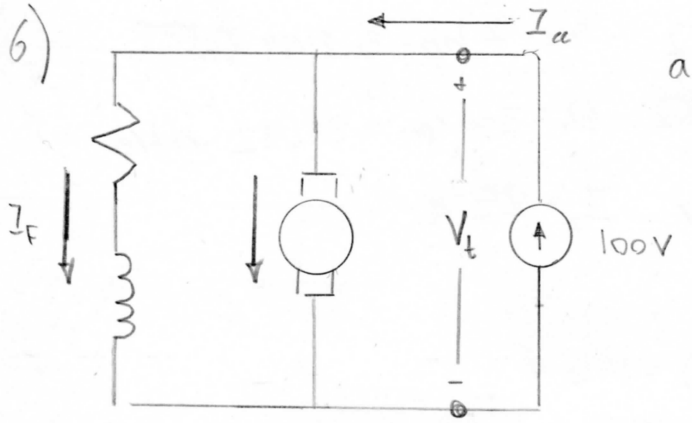
4.6)



a) No load $\Rightarrow I_a = 6A$

$E_a = K_v \omega_r = V_t - R_a I_a$

$R_a = 0.1\Omega$ (Example 4.2)

$E_a = 100 - 0.1(6) = 99.4\ V$

$\downarrow$ $I_f = 0.98\ A$ (Figure 4.24)

$R_f = \frac{V_t}{I_f} = \frac{100}{0.98} = 102.04\ \Omega$

$R_f = R_{fc} + R_{fw} \Rightarrow R_{fw} = 80\Omega$ (Example 4.2)

$\boxed{R_{fc} = 102 - 80 = 22.04\ \Omega}$

b) $P_{loss} = P_{in} - P_{out}$

$P_{in} = E_a I_a = 99.4(6) = 596.4\ W$

$P_{out} = 0$ (no load)

$\boxed{P_{loss} = P_{in} = 596.4\ W}$

c) $I_{a,c} = 120\ A$ (example 4.2) $\quad E_{a,c} = V_t - I_{a,c} R_a = 100 - 120(0.1) = 88\ V$

$E_a = K_a \Phi_p \omega_r \Rightarrow \frac{E_{a,c}}{E_{a,a}} = \frac{\omega_c}{\omega_a} = \frac{88}{99.4} = 0.8853$

$\omega_c = 0.8853\,\omega_a = 0.8853\,(1000) = 885.3\ rpm$

$\omega_c = 885.3 \frac{\text{rotations}}{\text{min}} \cdot \frac{2\pi\ rad}{\text{rotation}} \cdot \frac{1\ \text{min}}{60\ sec} = \boxed{92.7\ rad/sec}$

$T = \frac{E_{a,c} I_{a,c}}{\omega_c} = \frac{88(120)}{92.7} = \boxed{113.9\ N\cdot m}$

$P_{out} = E_{a,c} I_{a,c} - P_{loss} = 120(88) - 596.4 = 9963.6\ W$

$P_{in} = V_t I_t = V_t (I_a + I_f) = 100(120 + 0.98) = 12098\ W$

$\eta = \frac{P_{out}}{P_{in}} = \frac{9963.6}{12098} = \boxed{0.8236 = 82.36\%}$

d) $E_{a,d} = K_a \Phi\, \omega_a = 99.4 = K_a \Phi\, 1000 \frac{\text{rotations}}{\text{min}} \cdot \frac{2\pi\ rad}{\text{rotation}} \cdot \frac{1\ \text{min}}{60\ sec} \Rightarrow K_a \Phi = 0.9492\ \frac{V \cdot sec}{rad}$

$I_{a,d} = 1.5(120) = 180\ A \quad T = K_a \Phi\, I_{a,d} = 0.9492(180) = \boxed{170.86\ N\cdot m}$

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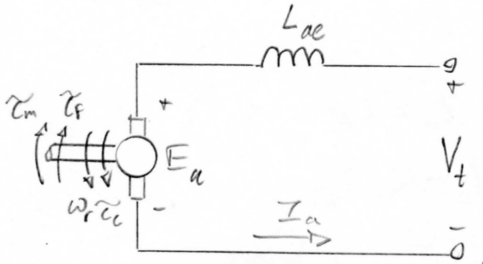
4.9)



$R_a = 0.6\Omega$ $P = 7\ hp = 5.2199\ KW$

$R_{sr} = 0.4\Omega$ $\omega_r = 300\ rpm = 31.42\ rad/s$

$V_t = 220\ V$ $I_a = 25\ A$

a)

$V_t = E_a + R_t I_a \Rightarrow E_a = 220 - 25(0.6+0.4) = 195\ V$

$P_a = E_a I_a = 195(25) = \boxed{4.875\ kW = 6.537\ H_p}$

$\tau_e = \frac{E_a I_a}{\omega_r} = \frac{4875}{31.42} = \boxed{155.16\ N.m}$

b) $\omega_r = 200\ rpm = 20.94\ rad/s$

$\tau_m \propto \omega_r^2$ $\quad \tau_{m_a} = 155.16\ N.m \Rightarrow a = \frac{155.16\ N.m}{(31.42)^2 \frac{rad^2}{s^2}} = 0.157 \frac{N m s^2}{rad^2}$

$\tau_m = a\omega_r^2$ $\quad \omega_{r_a} = 31.42\ rad/s$

$\tau_{m_b} = 0.157 \frac{N m s^2}{rad^2} (20.94)^2 \frac{rad^2}{s^2} = 68.92\ N.m$

$\tau_e = K_{sr} I_a^2 \Rightarrow \frac{155.16}{25^2} = K_{sr} = 0.2483 \frac{N.m}{A^2}$

