from the readings taken in F-4 above.
- R-4. Graphically determine the power lost in the core from the BH curve. Compare this with the wattmeter reading and explain any difference.
- R-5. Determine the admittance-equivalent circuit for the transformer (G_0 and B_0).
- R-6. Determine the average dynamic permeability of the core in the region $B = 0$ and B_{max} .
- R-7. Calculate the reluctance, R , for the conditions in R-6 above.
- R-8. Discuss the results.

MAGNETIC
DENSITY, B
Webers/meters²



Magnetic Intensity, H , Ampere-turns/meter

Figure 1.

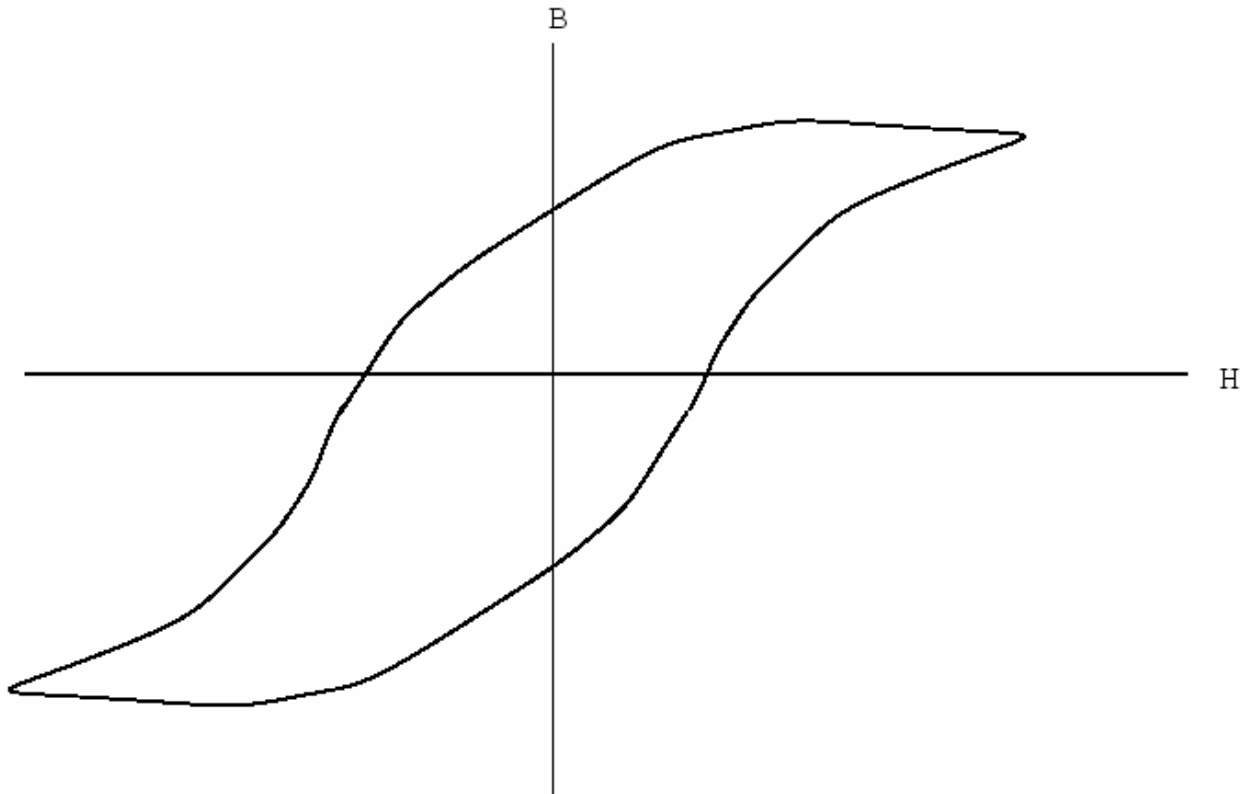


Figure 2.

