1–7. How does the relative permeability of a ferromagnetic material vary with magnetomotive force?

1–8. What is hysteresis? Explain hysteresis in terms of magnetic domain theory.

1–9. What are eddy current losses? What can be done to minimize eddy current losses in a core?

1–10. Why are all cores exposed to ac flux variations laminated?

1–11. What is Faraday's law?

1–12. What conditions are necessary for a magnetic field to produce a force on a wire?

1–13. What conditions are necessary for a magnetic field to produce a voltage in a wire?

1–14. Why is the linear machine a good example of the behavior observed in real dc machines?

1–15. The linear machine in Figure 1–19 is running at steady state. What would happen to the bar if the voltage in the battery were increased? Explain in detail.

1–16. Just how does a decrease in flux produce an increase in speed in a linear machine?

1–17. Will current be leading or lagging voltage in an inductive load? Will the reactive power of the load be positive or negative?

1–18. What are real, reactive, and apparent power? What units are they measured in? How are they related?

1–19. What is power factor?

PROBLEMS

1–1. A motor's shaft is spinning at a speed of 1800 r/min. What is the shaft speed in radians per second?

1–2. A flywheel with a moment of inertia of 4 kg • m^2 is initially at rest. If a torque of 6 N • m (counterclockwise) is suddenly applied to the flywheel, what will be the speed of the flywheel after 5 s? Express that speed in both radians per second and revolutions per minute.

1–3. A force of 10 N is applied to a cylinder of radius $r = 0.15$ m, as shown in Figure P1–1. The moment of inertia of this cylinder is $J = 4$ kg • m^2. What are the magnitude and direction of the torque produced on the cylinder? What is the angular acceleration α of the cylinder?

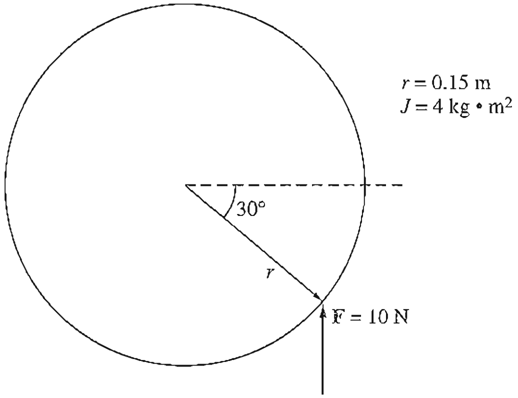

FIGURE P1–1
The cylinder of Problem 1–3.

1–4. A motor is supplying 50 N • m of torque to its load. If the motor s shaft is turning at 1500 r/min, what is the mechanical power supplied to the load in watts? In horsepower?

1–5. A ferromagnetic core is shown in Figure P1–2. The depth of the core is 5 cm. The other dimensions of the core are as shown in the figure. Find the value of the current that will produce a flux of 0.005 Wb. With this current, what is the flux density at the top of the core? What is the flux density at the right side of the core? Assume that the relative permeability of the core is 800.

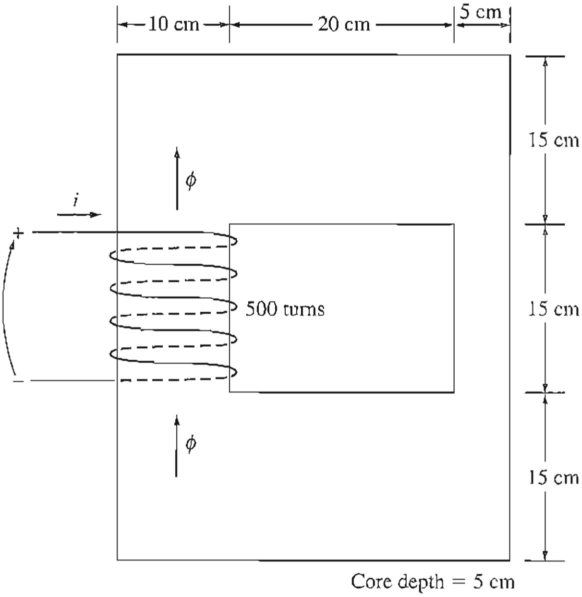

FIGURE P1–2
The core of Problems 1–5 and 1–16.

