PROBLEMS

1.1 The long solenoid coil shown in Fig. P1.1 has 250 turns. As its length is much greater than its diameter, the field inside the coil may be considered uniform. Neglect the field outside.

(a) Determine the field intensity (H) and flux density (B) inside the solenoid ($i = 100$ A).

(b) Determine the inductance of the solenoid coil.

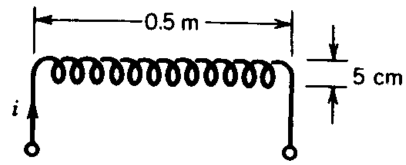

FIGURE P1.1

1.2 In the magnetic system of Fig. P1.2 two sides are thicker than the other two sides. The depth of the core is 10 cm, the relative permeability of the core $\mu_r = 2000$, the number of turns $N = 300$, and the current flowing through the coil is $i = 1$ A.

(a) Determine the flux in the core.

(b) Determine the flux densities in the parts of the core.

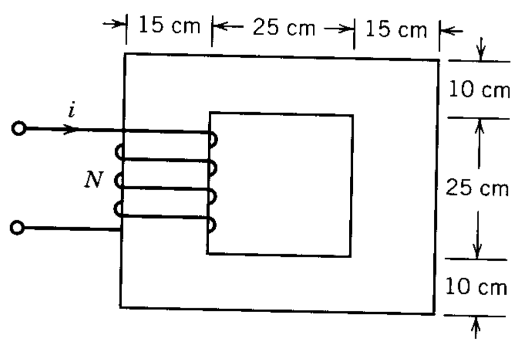

FIGURE P1.2

1.3 For the magnetic system of Problem 1.2, find the current i in the coil to produce a flux $\Phi = 0.012$ Wb.

1.4 Two coils are wound on a toroidal core as shown in Fig. P1.4. The core is made of silicon sheet steel and has a square cross section. The coil currents are $i_1 = 0.28$ A and $i_2 = 0.56$ A.

(a) Determine the flux density at the mean radius of the core.

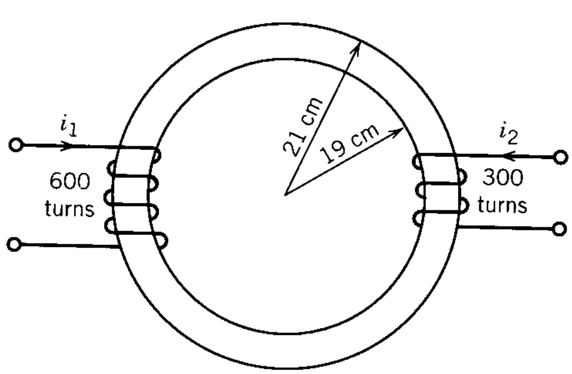

FIGURE P1.4

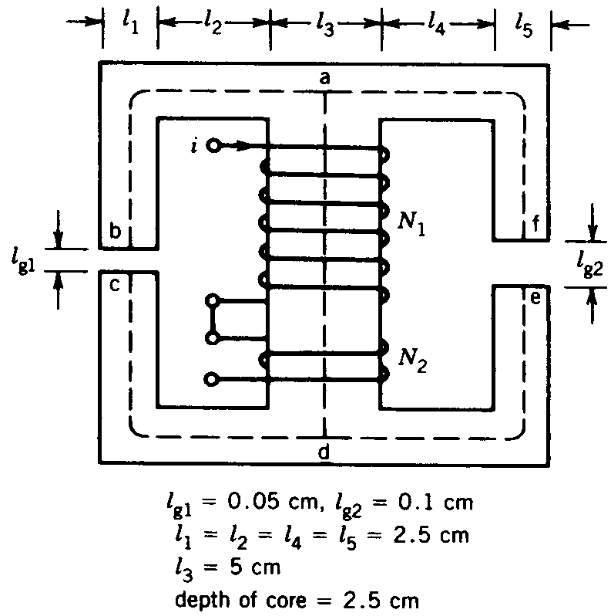

FIGURE P1.5

(b) Assuming constant flux density (same as at the mean radius) over the cross section of the core, determine the flux in the core.

(c) Determine the relative permeability, μ_r, of the core.

