P16.7, P16.8, P16.17, P16.20, P16.23, P16.30, P16.31

P16.7. A three-phase induction motor is rated at 5 hp, 1760 rpm, with a line-to-line voltage of 220 V rms. The motor has a power factor of 80 percent lagging and an efficiency of 75 percent under full-load conditions. Find the electrical input power absorbed by the motor under full-load conditions. Also, find the rms line current.

P16.7 The input power is the output power divided by the efficiency.

$$P_{in} = \frac{P_{out}}{\eta} = \frac{5 \times 746}{0.75} = 4073 \text{ W}$$

Solving Equation 16.1 for the line current, we have

$$I_{rms} = \frac{P_{in}}{\sqrt{3}V_{rms}\cos\theta} = \frac{4973}{\sqrt{3} \times 220 \times 0.8} = 16.3 \text{ A}$$

***P16.8.** The no-load speed of the motor in Problem P16.7 is 1800 rpm. Determine the percentage speed regulation.

P16.8* speed regulation $= \dfrac{n_{\text{no-load}} - n_{\text{full-load}}}{n_{\text{full-load}}} \times 100\%$

$$= \frac{1800 - 1760}{1760} = 100\%$$

$$= 2.27\%$$

***P16.17.** A 440-V-rms (line-to-line voltage) three-phase induction motor runs at 1150 rpm driving a load requiring 15 Nm of torque. The line current is 3.4 A rms at a power factor of 80 percent lagging. Find the output power, the power loss, and the efficiency.

P16.17* $\omega_m = n_m \times \frac{2\pi}{60} = 1150 \times \frac{2\pi}{60} = 120.4$ radian/s

$$P_{out} = T_{out}\omega_m = 15 \times 120.4 = 1806 \text{ W}$$
$$P_{out} = 2.42 \text{ hp}$$

$$\begin{aligned} P_{in} &= \sqrt{3} V_{rms} I_{rms} \cos\theta \\ &= \sqrt{3} \times 440 \times 3.4 \times 0.8 \\ &= 2073 \text{ W} \end{aligned}$$

$$\begin{aligned} P_{loss} &= P_{in} - P_{out} \\ &= 267 \text{ W} \end{aligned}$$

$$\begin{aligned} \eta &= \frac{P_{out}}{P_{in}} \times 100\% \\ &= 87.1\% \end{aligned}$$

***P16.20.** Consider the linear dc machine shown in Figure 16.6 on page 772 with no load force applied. What happens to the steady-state velocity of the bar if **a.** the source voltage V_T is doubled in magnitude; **b.** the resistance R_A is doubled; **c.** the magnetic flux density B is doubled in magnitude?

P16.20* In steady-state with no load, we have $V_T = e_A = B\ell u$ and the current i_A is zero.

(a) If V_T is doubled, the steady-state no-load speed is doubled.

(b) If the resistance is doubled, the steady-state no-load speed is not changed. (However, it will take longer for the motor to achieve this speed.)

(c) If B is doubled, the steady-state no-load speed is halved.

***P16.23.** Consider the linear dc machine of Figure P16.23. When the switch closes, is the force on the bar toward the top of the page or toward the bottom? Determine the magnitude of the initial (starting) force. Also, determine the final velocity of the bar neglecting friction.

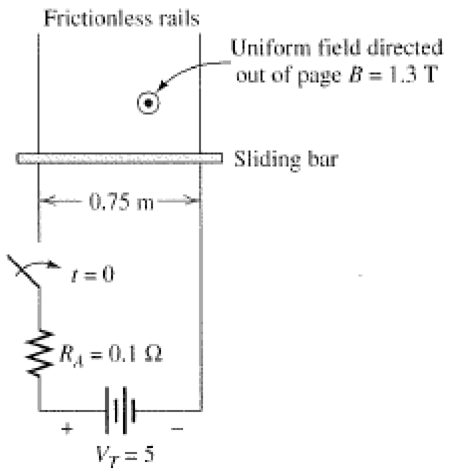

Figure P16.23

P16.23* When the switch is closed, current flows toward the right through the sliding bar. The force on the bar is given by:

$$\mathbf{f} = i_A \mathbf{l} \times \mathbf{B}$$

Thus, the force is directed toward the bottom of the page. The starting current and starting force are:

$$i_{A,\,starting} = V_T / R_A = 5/0.1 = 50\ A$$

$$f_{starting} = i_A B\ell = 50 \times 0.75 \times 1.3 = 48.75\ \mathrm{N}$$

Under no-load conditions in steady state, we have

$$i_A = 0$$

$$V_T = e_A = B\ell u$$

Thus, the steady-state speed is

$$u = \frac{V_T}{B\ell} = \frac{5}{1.3 \times 0.75}$$

$$= 5.13\ \mathrm{m/s}$$

***P16.30.** A certain dc motor has $R_A = 1.3\ \Omega$, $I_A = 10$ A, and produces a back emf $E_A = 240$ V, while operating at a speed of 1200 rpm. Determine the voltage applied to the armature, the developed torque, and the developed power.

P16.30* Converting the speed of 1200 rpm to angular velocity, we have

$$\omega_m = n_m \times \frac{2\pi}{60} = 1200 \times \frac{2\pi}{60} = 40\pi$$

Solving Equation 16.15 for the machine constant $K\varphi$ and substituting values, we have

$$K\varphi = \frac{E_A}{\omega_m} = \frac{240}{40\pi} = \frac{6}{\pi}$$

Then we use Equation 16.16 to compute the torque

$$T_{\text{dev}} = K\varphi I_A = \frac{6}{\pi} \times 10 = 19.10 \text{ Nm}$$

$$P_{\text{dev}} = \omega_m T_{\text{dev}} = 2400 \text{ W}$$

The voltage applied to the armature circuit is

$$\begin{aligned} V_T &= R_A I_A + E_A \\ &= 1.3 \times 10 + 240 \\ &= 253 \text{ V} \end{aligned}$$

P16.31. A certain motor has an induced armature voltage of 200 V at $n_{m1} = 1200$ rpm. Suppose that this motor is operating at a speed of $n_{m2} = 1500$ rpm with a developed power of 5 hp. Find the armature current and the developed torque.

P16.31

$$\omega_{m1} = n_{m1} \times \frac{2\pi}{60} = 1200 \times \frac{2\pi}{60} = 40\pi$$

$$\omega_{m2} = n_{m2} \times \frac{2\pi}{60} = 1500 \times \frac{2\pi}{60} = 50\pi$$

$$K\varphi = \frac{E_A}{\omega_{m1}} = \frac{200}{40\pi} = \frac{5}{\pi} = 1.592$$

$$T_{\text{dev}} = \frac{P_{\text{dev}}}{\omega_{m2}} = \frac{5 \times 746}{50\pi} = 23.75 \text{ Nm}$$

$$I_A = \frac{T_{\text{dev}}}{K\varphi} = \frac{23.75}{1.592} = 14.92 \text{ A}$$