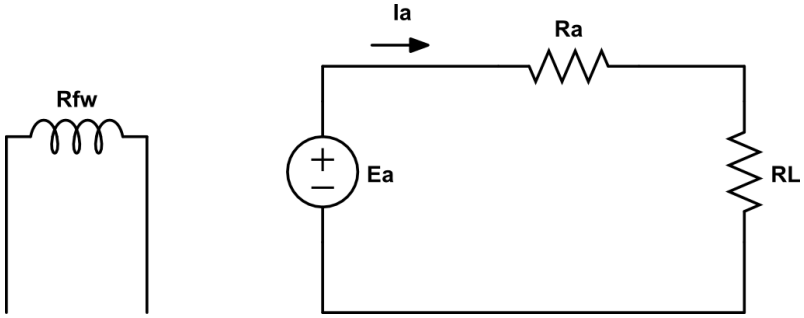
1) We are given :

$P = 6kW$
$U = 120V$
$n = 1200rpm$
$R_a = 0.2\Omega$
$R_{fw} = 100\Omega$
$I_f = 0.8A$
$R_L = 2\Omega$



a)

$$E_{an} = K_a \phi w_{mn} = K_a \phi 2\pi f_n = K_a \phi 2\pi \frac{n_n}{60}$$

$$K_a \phi = \frac{E_{an(I_f = 0.8A)}}{2\pi \frac{n_n}{60}} = \frac{114}{2\pi \frac{1200}{60}} = 0.907$$

b)

$$E_{a1} = K_a \phi 2\pi \frac{n_1}{60} = 0.907 \cdot 2\pi \cdot \frac{800}{60} = 76V$$

$$I_{a1} = \frac{E_{a1}}{R_a + R_L} = \frac{76}{0.2 + 2} = 34.5A$$

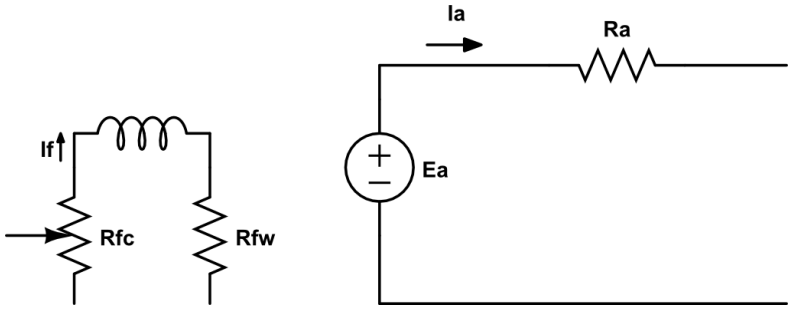
c)

$$T = K_a \phi I_a = 0.907 \cdot 34.5 = 31.33Nm$$

$$P_L = R_L I_a^2 = 2 \cdot 34.5^2 = 2380.5W$$

2) We are given :

$R_{fc} = 0 - 150\Omega$
$n = 1200rpm$
$U_{fw} = 120V$



$$I_f = \frac{U_f}{R_{fw} + R_{fc}}$$

$$I_{f,\min} = \frac{120}{100+150} = 0.48A, \qquad I_{f,\max} = \frac{120}{100+0} = 1.2A$$

From the given characteristic table:

$$E_{a,\min(I_f=0.48A)} = 79 + (0.48-0.4)\cdot\frac{93-79}{0.5-0.4} = 90.2V, \qquad E_{a,\max(I_f=1.2A)} = 125V$$

b)

$$U_f = I_f(R_{fw}+R_{fc}) = I_f R_{fw} + I_f R_{fc}$$

$$I_{f(E_a=120V)} = 1A \text{ (from given table)}$$

$$R_{fc} = \frac{U_f - I_f R_{fw}}{I_f} = \frac{120-100\cdot 1}{1} = 20\Omega$$

$$P = U\cdot I \Rightarrow I_a = \frac{P}{U} = \frac{6000}{120} = 50A$$

$$U_t = E_a - I_a R_a = 120 - 50\cdot 0.2 = 110V \text{ (no armature reaction)}$$

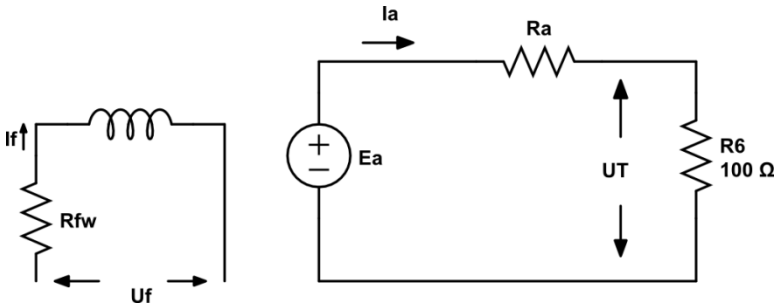
$$I_{f1} = I_f - I_{f(AR)} = 1 - 0.1 = 0.9A$$

$$U_t = E_{a(I_f=0.9A)} - I_a R_a = 114 + \frac{120-114}{1-0.8}(0.9-0.8) - 10 = 107V \text{ (with armature reaction)}$$