1.5 The magnetic circuit of Fig. P1.5 provides flux in the two air gaps. The coils ($N_1 = 700, N_2 = 200$) are connected in series and carry a current of 0.5 ampere. Neglect leakage flux, reluctance of the iron (i.e., infinite permeability), and fringing at the air gaps. Determine the flux and flux density in the air gaps.

1.6 A two-pole generator, as shown in Fig. P1.6, has a magnetic circuit with the following dimensions:

Each pole (cast steel):

magnetic length = 10 cm

cross section = 400 cm^2

Each air gap:

length = 0.1 cm

cross section = 400 cm^2

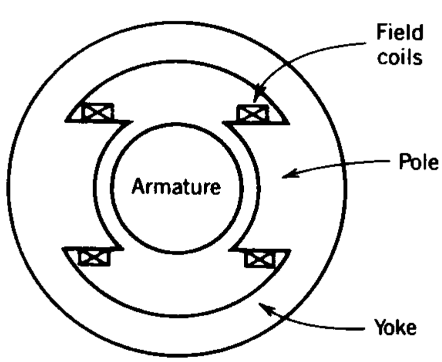

FIGURE P1.6

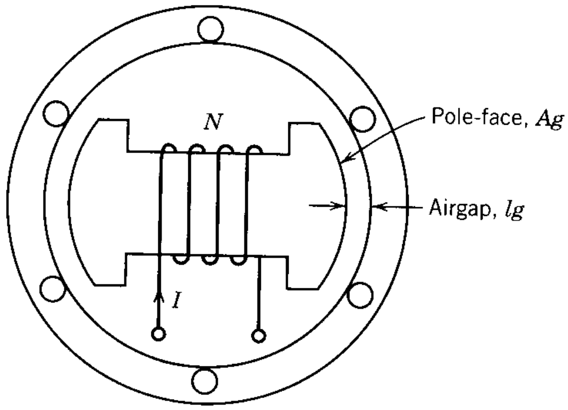

FIGURE P1.7

Armature (Si-steel):

average length = 20 cm

average cross section = 400 cm^2

Yoke (cast steel):

mean circumference = 160 cm

average cross section = 200 cm^2

Half the exciting ampere-turns are placed on each of the two poles.

(a) Draw the magnetic equivalent circuit.

(b) How many ampere-turns per pole are required to produce a flux density of 1.1 tesla in the magnetic circuit. (Use the magnetization curves for the respective materials.)

(c) Calculate the armature flux.

1.7 A two-pole synchronous machine, as shown in Fig. P1.7, has the following dimensions:

Each air gap length, l_g = 2.5 mm

Cross-sectional area of pole face, A_g = 500 cm^2

N = 500 turns

I = 5 A

μ_c = infinity

(a) Draw the magnetic equivalent circuit.

(b) Find the flux density in the air gap.

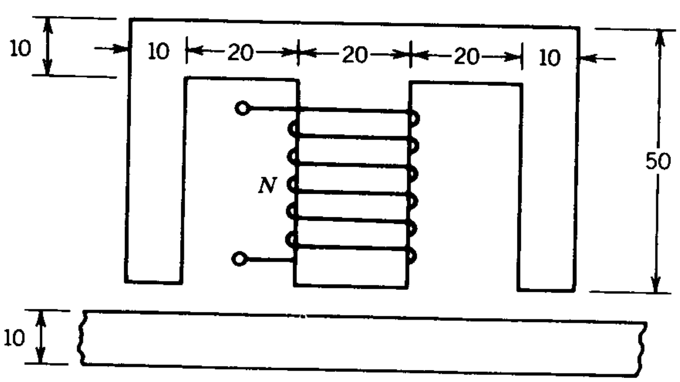

FIGURE P1.8

1.8 The electromagnet shown in Fig. P1.8 can be used to lift a length of steel strip. The coil has 500 turns and can carry a current of 20 amps without overheating. The magnetic material has negligible reluctance at flux densities up to 1.4 tesla. Determine the maximum air gap for which a flux density of 1.4 tesla can be established with a coil current of 20 amps. Neglect magnetic leakage and fringing of flux at the air gap.

1.9 The toroidal (circular cross section) core shown in Fig. P1.9 is made from cast steel.

(a) Calculate the coil current required to produce a core flux density of 1.2 tesla at the mean radius of the toroid.

(b) What is the core flux, in webers? Assume uniform flux density in the core.

(c) If a 2-mm-wide air gap is made in the toroid (across A–A'), determine the new coil current required to maintain a core flux density of 1.2 tesla.

