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An Inexpensive 8000 Gauss Laboratory Electromagnet

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Abstract. A 10 KVA 2300/220 volt transformer, obtained through government surplus for less than $10, was converted into an electromagnet. The resulting magnetic field and its measurement, power supply requirements, and laboratory experiments are discussed.

TRANSFORMER CONVERSION

A 10 KVA 2300/220 volt core-type transformer was obtained through government surplus for less than $10. The transformer was removed from the oil and the top frame was removed. It was found that the laminations were such that they could be slid back and cut off, forming a gap 8 x 13 cm in cross section and 8.5 cm in width. The primary was found to be wound with approximately 1400 turns of number 13 wire, and a resistance of 5.2 ohms was measured when the two coils were connected in series.

POLE PIECES

Several types of pole pieces were used. Pyramidal pole pieces with a 2.5 x 2.5 cm pole face and a gap of 2 cm were first used. A field of about 6000 gauss was produced by a current of 8 amperes in the magnet coils. The field was very inhomogeneous, as 0.25 inch unmachined laminations were used to make the pole pieces, and small air gaps were thus introduced.

Flat pole pieces were next used with a pole face of 8 x 13 cm and a gap width of 2.5 cm. A field of about 4000 gauss was produced by a current of 8 amperes in the magnet coils. The field was found to be homogeneous to at least 1% over an area of 4 x 5 cm. These pole pieces were not machined. A much higher degree of homogeneity could be expected from machined pole pieces of low carbon magnet steel. The third set of pole pieces was made by adding a lamination to each of the flat pole pieces, thereby reducing the pole face to 4 x 5 cm and the gap to 1 cm. A current of 8 amperes in the magnet coils produced a field of 8000 gauss. This field was found to be homogeneous to 1% over an area of 0.5 x 0.5 cm. The gap was then

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closed to 0.25 cm and the current was increased to 9.6 amperes. This produced a field of 15,200 gauss!

Power Supply

A Standard Flexlab laboratory supply was used. The full-wave rectified voltage was filtered by two L sections, each of which consisted of a 0.11 ohm, 0.01 h choke and a 5300 uf capacitor. A ripple factor was reduced by the filter to 4 parts in 10.[1]

Field Measurements

The first measurements of the field were made by an arrangement similar to the one of Thomas, Driscoll and Hipple of the National Bureau of Standards.[4] Fifteen windings of copper wire were used for the coil, which was 1.34 cm across and 47 cm in length, and a current of 0.8 amperes was used in this coil. An old analytical balance was modified by drilling a hole under one of the pans such that the coil could be suspended from the balance. From $\mathbf{F} = \text{nil} \times \mathbf{B}$, the value of B can be found. The disadvantage of this method was the difficulty of determining the exact position of the probe in the field.

The second method of measuring the field employed a Hall probe gaussmeter. A calibration curve was drawn for the probe using known fields at Iowa State University (Ames Laboratory). The field could then be determined from the curve and the measured Hall voltage. A Keithley 600 electrometer was used to measure the Hall voltage. This method of measuring the magnetic field is accurate to within 1%.

Experiments

The electromagnet in its present form may be used for several demonstration and laboratory experiments such as Faraday's law of induction, the force on a current-carrying conductor, eddy currents, the direction of B and H in various parts of a magnetic circuit, the Hall effect in semiconductors, diamagnetism of bismuth, and magnetoresistive effects.

It is anticipated that the use of machined pole pieces and a current regulator will provide a magnetic field of sufficient homogeneity and stability such that the Zeeman effect, nuclear magnetic resonance, and electron spin resonance experiments may be performed.

Literature Cited

1. Resnick, R. and Halliday, D., *Physics for Students of Science and Engineering* (John Wiley and Sons, Inc., New York, 1962), 1st ed., p. 729-30.