Problems – Magnetic Materials

1. Suppose a design is needed for a solenoid that will develop a magnetic field of 10 kA/m when powered with 1A in vacuum. The solenoid dimensions are 0.3m in length and 2 cm in diameter.
a. How many turns of wire are required?
b. If the solenoid is wound with 0.5 mm diameter copper wire, what dc voltage is required to power it?

2. Explain the physical difference between magnetization M and induction B.

3. (A) Sketch a well-labeled B-H diagram characteristic of a ferromagnetic material at 0 K. Indicate the saturation induction, the remnant induction, and the coercive field.

(B) Briefly describe how the area of the hysteresis loop changes as the temperature approaches the Curie temperature. Briefly justify your answer.

4. Problem M-3 in Fischer: Schematically sketch the hysteresis loop for a ferromagnet at a temperature close to 0 K, just below the Curie temperature, and just above the Curie temperature. Briefly explain why these curves are different.

5. The B-H curve for a hard ferromagnet can be described by the adjacent figure (M1a).
a. What is the total hysteresis energy loss per cycle?
b. What is the BH_{max} product?

6. The B-H curve for a hard ferromagnet outlines the parallelogram of figure M1b.
a. What is the total hysteresis energy loss per cycle?
b. What is the $(BH)_{max}$ product?

7. Describe two ways in which soft and hard magnets differ.

8. Magnetic shielding materials protect electrical instruments and systems from interference by external magnetic fields e.g., the earth's magnetic field.
a. Which of the following materials are suitable for magnetic shielding applications; paramagnetic, diamagnetic, soft ferromagnetic, hard ferromagnetic ?

b. What specific property is important for magnetic shielding?

9. Suppose for a permanent magnet material the hysteresis loop second quadrant BH product varies parabolically with B as:

BH (J/m^3) = $-2X10^5B^2 + 2X10^5B$ (units of B are T).

a. Plot BH vs. B.

b. What is the maximum value of BH or BH_{max} ?

c. What is the value of H at BH_{max} ?

10. When is the electrical resistance of a ferromagnet an issue of concern in applications? What materials are available to address required electrical resistance needs?

11. A soft ferrite has rectangular hysteresis characteristics with $B_S = 0.4T$ and $H_c = 0.7$ A/m. The ferrite density is 5 g/cm^3 and the heat capacity is 0.85 J / g-C.

a. Estimate the temperature rise after one magnetizing cycle if the process is carried out adiabatically, i.e., with no heat loss.

b. At 60 Hz operation how long would it take for the magnet temperature to rise from 25C to 420C, the Curie temperature.

c. How will the temperature vary above the Curie temperature.

12. A) Predict the value of the saturation magnetization of body centered cubic iron metal at room temperature?

B) If Fe has an actual magnetization of 2.2 m_B per atom, what is M_S?

13. The ferrite $NiFe_2O_4$ is a derivative of magnetite with Ni^{2+} substituting for Fe^{2+}.

a. If the lattice constant is unchanged, what is M_S for this ferrite?

b. Suppose that Zn^{2+} substituted for half of the Ni^{2+} so that the ferrite formula is now $Ni_{0.5}Zn_{0.5}Fe_2O_4$. What is M_S for this ferrite?

14. Suppose the platter of a particular magnetic hard disk drive has an ID of 1 inch and an OD of 3 inches. If 100 Mbytes of storage can be written onto this surface, estimate the average linear dimension (in microns) of a single data bit.

15. Computer memories require stable binary states - 1 or 0 , or + M and – M - for operation. Electrical methods must be provided to write in a 1 or 0, and read out a 1 or 0. Explain how magnetic bars plus wires (solenoids) etc, can be configured to work as memory elements. What material hysteresis loop would be ideal for this application?

16. Distinguish between hysteresis losses and eddy current losses in soft ferromagnets.
a. When do the former dominate the latter?
b. When do the latter dominate the former?
c. Mention an application that capitalizes on eddy current losses.

17. An Alnico magnet bar whose coercive field is 120 kA/m, is contained within a 0.2 m long, 2000 turn, air solenoid far from either end. The axis of the bar is oriented parallel to the solenoid axis. Approximately what current will cause the Alnico magnet to demagnetize and essentially go on to reverse its polarity ?

18. How would you make a flexible magnet that would conformally hug the surface of a nonplanar sheet steel ?

19. For the following applications, state whether high values of B_r and H_c are required.

a. strong electromagnet
b. strong permanent magnet
c. magnetic tape for VCR
d. loud speaker
e. transformer core
f. compass needle
g. VCR tape head

Multiple Choice Review Questions.

In the following, choose the single best answer that completes the phrase.

30. Ferromagnetism is due to:

a. uncompensated charge in the atomic nucleus;
b. paired electrons in the d-shell of transition metals;
c. the spin and orbital properties of atomic electrons;
d. transitions from donor levels to the conduction band;
e. none of the above.

31. Magnetic domains:

a. have the same size and shape as grains in a polycrystalline material;
b. are regions of a material where all the atomic magnetic moments are aligned;
c. are only found in hard magnetic materials;
d. are only found in soft magnetic materials;
e. are due to electrical dipoles.