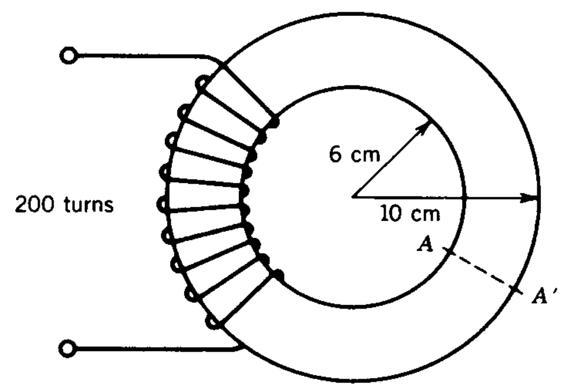

FIGURE P1.9

1.10 In the toroidal core coil system of Fig. P1.9 the coil current is 2.0 A and the relative permeability of the core is 2000. The core has a square cross section.

(a) Determine the maximum and minimum values of the flux density in the core.

(b) Determine the magnetic flux in the core.

(c) Determine the flux density at the mean radius of the toroid, and compare it with the average flux density across the core.

1.11 The magnetic circuit of Fig. P1.11 has a core of relative permeability μ_r = 2000. The depth of the core is 5 cm. The coil has 400 turns and carries a current of 1.5 A.

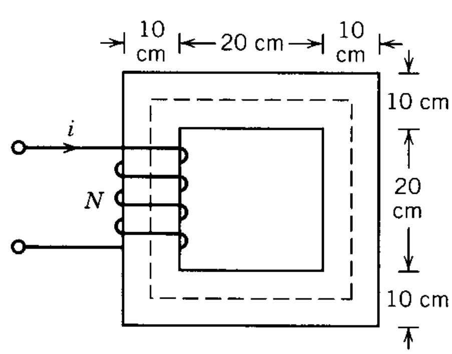

FIGURE P1.11

(a) Draw the magnetic equivalent circuit.

(b) Find the flux and the flux density in the core.

(c) Determine the inductance of the coil.

1.12 Repeat Problem 1.11 for a 1.0-cm-wide air gap in the core. Assume a 10% increase in the effective cross-sectional area of the air gap due to fringing in the air gap.

1.13 The magnetic circuit of Fig. 1.9 has the following parameters.

$N = 100$ turns

$A_c = A_g = 5\ \text{cm}^2$

$\mu_{core} =$ infinity

Determine the air gap length, l_g, to provide a coil inductance of 10 mH.

1.14 An inductor is made of two coils, A and B, having 350 and 150 turns, respectively. The coils are wound on a cast steel core and in directions as shown in Fig. P1.14. The two coils are connected *in series* to a dc voltage.

(a) Determine the two possible values of current required in the coils to establish a flux density of 0.5 T in the air gap.

(b) Determine the self-inductances L_A and L_B of the two coils. Neglect magnetic leakage and fringing.

(c) If coil B is now disconnected and the current in coil A is adjusted to 2.0 A, determine the mean flux density in the air gap.

1.15 The magnetic circuit for a saturable reactor is shown in Fig. P1.15. The *B–H* curve for the core material can be approximated as two straight lines as in Fig. P1.15.

(a) If $I_1 = 2.0$ A, calculate the value of I_2 required to produce a flux density of 0.6 T in the vertical limbs.

(b) If $I_1 = 0.5$ A and $I_2 = 1.96$ A, calculate the total flux in the core.

Neglect magnetic leakage.

(*Hint: Trial-and-error method.*)

1.16 A toroidal core has a rectangular cross section as shown in Fig. P1.16*a*. It is wound with a coil having 100 turns. The *B–H* characteristic of the core may be represented by the linearized magnetization curve of Fig. P1.16*b*.