3) We are given:

$n = 1200rpm$

$P_{rot} = 400W$ at $n = 1200rpm$



a)

$$I_f = 1A, \qquad E_{a(I_f=1A)} = 120V, \qquad I_{an} = 50A \text{ (from previous solution)}$$

$$U_T = E_a - R_a I_a = 120 - 0.2\cdot 50 = 110V$$

$$P_o = U_T I_a = 110\cdot 50 = 5.5kW$$

$$\eta = \frac{P_o}{P_{in}} = \frac{P_o}{P_o + P_{loss}} = \frac{P_o}{P_o + P_{rot} + R_a I_a^2 + R_f I_f^2}$$

$$P_{loss} = P_{rot} + R_a I_a^2 + R_f I_f^2 = 400 + 0.2\cdot 50^2 + 100\cdot 1^2 = 1000W$$

$$\eta = 84.6\%$$

b) We are given: $n = 1500rpm$

$$\left\{\begin{array}{l}\text{for } n = 1200rpm,\ P_{rot} = 400W \\ \Rightarrow \text{for } n = 1500rpm,\ P_{rot1} = \dfrac{1500}{1200}\cdot 400 = 500W\end{array}\right\}$$

$$\left\{\begin{array}{l}\text{for } n = 1200rpm,\ E_a = 120V \\ \Rightarrow \text{for } n = 1500rpm,\ \mathrm{E}_{a1} = \dfrac{1500}{1200}\cdot 120 = 150V\end{array}\right\}$$

$$U_{T1} = E_a - R_a I_a = 140V$$

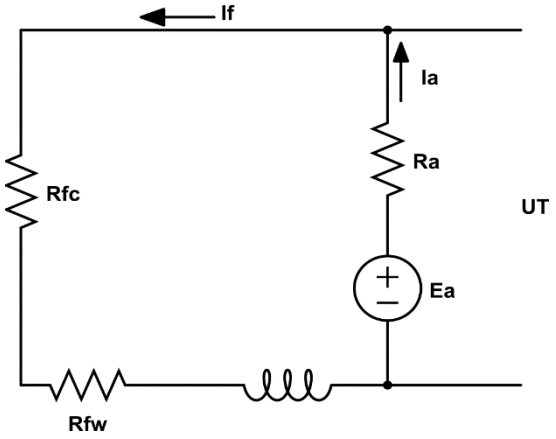
$$P_o = U_{T1} I_a = 140 \cdot 50 = 7000W$$

$$P_{loss1} = 500 + 0.2 \cdot 50^2 + 100 = 1100W$$

$$\eta_1 = \frac{7000}{7000 + 1100} \cdot 100 = 86.4\%$$

4) We are given:

$P = 20kW$
$U = 200V$
$n = 1800rpm$
$R_a = 0.1\Omega$
$R_{fw} = 150\Omega$



a)

$$U_T = U_f = E_a - R_a I_a$$

$$U_f = I_f(\mathrm{R}_{fw} + \mathrm{R}_a)$$

$$I_f = 1.25A\ ,\quad U_T = U_{T(rated)} = 200V = U_f$$

$$R_{fc} = \frac{U_f - I_f R_{fw}}{I_f} = \frac{200 - 1.25 \cdot 150}{1.25} = 10\Omega$$

b)

$$T_e = K_a \phi I_a$$

$$E_a = K_a \phi w \Rightarrow K_a \phi = \frac{E_a}{w} = \frac{E_a}{2\pi \frac{n}{60}}$$

$$U_T = E_a - R_a I_a \Rightarrow E_a = U_T + R_a I_a = U_T + R_a \frac{P}{U_T}$$

$$E_a = 200 + 0.1 \cdot \frac{20000}{200} = 210V \ , \qquad \mathrm{I}_a = 100A$$

$$K_a \phi = \frac{210}{2\pi \frac{1800}{60}} = 1.11$$

$$T_e = 1.11 \cdot 100 = 111Nm$$

$$P_e = T \cdot w = T \cdot 2\pi \cdot \frac{n}{60} = 111 \cdot 2\pi \cdot \frac{1800}{60} = 2.09 \cdot 10^4 W$$

OR

$$P_e = E_a I_a = 21000W$$

$$T_e = \frac{P_e}{w} = 111Nm$$

c)

$$I_f = 1.25A \Rightarrow I_{f(actual)} = 1.25A$$

$$E_{a(no-load,1.25A)} = 214V$$

$$E_{a(\text{full}-load,1.25A)} = U_T + I_a R_a = 200 + 100 \cdot 0.1 = 210V$$

$$\text{from the graph } \Rightarrow \text{for } E_a = 210V \qquad I_{f1} = 1.15A$$

$$I_{f(AR)} = I_{f(actual)} - I_{f1} = 1.25 - 1.15 = 0.1A$$

d)