1–6. A ferromagnetic core with a relative permeability of 1500 is shown in Figure P1–3. The dimensions are as shown in the diagram, and the depth of the core is 5 cm. The air gaps on the left and right sides of the core are 0.050 and 0.070 cm, respectively. Because of fringing effects, the effective area of the air gaps is 5 percent larger than their physical size. If there are 300 turns in the coil wrapped around the center leg of the core and if the current in the coil is 1.0 A, what are the flux values for the left, center, and right legs of the core? What is the flux density in each air gap?

1–7. A two-legged core is shown in Figure P1–4. The winding on the left leg of the core (N_1) has 600 turns, and the winding on the right (N_2) has 200 turns. The coils are wound in the directions shown in the figure. If the dimensions are as shown, then what flux would be produced by currents $i_1 = 0.5$ A and $i_2 = 1.00$ A? Assume $\mu_r = 1200$ and constant.

1–8. A core with three legs is shown in Figure P1–5. Its depth is 5 cm, and there are 100 turns on the leftmost leg. The relative permeability of the core can be assumed to be 2000 and constant. What flux exists in each of the three legs of the core? What is the flux density in each of the legs? Assume a 5 percent increase in the effective area of the air gap due to fringing effects.

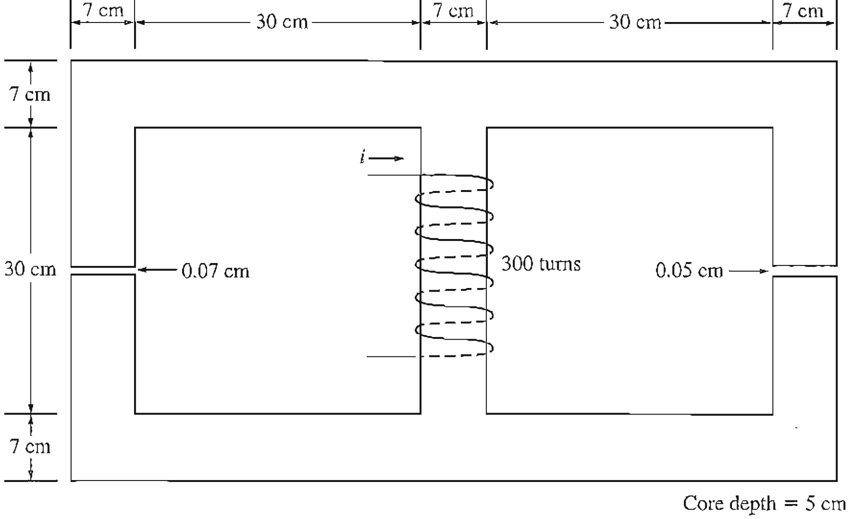

FIGURE P1–3
The core of Problem 1–6.