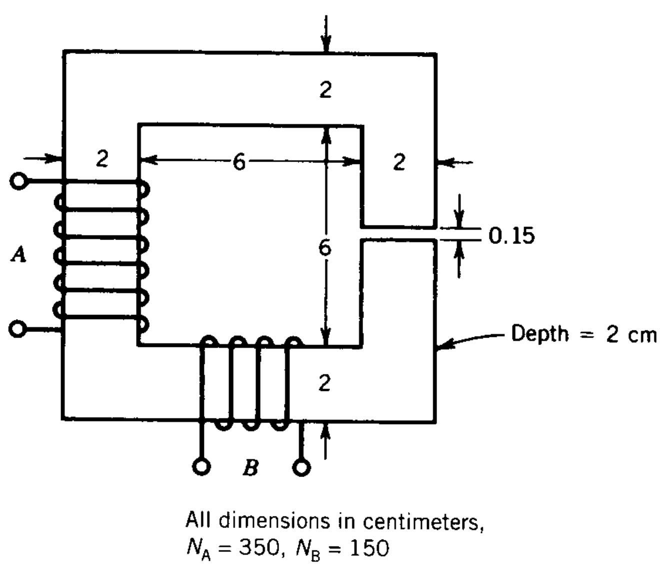

FIGURE P1.14

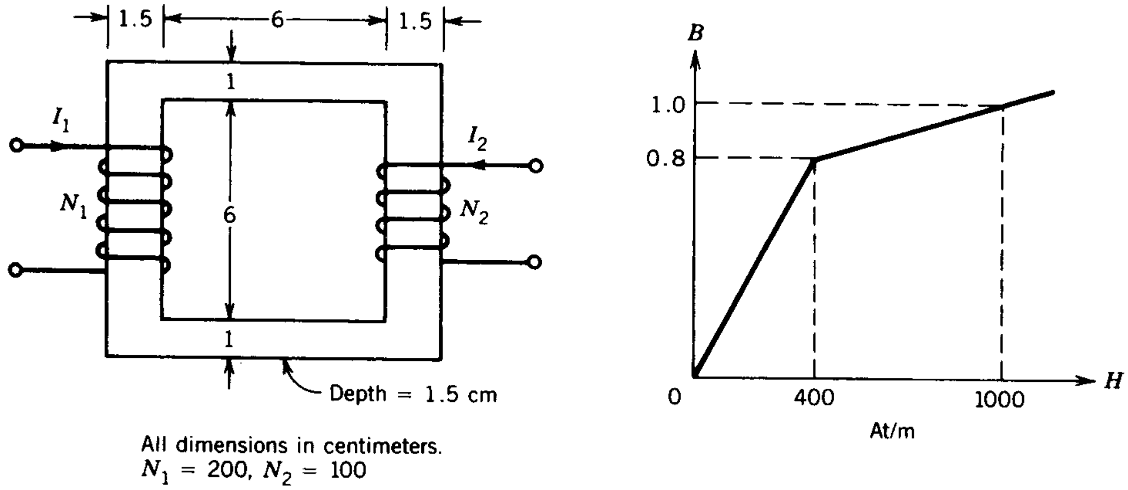

FIGURE P1.15

(a) Determine the inductance of the coil if the flux density in any part of the core is below 1.0 Wb/m^2.

(b) Determine the maximum value of the current for the condition of part (a).

(c) Determine the minimum value of the current for which the complete core has a flux density of 1.0 Wb/m^2 or greater.

1.17 A coil wound on a magnetic core is excited by the following voltage sources.

(a) 100 V, 50 Hz.

(b) 110 V, 60 Hz.

Compare the hysteresis losses and eddy current losses with these two different sources. For hysteresis loss consider $n = 2$.

1.18 A toroidal core of mean length 15 cm and cross-sectional area 10 cm^2 has a uniformly distributed winding of 300 turns. The B–H characteristic of the core can be assumed to be of rectangular form, as shown in Fig. P1.18. The coil is connected to a 100 V, 400 Hz supply. Determine the hysteresis loss in the core.

1.19 The core in Fig. 1.17 has the following dimensions: cross-sectional area A_c = 5 cm^2, mean magnetic path length l_c = 25 cm. The core material is silicon

