The coil has 150 turns, its length is 30 cm, and its diameter is 2.5 cm. A current \( I = 30 \) A is supplied to the coil. Neglect the magnetic field outside the coil.

a. Determine the magnetic field intensity \( H \) and the magnetic flux density \( B \) inside the solenoid.

b. Determine the inductance of the coil.

4.3 A toroid has a circular cross section as shown in Fig. 4.31. It is made from cast iron with a relative permeability of 2500. Its outer diameter is 24 cm, and its inner diameter is 16 cm. The magnetic flux density in the core is 1.25 tesla measured at the mean diameter of the toroid.

![Figure 4.31](image)

**FIGURE 4.31** Magnetic circuit of Problem 4.2.

a. Find the current that must be supplied to the coil, which consists of 250 turns.

b. Determine the magnetic flux in the core.

c. A 10-mm air gap is cut across the toroid. Determine the current that must be supplied to the coil to produce the same value of magnetic flux density as in part (a).

4.3 A ferromagnetic circuit has a magnetic core with infinitely high relative permeability. It has three legs, and air gaps of 2 mm and 1 mm are cut from sections A and C, respectively, as shown in Fig. 4.32. A coil is wound on the center leg B, and it has 200 turns and a resistance of 2.5 \( \Omega \). The magnetic core has a 5 \( \times \) 5 cm uniform cross-sectional area. A DC voltage is applied to the coil.

![Figure 4.32](image)

**FIGURE 4.32** Magnetic circuit of Problem 4.3.

a. Determine the voltage that will produce a flux density of 0.75 T in the right leg C, which contains the 1-mm air gap.

b. Find the magnetic flux in the other two legs of the core.

4.4 Repeat Problem 4.3 if the coil is removed from the center leg B and placed on the right leg C, which contains the 1-mm air gap.
4.5 The electromagnetic system shown in Fig. 4.33 has a magnetic core of infinite relative permeability. Neglect fringing and leakage flux. Determine the expressions for:

a. The magnetic flux in each of the three legs
b. The flux linkage and self-inductance of each coil
c. The mutual inductance

![Figure 4.33 Magnetic circuit of Problem 4.5.](image)

4.6 For the electromagnetic system of Fig. 4.33, the polarity of the voltage source $V_1$ is reversed so that the current $I_1$ flows in the opposite direction. The magnetic core has infinite relative permeability. Determine the expressions for:

a. The magnetic flux in each of the three legs
b. The flux linkage of each coil
c. The self-inductance of each coil
d. The mutual inductance

4.7 The magnetic circuit shown in Fig. 4.34 has an infinitely permeable magnetic core. The following are given:

\[
\begin{align*}
g_1 &= 5 \text{ mm} & A_1 &= 5 \text{ cm}^2 & N_1 &= 80 \text{ turns} \\
g_2 &= 5 \text{ mm} & A_2 &= 5 \text{ cm}^2 & N_2 &= 100 \text{ turns} \\
g_3 &= 10 \text{ mm} & A_3 &= 10 \text{ cm}^2 & N_3 &= 125 \text{ turns}
\end{align*}
\]

![Figure 4.34 Magnetic circuit of Problem 4.7.](image)

A current of 12 A flows in the first coil, $N_1$. The second and third coils, $N_2$ and $N_3$, respectively, are unexcited. Determine the flux densities in each of the air gaps $g_1$, $g_2$, and $g_3$.

4.8 In the electromagnetic circuit of Fig. 4.34, the three coils are excited simultaneously such that $I_1 = 12 \text{ A}$, $I_2 = 10 \text{ A}$, and $I_3 = 8 \text{ A}$, with the directions of currents as shown. Determine the magnetic flux densities in the three air gaps.

4.9 In the electromagnetic circuit of Fig. 4.34, assume that there is no air gap in the center leg containing coil $N_3$, and only the first coil, $N_1$, carries a current of 12 A. Determine the flux densities in the air gaps $g_1$ and $g_2$.

b. Suppose that the length of air gap $g_2$ is also reduced to zero; that is, there is also no air gap in the leg containing coil $N_2$. Determine the flux density in the first air gap $g_1$.

4.10 Refer to the electromagnetic system described in Problem 4.7 and shown in Fig. 4.34. Determine the self- and mutual inducances of the three coils.

4.11 The magnetic circuit shown in Fig. 4.35 has an iron core with infinite permeability. The core dimensions are:

\[
A_c = 16 \text{ cm}^2 \quad g = 2 \text{ mm} \quad l_c = 80 \text{ cm}
\]

![Figure 4.35 Magnetic circuit of Problem 4.11.](image)

The coil has 500 turns and draws a current $I = 4 \text{ A}$ from the source. Neglect magnetic leakage and fringing. Calculate:

a. The total magnetic flux
b. The flux linkages of the coil
c. The coil inductance

4.12 Repeat Problem 4.11 assuming that the core has a relative permeability of $\mu = 2000$.

4.13 A toroidal magnetic circuit consists of a coil of $N = 200$ turns each of circular cross section of radius $\rho = 0.25 \text{ m}$, as shown in Fig. 4.36. The radius of the toroid is $R = 5 \text{ m}$, as measured to the center of each circular turn. Assume that the magnetic field intensity is zero outside the toroid and the magnetic field intensity inside the toroid is given by

\[
H = \frac{NI}{2\pi R}
\]