Problem 9. A separately-excited generator develops a no-load e.m.f. of 150 V at an armature speed of 20 rev/s and a flux per pole of 0.10 Wb. Determine the generated e.m.f. when (a) the speed increases to 25 rev/s and the pole flux remains unchanged, (b) the speed remains at 20 rev/s and the pole flux is decreased to 0.08 Wb, and (c) the speed increases to 24 rev/s and the pole flux is decreased to 0.07 Wb.

(a) From Section 22.5, generated e.m.f. $E \propto \Phi n$

$$\text{from which, } \frac{E_1}{E_2} = \frac{\Phi_1 N_1}{\Phi_2 N_2}$$

$$\text{Hence } \frac{150}{E_2} = \frac{(0.10)(20)}{(0.1)(25)}$$

$$\text{from which, } E_2 = \frac{(150)(0.10)(25)}{(0.10)(20)}$$

$$= \mathbf{187.5\ volts}$$

(b) $$\frac{150}{E_3} = \frac{(0.10)(20)}{(0.08)(20)}$$

$$\text{from which, e.m.f., } \boldsymbol{E_3} = \frac{(150)(0.08)(20)}{(0.10)(20)}$$

$$= \mathbf{120\ volts}$$

(c) $$\frac{150}{E_4} = \frac{(0.10)(20)}{(0.07)(24)}$$

$$\text{from which, e.m.f., } \boldsymbol{E_4} = \frac{(150)(0.07)(24)}{(0.10)(20)}$$

$$= \mathbf{126\ volts}$$

Problem 10. A shunt generator supplies a 20 kW load at 200 V through cables of resistance, $R = 100\,\text{m}\Omega$. If the field winding resistance, $R_f = 50\,\Omega$ and the armature resistance, $R_a = 40\,\text{m}\Omega$, determine (a) the terminal voltage, and (b) the e.m.f. generated in the armature.

(a) The circuit is as shown in Fig. 22.8

Load current, $I = \dfrac{20\,000 \text{ watts}}{200 \text{ volts}} = 100\,\text{A}$

Volt drop in the cables to the load $= IR = (100)(100 \times 10^{-3}) = 10\,\text{V}$. Hence **terminal voltage,** $V = 200 + 10 =$ **210 volts.**

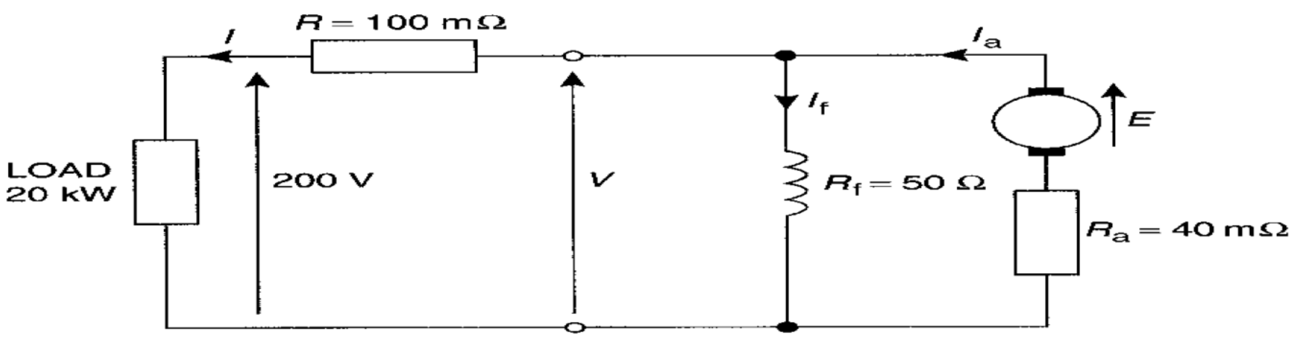

Figure 22.8

(b) Armature current $I_a = I_f + I$

Field current, $I_f = \dfrac{V}{R_f} = \dfrac{210}{50} = 4.2\,\text{A}$

Hence $I_a = I_f + I = 4.2 + 100 = 104.2\,\text{A}$

Generated e.m.f. $E = V + I_a R_a$

$= 210 + (104.2)(40 \times 10^{-3})$

$= 210 + 4.168$

$=$ **214.17 volts**

Problem 11. A short-shunt compound generator supplies 80 A at 200 V. If the field resistance, $R_f = 40\,\Omega$, the series resistance, $R_{Se} = 0.02\,\Omega$ and the armature resistance, $R_a = 0.04\,\Omega$, determine the e.m.f. generated.