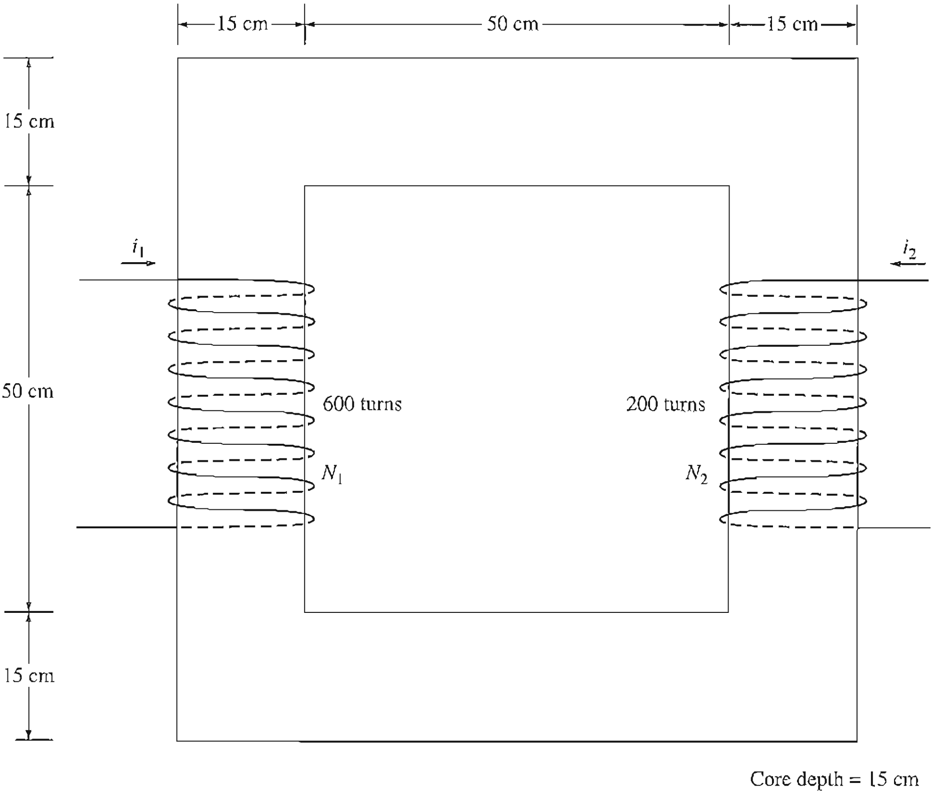

FIGURE P1–4
The core of Problems 1–7 and 1–12.

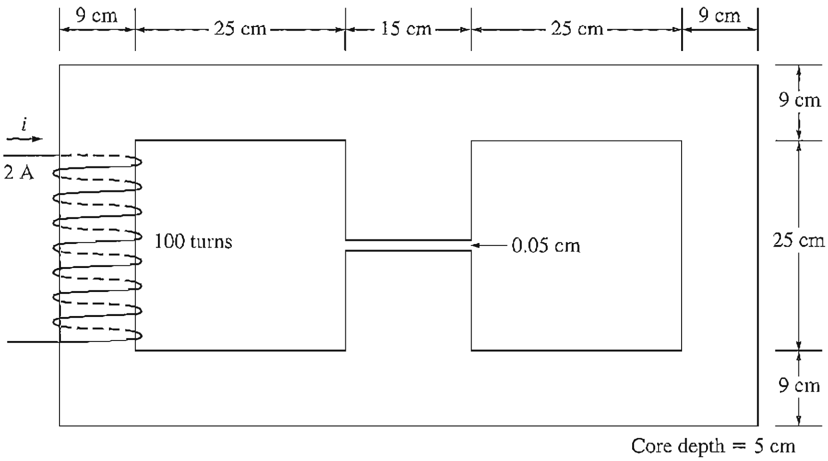

FIGURE P1-5
The core of Problem 1-8.

1-9. A wire is shown in Figure P1-6 that is carrying 2.0 A in the presence of a magnetic field. Calculate the magnitude and direction of the force induced on the wire.

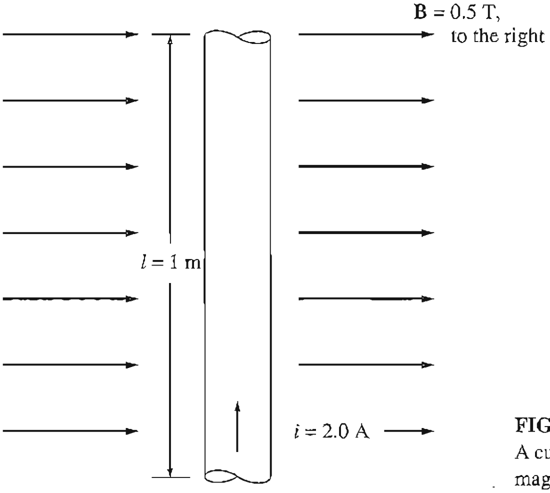

FIGURE P1-6
A current-carrying wire in a magnetic field (Problem 1-9).