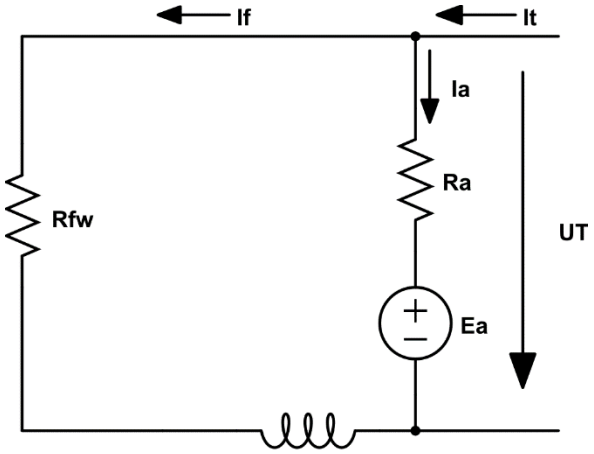
$$I_f = 0.1 \Rightarrow E_a = 25V \ \left(\text{from the graph}\right)$$

$$R_a I_{a\max} = 25V$$

$$I_{a\max} = \frac{25}{0.1} = 250A$$

5) We are given:

$U_t = 230V$
$I_a = 200A$
$n = 1200rpm$
$R_a = 0.2\Omega$



a)

$$E_a + R_a I_a = U_t \Rightarrow E_a = U_t - R_a I_a$$

$$E_a = 230 - 0.2 \cdot 200 = 190V$$

b)

$$P_{rot} = 500W$$

$$T_e = T_{rot} + T_L \Rightarrow T_L = T_e - T_{rot}$$

$$E_a I_a = T_e w \Rightarrow T_e = \frac{E_a I_a}{w}$$

$$P_{rot} = T_{rot} w \Rightarrow T_{rot} = \frac{P_{rot}}{w}$$

$$T_L = \frac{1}{w}\left(E_a I_a - P_{rot}\right) \text{ where } w = \frac{2\pi n}{60}$$

$$\mathrm{T_L} = \frac{1}{\frac{2\pi \cdot 1200}{60}}(190 \cdot 200 - 500) = 298.42 \text{ Nm}$$

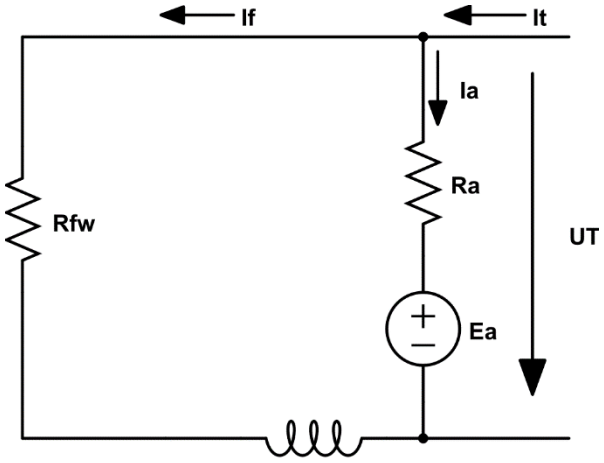
c)

$$R_{fw} = 115\Omega \Rightarrow I_f = \frac{U_t}{R_{fw}} = \frac{230}{115} = 2A$$

$$\eta = \frac{P_{out}}{P_{in}} = \frac{E_a I_a - P_{rot}}{U_t I_t} = \frac{190 \cdot 200 - 500}{230 \cdot (200 + 2)} = 0.807$$

6) We are given:

$P = 10kW$
$U_t = 250V$
$n = 1200rpm$
$R_a = 0.25\Omega$



a)

$$I_a = \frac{P}{U} = \frac{10000}{250} = 40A$$

$$E_a = U_t - R_a I_a = 250 - 0.25 \cdot 40 = 240V$$

$$P_e = E_a \cdot I_a = 240 \cdot 40 = 9600W$$

$$T_e = \frac{P_e}{w} \quad \text{where } w = \frac{2\pi n}{60} = 125.67rad/s$$

$$\Rightarrow T_e = \frac{9600}{125.67} = 76.4Nm$$

b)

$$I_{a0} = 4A$$

$$T_e = T_L + T_{rot}$$
$$P_e = P_L + P_{rot}$$

$$T_L = 0, P_L = 0 \Rightarrow T_e = T_{rot}, P_e = P_{rot}$$

$$E_{a0} = U_T - R_a I_{a0} = 250 - 0.25 \cdot 4 = 249V$$

$$P_{rot} = P_e = E_{a0} \cdot I_{a0} = 249 \cdot 4 = 996W$$

$$E_a = K\emptyset w \Rightarrow K\emptyset = \frac{E_a}{w} = \frac{240}{125.6} = 1.91$$

$$E_{a0} = K\phi w_0 \Rightarrow w_0 = \frac{E_{a0}}{K\phi} = \frac{249}{1.91} = 130.4rad/s$$

$$w_0 = \frac{2\pi n_0}{60} \Rightarrow n_0 = \frac{60 \cdot w_0}{2\pi} = 1244rpm$$