The circuit is shown in Fig. 22.13.

Volt drop in series winding $= IR_{Se} = (80)(0.02) = 1.6\,\text{V}$.

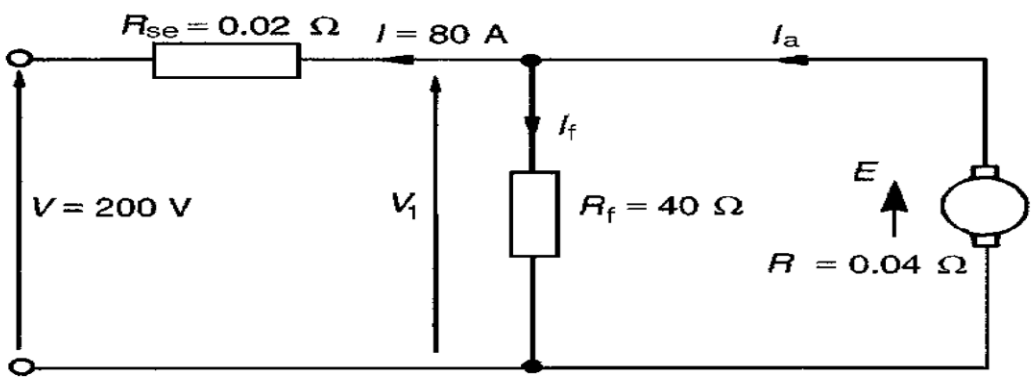

Figure 22.13

P.d. across the field winding = p.d. across armature $= V_1 = 200 + 1.6 = 201.6\,\text{V}$

$$\text{Field current } I_f = \frac{V_1}{R_f} = \frac{201.6}{40} = 5.04\,\text{A}$$

Armature current, $I_a = I + I_f = 80 + 5.04 = 85.04\,\text{A}$

$$\textbf{Generated e.m.f., } E = V_1 + I_a R_a$$
$$= 201.6 + (85.04)(0.04)$$
$$= 201.6 + 3.4016$$
$$= \textbf{205 volts}$$

Problem 12. A 10 kW shunt generator having an armature circuit resistance of 0.75 Ω and a field resistance of 125 Ω, generates a terminal voltage of 250 V at full load. Determine the efficiency of the generator at full load, assuming the iron, friction and windage losses amount to 600 W.

Output power = 10 000 W = VI from which, load current $I = 10\,000/V = 10\,000/250 = 40$ A. Field current, $I_f = V/R_f = 250/125 = 2$ A. Armature current, $I_a = I_f + I = 2 + 40 = 42$ A

$$\text{Efficiency, } \eta = \left(\frac{VI}{VI + I_a^2 R + I_f V + C}\right) \times 100\%$$

$$= \left(\frac{10\,000}{10\,000 + (42)^2(0.75) + (2)(250) + 600}\right) \times 100\%$$

$$= \left(\frac{10\,000}{12\,423}\right) \times 100\%$$

$$= \mathbf{80.50\%}$$

Problem 17. A six-pole lap-wound motor is connected to a 250 V d.c. supply. The armature has 500 conductors and a resistance of 1 Ω. The flux per pole is 20 mWb. Calculate (a) the speed and (b) the torque developed when the armature current is 40 A.

