Homework I

22 March 2018

1.2 A cylinder of ferromagnetic material is 6.0 cm long and 1.25 cm in diameter, and has a magnetic moment of 7.45 x 103 emu.

(a) Find the magnetization of the material.

$$M = \frac{m}{V} = \frac{7.45 \times 10^3}{\left(\frac{1.25}{2}\right)^2 \times 6 \times \pi} = 1011.8\, emu/cm^3$$

(b) What current would have to be passed through a coil of 200 turns, 6.0 cm long and 1.25 cm in diameter, to produce the same magnetic moment?

$$m = \frac{nAi}{10}$$

Thus,

$$i = \frac{10m}{nA} = \frac{10 \times 7.45 \times 10^3}{200 \times \left(\frac{1.25}{2}\right)^2 \times \pi} = 303.54\,(A)$$

(c) If a more reasonable current of 1.5 ampere is passed through this coil, what is the resulting magnetic moment?

$$m = \frac{nAi}{10}$$

Thus,

$$m = \frac{200 \times \left(\frac{1.25}{2}\right)^2 \times \pi \times 1.5}{10} = 36.81\,(erg/Oe)$$

Homework II

11 April 2018

2.1. A solenoid is 50 cm long and 2.5 cm in diameter is uniformly wound with insulated copper wire of American Wire Gage (AWG) size 22, which has copper diameter 0.02535 inch or 0.0644 cm and resistance at 20 ℃ of 6.14 ohm/1000 feet or 53 ohm/1000 meter. The coil carries a current of 2.75 A. Find the voltage required to produce this current, the power dissipated, and the magnitude of the field at the corner of the solenoid.

$$\mathrm{n} = \frac{50\ cm}{0.0644\ cm} = 776.4\ turns$$

$$\text{Wire length} = 2\pi\frac{d}{2} \times 776.4 = 6097.83\ \text{cm}$$

$$\mathrm{R} = \frac{53\ ohm}{1000 \times 100\ cm} \times 6097.83\ cm = 3.23\ ohm$$

$$\mathrm{V} = \mathrm{I} \times \mathrm{R} = 2.75\ \mathrm{A} \times 3.23\ \mathrm{ohm} = 8.89\ \mathrm{V}$$

$$\text{Power} = \mathrm{V} \times \mathrm{I} = 8.89\ \mathrm{V} \times 2.75\ \mathrm{A} = 24.44\ \mathrm{W}$$

$$\mathrm{H} = \frac{4\pi nI}{10\ L} = \frac{4\pi \times 776.4 \times 2.75\ A}{10 \times 50\ cm} = 53.66\ \mathrm{Oe} = 4270.2\ \mathrm{A/m}$$

or

$$\mathrm{H} = \frac{4\pi nI}{10\ L} \times \frac{L}{\sqrt{D^2 + L^2}}$$

$$= \frac{4\pi \times 776.4 \times 2.75\ A}{10 \times 50\ cm} \times \frac{50\ cm}{\sqrt{6.25\ cm^2 + 2500\ cm^2}}$$

$$= 53.59\ \mathrm{Oe} = 4264.56\ \mathrm{A/m}$$

2.3 A given power source can deliver a maximum of 4.0 A at a voltage of 20 V. A solenoid of length 30 cm and diameter 2.0 cm is to be wound with a single layer of copper wire of diameter d. Copper has a room-temperature resistivity of 1.7 x 10-6 ohm cm. Find the optimum wire diameter to produce a maximum field of 100 oersted. Neglect the thickness of the electrical insulation on the wire, and assume the winding diameter is the same as the solenoid diameter.

$$\mathrm{H} = \frac{4\pi n I}{10\,L} \times \frac{L}{\sqrt{D^2 + L^2}} = \frac{4\pi \times n \times 4\,A}{10 \times 30\,cm} \times \frac{30\,cm}{\sqrt{4\,cm^2 + 900\,cm^2}} = 100\,Oe$$

$$\mathrm{n} = 100\ \mathrm{Oe}\ \times \frac{\sqrt{4\,cm^2 + 900\,cm^2}}{30\,cm} \times \frac{10 \times 30\,cm}{4\pi \times 4\,A} = 598.2\,turns$$

$$\mathrm{L} = \mathrm{n} \times 2\pi R = 598.2 \times 2\pi \times 1\,cm = 3758.3\,cm$$

$$\mathrm{R} = \ \rho \frac{L}{A} = 1.7 \times 10^{-6}\,ohm\,cm \times \frac{3758.3\,cm}{\pi \times (\frac{d}{2})^2}$$

$$= \frac{V}{I} = \frac{20\,V}{4\,A} = 5\,ohm$$

$$d^2 = \ 1.7 \times 10^{-6}\,ohm\,cm \times \frac{3758.3\,cm}{\pi \times 5\,ohm} \times 4$$

$\therefore \mathrm{d} = 0.0403\ \mathrm{cm}$

2.6 A nickel-iron ring with cross-sectional area 0.85 cm2 is expected to be driven to its saturation magnetization of 1.1 T in a field of 800 A/m. The flux density will be measured by an electronic flux integrator with input resistance of 1 kOhm and an integrating capacitor of 10μF. How many turns should be would on the secondary (flux-measuring) coil to give an output signal of ± 5 V as the ring sample is driven to ±1.1 T?

$$e_{out} = \frac{1}{RC} \int e_{in}\,dt$$

$$\int e_{in}\,dt = \ -C_2\,N\,A\,\Delta B \quad V \cdot sec$$

$$C_2 = 1\,(SI\,unit) = \ 10^{-8}\,(cgs\,unit)$$

$$e_{out} = \frac{1}{RC} \times C_2\,N\,A\,\Delta B = 5\,\mathrm{V}$$

$$= \frac{1}{1000\,ohm \times 10^{-5}\,F} \times 1 \times N \times (0.85 \times 10^{-4}\,m^2) \times 2.2T$$

$$\therefore \mathrm{N} = \frac{1000\, ohm \times 10^{-5}\, F}{(0.85 \times 10^{-4}\, m^2) \times 2.2T} \times 5\, V = \text{267 turns}$$

2.8 A field of 750 Oe is applied perpendicular to the surface of a large iron plate (the surface area may be taken to be infinite). The permeability of the iron is 1200 (cgs unit). What is the flux density ***B*** in the iron?

$$\mathrm{B} = H_{tr} + 4\pi M$$

$$= H_a + 4\pi M - N_d M$$

$$= H_a \qquad \Leftarrow (N_d = 4\pi\ for\ the\ case)$$

$$\therefore \mathrm{B} = 750\ \mathrm{G}$$

(Normal component of ***B*** is continuous at an interface.)