1-10. A wire is shown in Figure P1-7 that is moving in the presence of a magnetic field. With the information given in the figure, determine the magnitude and direction of the induced voltage in the wire.

1-11. Repeat Problem 1-10 for the wire in Figure P1-8.

1-12. The core shown in Figure P1-4 is made of a steel whose magnetization curve is shown in Figure P1-9. Repeat Problem 1-7, but this time do *not* assume a constant value of μ_r. How much flux is produced in the core by the currents specified? What is the relative permeability of this core under these conditions? Was the assumption

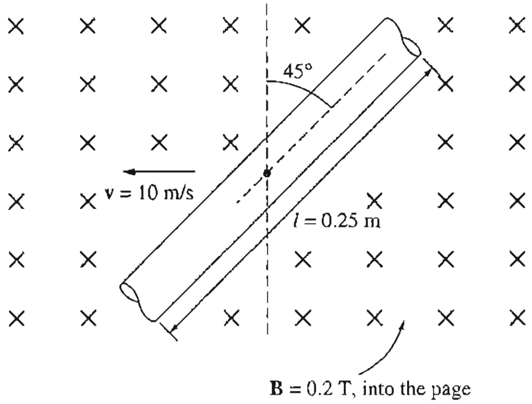

FIGURE P1–7
A wire moving in a magnetic field (Problem 1–10).

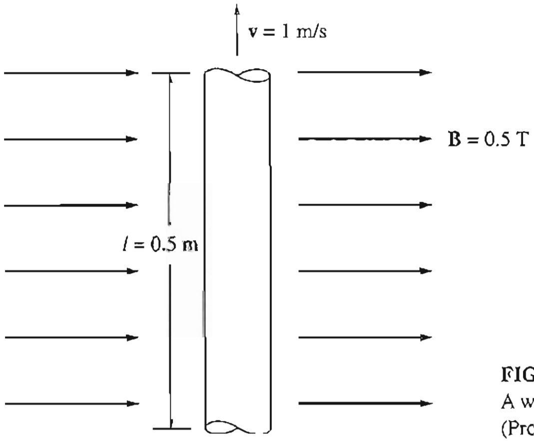

FIGURE P1–8
A wire moving in a magnetic field (Problem 1–11).

in Problem 1–7 that the relative permeability was equal to 1200 a good assumption for these conditions? Is it a good assumption in general?

1–13. A core with three legs is shown in Figure P1–10. Its depth is 5 cm, and there are 400 turns on the center leg. The remaining dimensions are shown in the figure. The core is composed of a steel having the magnetization curve shown in Figure 1–10*c*. Answer the following questions about this core:

(*a*) What current is required to produce a flux density of 0.5 T in the central leg of the core?

(*b*) What current is required to produce a flux density of 1.0 T in the central leg of the core? Is it twice the current in part (*a*)?

(*c*) What are the reluctances of the central and right legs of the core under the conditions in part (*a*)?

(*d*) What are the reluctances of the central and right legs of the core under the conditions in part (*b*)?

(*e*) What conclusion can you make about reluctances in real magnetic cores?

1–14. A two-legged magnetic core with an air gap is shown in Figure P1–11. The depth of the core is 5 cm, the length of the air gap in the core is 0.05 cm, and the number of turns on the coil is 1000. The magnetization curve of the core material is shown in