$V = 250$ V, $Z = 500$, $R_a = 1\,\Omega$, $\Phi = 20 \times 10^{-3}$ Wb, $I_a = 40$ A and $c = 2p$ for a lap winding

(a) Back e.m.f. $E = V - I_a R_a = 250 - (40)(1)$

$= 210$ V

$$\text{E.m.f. } E = \frac{2p\Phi nZ}{c}$$

$$\text{i.e. } 210 = \frac{2p(20 \times 10^{-3})n(500)}{2p} = 10n$$

$$\text{Hence } \textbf{speed } \boldsymbol{n} = \frac{210}{10} = \mathbf{21\ rev/s} \text{ or } (21 \times 60)$$

$$= \mathbf{1260\ rev/min}$$

(b) $$\textbf{Torque } \boldsymbol{T} = \frac{EI_a}{2\pi n} = \frac{(210)(40)}{2\pi(21)} = \mathbf{63.66\ Nm}$$

Problem 21. A 200 V, d.c. shunt-wound motor has an armature resistance of 0.4 Ω and at a certain load has an armature current of 30 A and runs at 1350 rev/min. If the load on the shaft of the motor is increased so that the armature current increases to 45 A, determine the speed of the motor, assuming the flux remains constant.

The relationship $E \propto \Phi n$ applies to both generators and motors. For a motor, $E = V - I_a R_a$, (see equation (5))

Hence $E_1 = 200 - 30 \times 0.4 = 188\,\text{V}$

and $E_2 = 200 - 45 \times 0.4 = 182\,\text{V}$

The relationship

$$\frac{E_1}{E_2} = \frac{\Phi_1 n_1}{\Phi_2 n_2}$$

applies to both generators and motors. Since the flux is constant, $\Phi_1 = \Phi_2$. Hence

$$\frac{188}{182} = \frac{\Phi_1 \times \left(\frac{1350}{60}\right)}{\Phi_1 \times n_2}$$

i.e. $$n_2 = \frac{22.5 \times 182}{188} = 21.78\,\text{rev/s}$$

Thus **the speed of the motor when the armature current is 45 A is** 21.78 × 60 rev/min i.e. **1307 rev/min**.

Problem 23. A series motor has an armature resistance of 0.2 Ω and a series field resistance of 0.3 Ω. It is connected to a 240 V supply and at a particular load runs at 24 rev/s when drawing 15 A from the supply. (a) Determine the generated e.m.f. at this load (b) Calculate the speed of the motor when the load is changed such that the current is increased to 30 A. Assume that this causes a doubling of the flux.

(a) With reference to Fig. 22.20, generated e.m.f., E_1 at initial load, is given by

$$\begin{aligned} \boldsymbol{E_1} &= V - I_a(R_a + R_f) \\ &= 240 - (15)(0.2 + 0.3) \\ &= 240 - 7.5 = \mathbf{232.5\ volts} \end{aligned}$$

(b) When the current is increased to 30 A, the generated e.m.f. is given by:

$$\begin{aligned} E_2 &= V - I_2(R_a + R_f) \\ &= 240 - (30)(0.2 + 0.3) \\ &= 240 - 15 = 225 \text{ volts} \end{aligned}$$

Now e.m.f. $E \propto \Phi n$ thus

$$\frac{E_1}{E_2} = \frac{\Phi_1 n_1}{\Phi_2 n_2}$$

i.e. $\dfrac{232.5}{22.5} = \dfrac{\Phi_1(24)}{(2\Phi_1)n_2}$ since $\Phi_2 = 2\Phi_1$

Hence

speed of motor, $\boldsymbol{n_2} = \dfrac{(24)(225)}{(232.5)(2)} = \mathbf{11.6\ rev/s}$

Problem 26. A 200 V d.c. motor develops a shaft torque of 15 Nm at 1200 rev/min. If the efficiency is 80 per cent, determine the current supplied to the motor.

The efficiency of a motor = output power/input power × 100%

The output power of a motor is the power available to do work at its shaft and is given by $T\omega$ or $T(2\pi n)$ watts, where T is the torque in Nm and n is the speed of rotation in rev/s. The input power is the electrical power in watts supplied to the motor, i.e. VI watts.