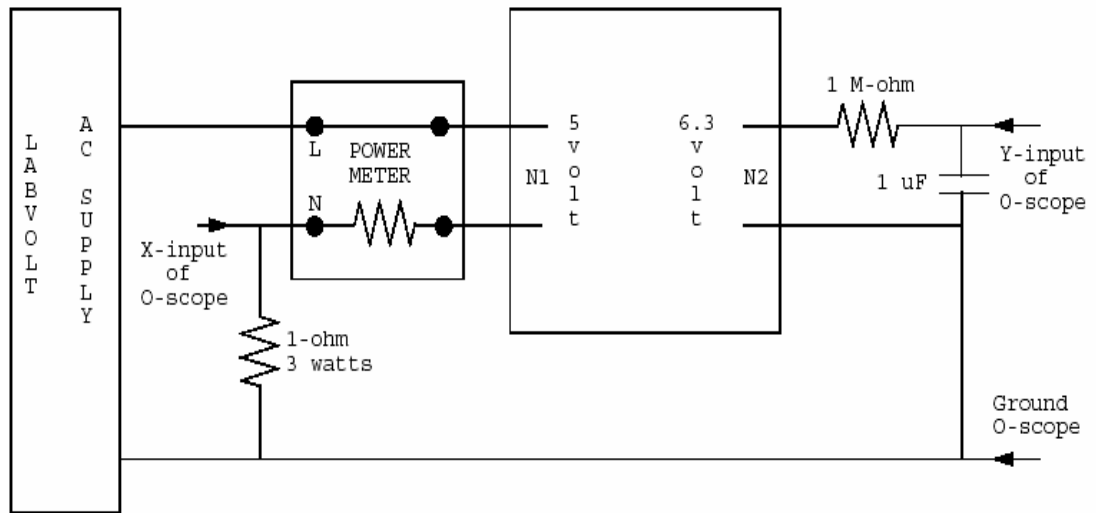
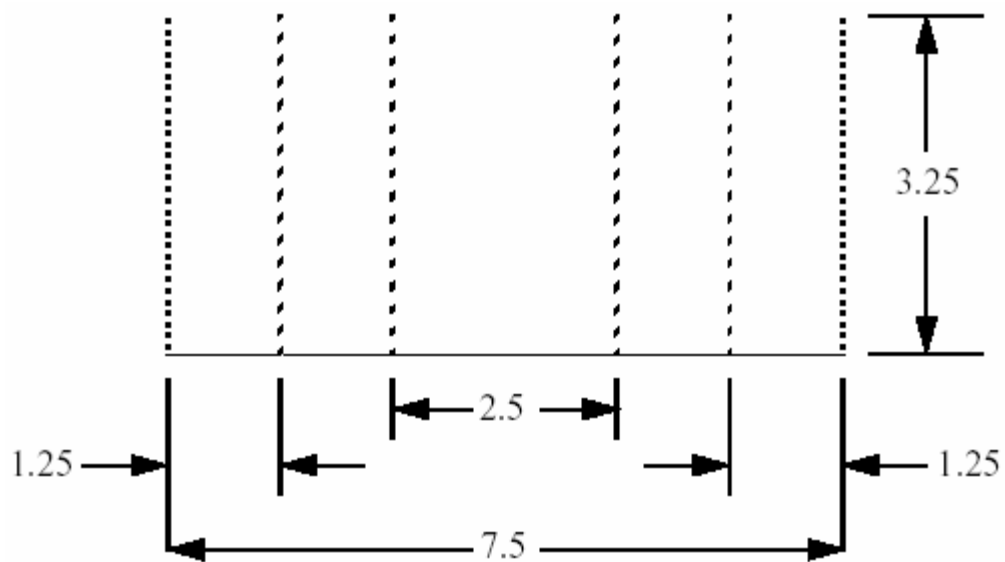
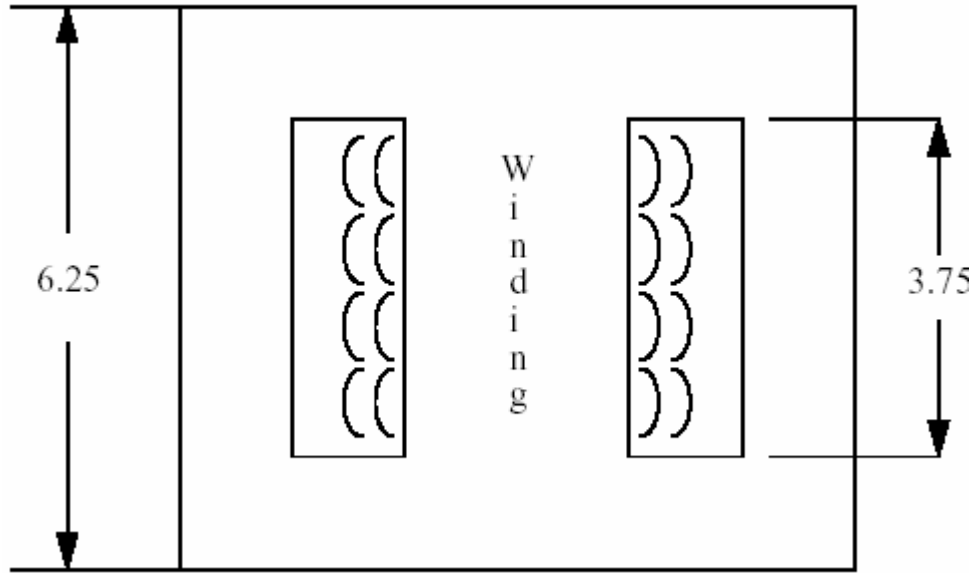


Figure 3. Test Circuit





ALL DIMENSIONS ARE IN CENTIMETERS

5-VOLT WINDING - N1, 100 TURNS
6.3 VOLT WINDING - N2, 126 TURNS

Figure 4. Transformer Core, Stancor PC8403