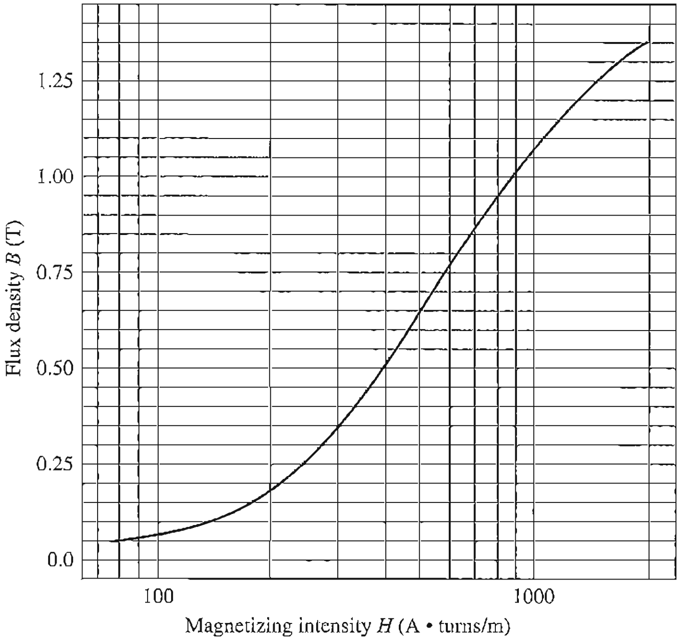

FIGURE P1–9
The magnetization curve for the core material of Problems 1–12 and 1–14.

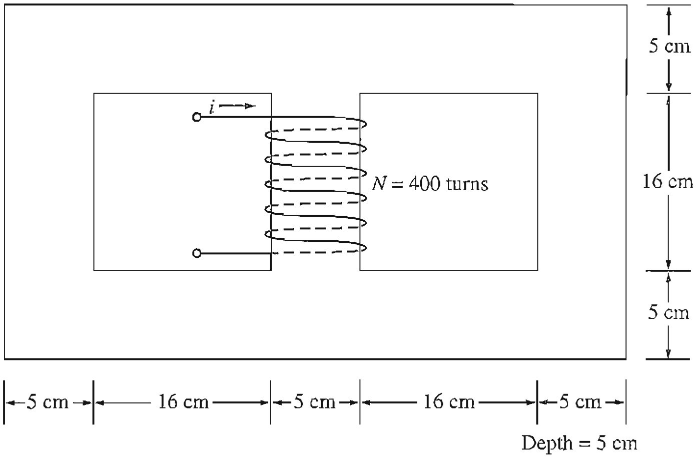

FIGURE P1–10
The core of Problem 1–13.

Figure P1–9. Assume a 5 percent increase in effective air-gap area to account for fringing. How much current is required to produce an air-gap flux density of 0.5 T? What are the flux densities of the four sides of the core at that current? What is the total flux present in the air gap?

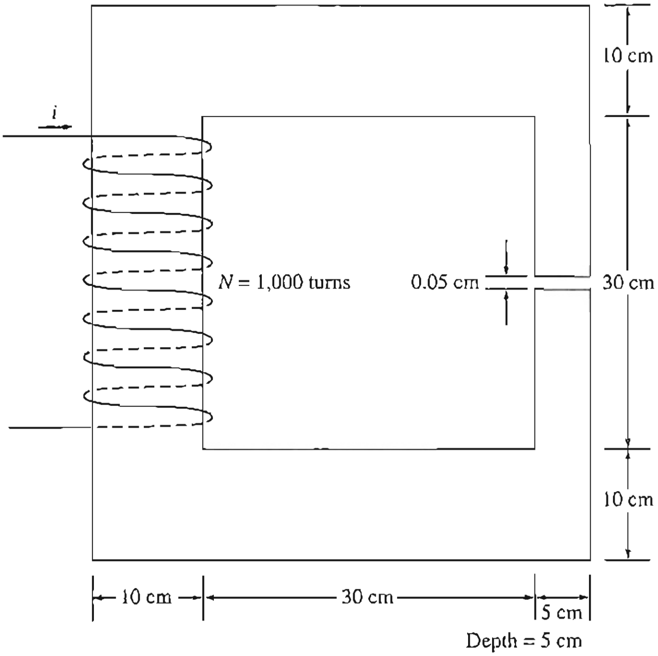

FIGURE P1–11
The core of Problem 1–14.

1–15. A transformer core with an effective mean path length of 6 in has a 200-turn coil wrapped around one leg. Its cross-sectional area is 0.25 in^2, and its magnetization curve is shown in Figure 1–10*c*. If current of 0.3 A is flowing in the coil, what is the total flux in the core? What is the flux density?

1–16. The core shown in Figure P1–2 has the flux ϕ shown in Figure P1–12. Sketch the voltage present at the terminals of the coil.