Thus for a motor,

$$\text{efficiency,} \quad \eta = \frac{T(2\pi n)}{VI} \times 100\%$$

$$\text{i.e.} \quad 80 = \left[\frac{(15)(2\pi n)\left(\dfrac{1200}{60}\right)}{(200)(I)}\right] \times 100$$

Thus the current supplied,

$$I = \frac{(15)(2\pi)(20)(100)}{(200)(80)}$$

$$= \mathbf{11.8\,A}$$

Problem 29. On full-load a 300 V series motor takes 90 A and runs at 15 rev/s. The armature resistance is 0.1 Ω and the series winding resistance is 50 mΩ. Determine the speed when developing full load torque but with a 0.2 Ω diverter in parallel with the field winding. (Assume that the flux is proportional to the field current).

At 300 V, e.m.f.

$$E_1 = V - IR = V - I(R_a + R_{se})$$
$$= 300 - (90)(0.1 + 0.05)$$
$$= 300 - (90)(0.15)$$
$$= 300 - 13.5 = 286.5 \text{ volts}$$

With the 0.2 Ω diverter in parallel with R_{se} (see Fig. 22.30(a)), the equivalent resistance,

$$R = \frac{(0.2)(0.05)}{0.2 + 0.05} = \frac{(0.2)(0.05)}{0.25} = 0.04\ \Omega$$

By current division, current

$$I_1 \text{ (in Fig. 22.30(a))} = \left(\frac{0.2}{0.2 + 0.05}\right) I = 0.8\,I$$

Torque, $T \propto I_a \Phi$ and for full load torque, $I_{a1}\Phi_1 = I_{a2}\Phi_2$

Since flux is proportional to field current $\Phi_1 \propto I_{a1}$ and $\Phi_2 \propto 0.8\,I_{a2}$ then $(90)(90) = (I_{a2})(0.8\,I_{a2})$

from which, $$I_{a2}^2 = \frac{90^2}{0.8}$$

and $$I_{a2} = \frac{90}{\sqrt{0.8}} = 100.62 \text{ A}$$

Hence e.m.f. $$E_2 = V - I_{a2}(R_a + R)$$
$$= 300 - (100.62)(0.1 + 0.04)$$
$$= 300 - (100.62)(0.14)$$
$$= 300 - 14.087 = 285.9 \text{ volts}$$

Now e.m.f., $E \propto \Phi n$, from which,

$$\frac{E_1}{E_2} = \frac{\Phi_1 n_1}{\Phi_2 n_2} = \frac{I_{a1} n_1}{0.8 I_{a2} n_2}$$

Hence $$\frac{286.5}{285.9} = \frac{(90)(15)}{(0.8)(100.62)n_2}$$

and **new speed,** $$n_2 = \frac{(285.9)(90)(15)}{(286.5)(0.8)(100.62)}$$
$$= \mathbf{16.74\ rev/s}$$

Thus the speed of the motor has increased from 15 rev/s (i.e. 900 rev/min) to 16.74 rev/s (i.e. 1004 rev/min) by inserting a 0.2 Ω diverter resistance in parallel with the series winding.

Problem 30. A series motor runs at 800 rev/min when the voltage is 400 V and the current is 25 A. The armature resistance is 0.4 Ω and the series field resistance is 0.2 Ω. Determine the resistance to be connected in series to reduce the speed to 600 rev/min with the same current.

With reference to Fig. 22.30(b), at 800 rev/min,

e.m.f., $E_1 = V - I(R_a + R_{se})$

$= 400 - (25)(0.4 + 0.2)$

$= 400 - (25)(0.6)$

$= 400 - 15 = 385$ volts

At 600 rev/min, since the current is unchanged, the flux is unchanged.

Thus $E \propto \Phi n$ or $E \propto n$ and

$$\frac{E_1}{E_2} = \frac{n_1}{n_2}$$

Hence $$\frac{385}{E_2} = \frac{800}{600}$$

from which, $$E_2 = \frac{(385)(600)}{800} = 288.75 \text{ volts}$$

and $E_2 = V - I(R_a + R_{se} + R)$

Hence $288.75 = 400 - 25(0.4 + 0.2 + R)$

Rearranging gives:

$$0.6 + R = \frac{400 - 288.75}{25} = 4.45$$

from which, extra series resistance, $R = 4.45 - 0.6$ i.e. **R = 3.85 Ω**.

Thus the addition of a series resistance of 3.85 Ω has reduced the speed from 800 rev/min to 600 rev/min.