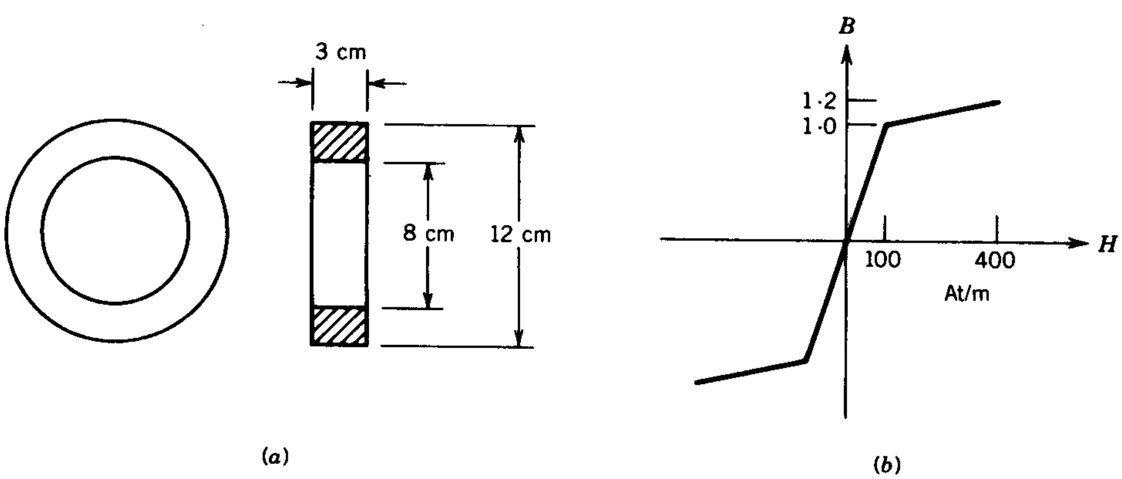

FIGURE P1.16

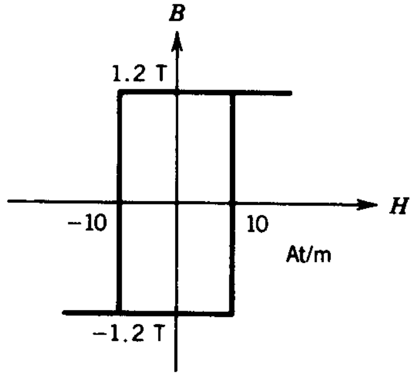

FIGURE P1.18

sheet steel. If the coil has 500 turns and negligible resistance, determine the rms value of the 60 Hz voltage applied to the coil that will produce a peak flux density of 1.2 T.

1.20 Figure P1.20 shows a two-winding transformer with a laminated core. The winding with $N_1 = 200$ turns is connected to a voltage to produce a flux density in the core $B = 1.2 \sin 377t$. The second winding, with $N_2 = 400$ turns, is left open-circuited. The stacking factor of the core is 0.95, i.e., the core occupies 95% of the gross core volume. The gross cross-sectional area of the core is 25 cm², and μ_r for the core is 10,000. The core length $l_c = 90$ cm.

(a) Determine the rms value of the applied voltage E_1.

(b) Determine the current in the winding.

(c) Determine the rms voltage E_r induced in the second winding.

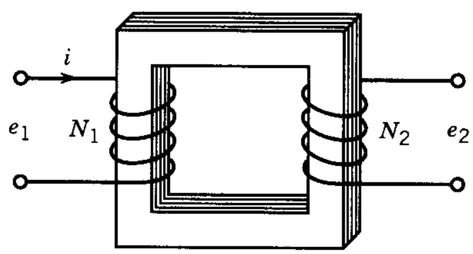

FIGURE P1.20

1.21 The flux in the core of the magnetic system of Fig. 1.17 varies with time as shown in Fig. P1.21. The coil has 400 turns. Sketch the waveform of the induced voltage, e, in the coil.