1–17. Figure P1–13 shows the core of a simple dc motor. The magnetization curve for the metal in this core is given by Figure 1–10*c* and *d*. Assume that the cross-sectional area of each air gap is 18 cm^2 and that the width of each air gap is 0.05 cm. The effective diameter of the rotor core is 5 cm.

(a) We wish to build a machine with as great a flux density as possible while avoiding excessive saturation in the core. What would be a reasonable maximum flux density for this core?

(b) What would be the total flux in the core at the flux density of part *(a)*?

(c) The maximum possible field current for this machine is 1 A. Select a reasonable number of turns of wire to provide the desired flux density while not exceeding the maximum available current.

1–18. Assume that the voltage applied to a load is $\mathbf{V} = 208\angle -30^\circ$ V and the current flowing through the load is $\mathbf{I} = 2\angle 20^\circ$ A.

(a) Calculate the complex power **S** consumed by this load.

(b) Is this load inductive or capacitive?

(c) Calculate the power factor of this load.

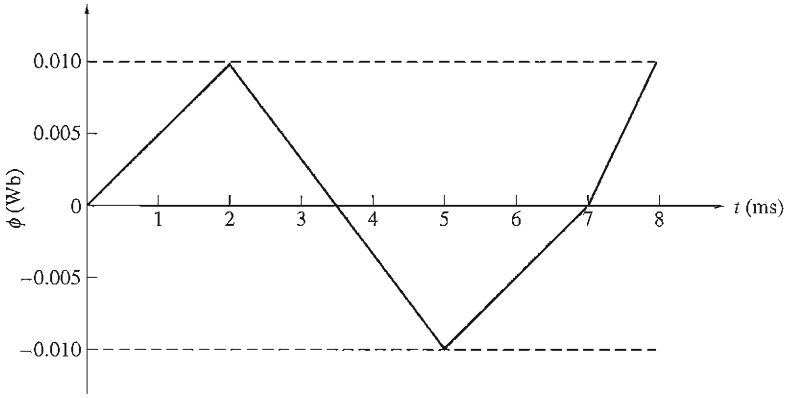

FIGURE P1–12
Plot of flux ϕ as a function of time for Problem 1–16.

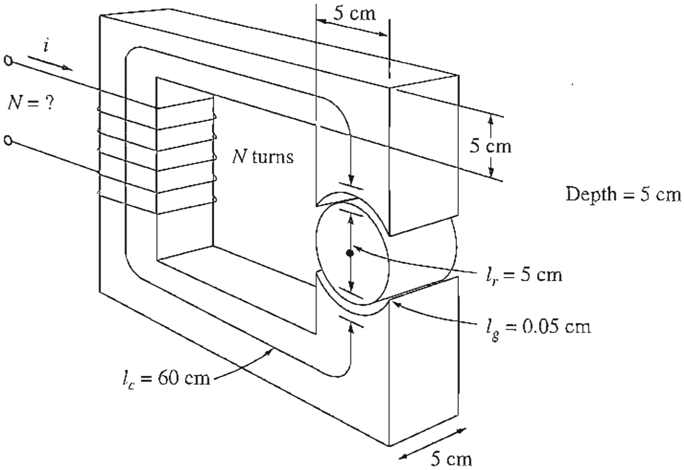

FIGURE P1–13
The core of Problem 1–17.

1–19. Figure P1–14 shows a simple single-phase ac power system with three loads. The voltage source is $\mathbf{V} = 240\angle 0^\circ$ V, and the impedances of these three loads are

$$Z_1 = 10\angle 30^\circ\ \Omega \qquad Z_2 = 10\angle 45^\circ\ \Omega \qquad Z_3 = 10\angle -90^\circ\ \Omega$$

Answer the following questions about this power system.

(*a*) Assume that the switch shown in the figure is initially open, and calculate the current **I**, the power factor, and the real, reactive, and apparent power being supplied by the source.

(*b*) How much real, reactive, and apparent power is being consumed by each load with the switch open?

(c) Assume that the switch shown in the figure is now closed, and calculate the current **I**, the power factor, and the real, reactive, and apparent power being supplied by the source.