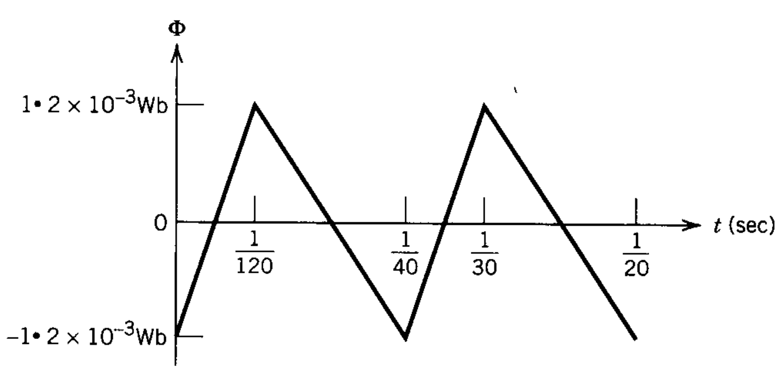

FIGURE P1.21

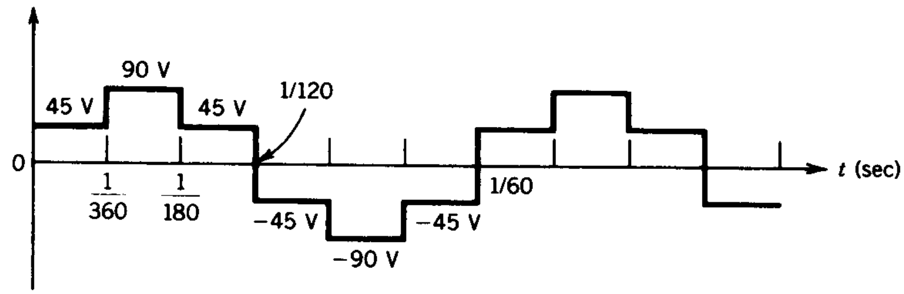

FIGURE P1.22

1.22 A six-step voltage of frequency 60 Hz, as shown in Fig. P1.22, is applied on a coil wound on a magnetic core. The coil has 500 turns. Find the maximum value of the flux and sketch the waveforms of voltage and flux as a function of time.

1.23 In the circuit of Fig. P1.23*a* a resistanceless toroidal winding of 1000 turns is wound on a ferromagnetic toroid of cross-sectional area 2 cm². The core is characterized by the ideal *B–H* relation shown in Fig. P1.23*b*. This circuit is excited by a 60 Hz square wave of input voltage (v_i) of amplitude 108 volts, as shown in Fig. P1.23*c*. Determine the switching instant and sketch the waveforms of the voltages v_L and v_o.

1.24 Suppose that the soft iron keeper in the permanent magnet of Example 1.8 is reinserted. Determine the flux density in the magnet if the recoil permeability (μ_{rec}) of the magnetic material is $4\mu_0$.

1.25 Repeat Example 1.8 if the permanent magnet material is samarium–cobalt. The demagnetization curve is given in Fig. 1.24.

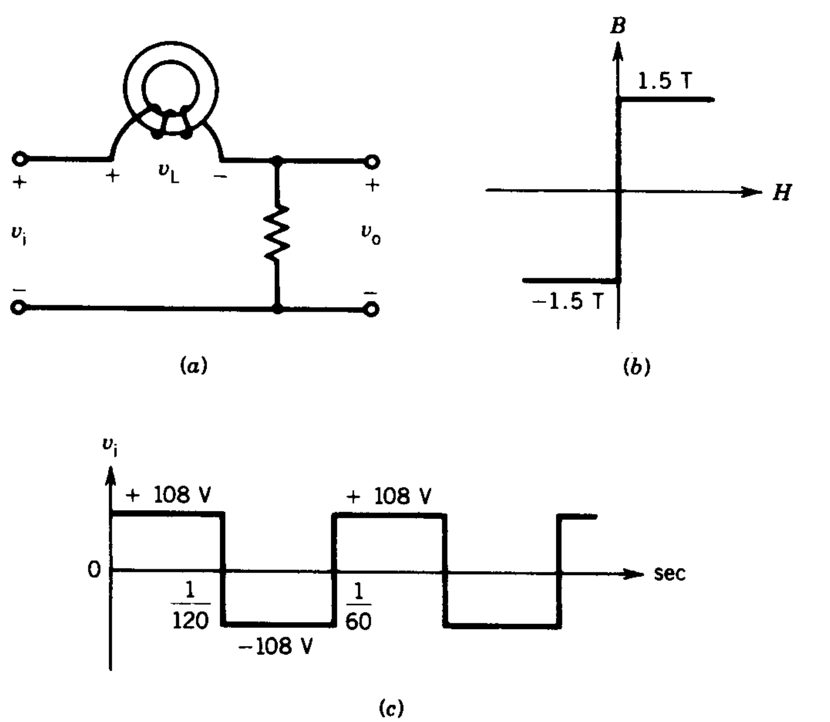

FIGURE P1.23

(a) Determine the point of maximum energy product and the corresponding values of B_m and H_m.

(b) Determine the dimensions (l_m and A_m) of the permanent magnet.

(c) Determine the reduction of the magnetic volume required to produce the same flux density in the air gap.

1.26 Repeat Problem 1.25 if the permanent magnet material is neodymium–iron–boron, whose demagnetization curve is given in Fig. 1.24.