(d) How much real, reactive, and apparent power is being consumed by each load with the switch closed?

(e) What happened to the current flowing from the source when the switch closed? Why?

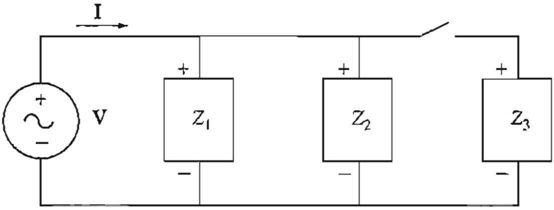

FIGURE P1–14
The circuit of Problem 1–19.

1–20. Demonstrate that Equation (1–59) can be derived from Equation (1–58) using simple trigonometric identities.

$$p(t) = v(t)i(t) = 2VI\cos\omega t\cos(\omega t - \theta) \qquad (1\text{–}58)$$

$$p(t) = VI\cos\theta\,(1 + \cos 2\omega t) + VI\sin\theta\sin 2\omega t \qquad (1\text{–}59)$$

Hint: The following identities will be useful:

$$\cos\alpha\cos\beta = \frac{1}{2}[\cos(\alpha - \beta) + \cos(\alpha + \beta)]$$

$$\cos(\alpha - \beta) = \cos\alpha\cos\beta + \sin\alpha\sin\beta$$

1–21. A linear machine shown in Figure P1–15 has a magnetic flux density of 0.5 T directed into the page, a resistance of 0.25 Ω, a bar length l = 1.0 m, and a battery voltage of 100 V.

(a) What is the initial force on the bar at starting? What is the initial current flow?

(b) What is the no-load steady-state speed of the bar?

(c) If the bar is loaded with a force of 25 N opposite to the direction of motion, what is the new steady-state speed? What is the efficiency of the machine under these circumstances?

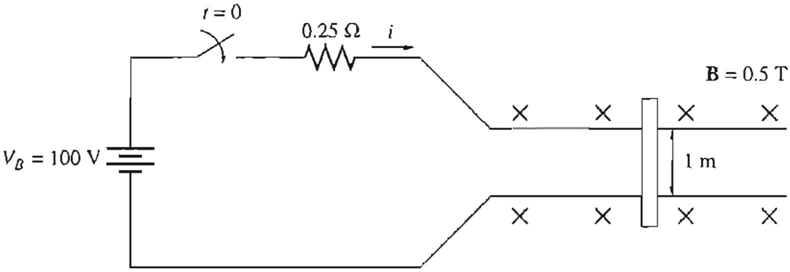

FIGURE P1–15
The linear machine in Problem 1–21.

1–22. A linear machine has the following characteristics:

$$\mathbf{B} = 0.5 \text{ T into page} \qquad R = 0.25\ \Omega$$
$$l = 0.5 \text{ m} \qquad V_B = 120 \text{ V}$$

(a) If this bar has a load of 20 N attached to it opposite to the direction of motion, what is the steady-state speed of the bar?

(b) If the bar runs off into a region where the flux density falls to 0.45 T, what happens to the bar? What is its final steady-state speed?

(c) Suppose V_B is now decreased to 100 V with everything else remaining as in part *(b)*. What is the new steady-state speed of the bar?

(d) From the results for parts *(b)* and *(c)*, what are two methods of controlling the speed of a linear machine (or a real dc motor)?

1–23. For the linear machine of Problem 1–22:

(a) When this machine is operating as a motor, calculate the speed of the bar for loads of 0 N to 30 N in 5 N steps. Plot the speed of the bar as a function of load.

(b) Assume that the motor is operation with a 30 N load, and calculate and plot the speed of the bar for magnetic flux densities of 0.3 T to 0.5 T in 0.05 T steps.

(c) Assume that the motor is running at no-load conditions with a flux density of 0.5 T. What is the speed of the bar? Now apply a 30 N load to the bar. What is the new speed of the bar? *What flux density would be required* to restore the loaded bar to the same speed that it had under no-load conditions?

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