$\tau_b = 68.92 = K_{sr} I_a^2 \Rightarrow I_a = \sqrt{\frac{68.92}{0.2483}} = 16.66\ A$

$E_a = K_{sr} I_a \omega_m = 0.2483(16.66)\,20.94 = 86.63\ V$

$E_a = V_t - I_a(R_a + R_{sr} + R_{ae}) \Rightarrow R_{ae} = \left(\frac{V_t - E_a}{I_a}\right) - (R_a + R_{sr}) = \left(\frac{220-86.63}{16.66}\right) - (1)$

$\boxed{R_{ae} = 7.01\Omega}$

$P = E_a I_a = 86.63(16.66) = \boxed{1.4433\ KW}$

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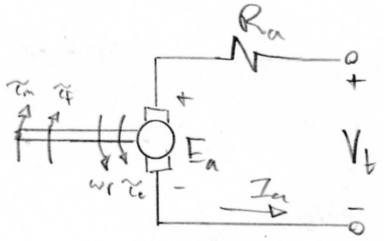
4.30)



$\tau_m = 25$ N·m

$\tau_e = 10$ N·m @ $I_a = 10$A

$R_a = 0.2\,\Omega$

$V_t = 200$V

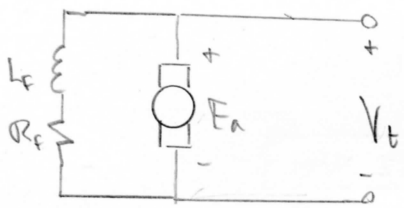
$\tau_e = K_t I_a \Rightarrow K_t = \frac{10\text{ N·m}}{10\text{ A}} = 1\ \frac{\text{N·m}}{\text{A}}$ $\Rightarrow$ Assume steady operation, $\tau_m = \tau_e = 25$ N·m

$\Rightarrow I_a = \frac{25\text{ N·m}}{1\ \frac{\text{N·m}}{\text{A}}} = 25$ A

$V_t = E_a + I_a R_a \Rightarrow E_a = V_t - I_a R_a = 200 - 25(0.2) = 195$V

$P = E_a I_a = 195(25) = \boxed{4.875\text{ KW}}$ $E_a = K_v \omega_r$, $K_v = K_t \Rightarrow \omega_r = \frac{E_a}{K_v} = \frac{195}{1} = \boxed{195\text{ rad/s}}$

4.31)



$\tau_m = 300$ N·m

$V_t = 600$ V

$\omega_r = 1500$ rpm $= 157.08$ rad/s

$R_a = 0.5\,\Omega$

a) Assume $\tau_m = \tau_e$ $\rightsquigarrow$ steady, no friction

$P = \tau_m \omega_r = 300(157.08) = 47.1239$ KW

$V_t = V_a = V_f = 600$ V

$E_a = V_a - I_a r_a$, $E_a = L_{af} I_f \omega_r$ & $\tau_e = L_{af} I_f I_a \Rightarrow I_a = \frac{\tau_e}{L_{af} I_f}$

$L_{af} I_f \omega_r = V_a - \frac{\tau_e}{L_{af} I_f} r_a \Rightarrow (L_{af} I_f)^2 \omega_r - (L_{af} I_f) V_a + \tau_e r_a = 0$

$\Rightarrow L_{af} I_f = 3.055$ or $0.27 \Rightarrow E_a = 557.63$V or ~~42.41 V~~ reject, too large of a current.

$\boxed{I_a = 84.51\text{ A}}$ or ~~411.11 A~~

b) $K_a \phi_p|_a = 3.055$

$K_a \phi_p|_b = 3.195$

$I_a = \frac{\tau_e}{3.195} = \boxed{93.89\text{ A}} \Rightarrow E_a = V_t - I_a r_a = 600 - 93.89(0.5) = 553.05$V

$E_a = K_a \phi_p \omega_r \Rightarrow \omega_r = \frac{E_a}{K_a \phi_p} = \frac{553.05}{3.195} = \boxed{173.10\text{ rad/s} = 1653\text{ rpm}}$

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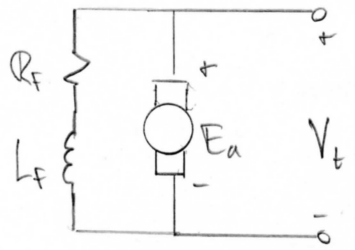
4.32)



$V_t = 230\ V$
$I_a = 200\ A$
$\omega_r = 1200\ rpm = 125.66\ rad/s$
$R_a = 0.2\ \Omega$

a) $E_a = V_t - I_a R_a = 230 - 200(0.2) = \boxed{190\ V}$

b) $P_{mech} = \tau_f \omega_r = 500\ W \Rightarrow \tau_f = \frac{500}{125.66} = 3.98\ N\cdot m$

$\tau_e = L_{af} I_f I_a$, $E_a = L_{af} I_f \omega_r \Rightarrow L_{af} I_f = \frac{E_a}{\omega_r} = \frac{190}{125.66} = 1.5121$

$\tau_e = 1.5121(200) = 302.40\ N\cdot m$

$\tau_e = \tau_m + \tau_f \Rightarrow \tau_m = \tau_e - \tau_f = 302.40 - 3.98 = \boxed{298.42\ N\cdot m}$

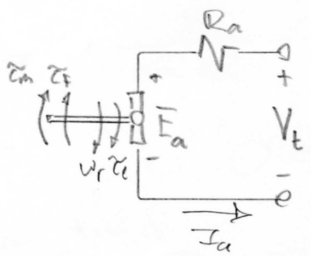
c) $R_f = 115\ \Omega \Rightarrow V_t = R_f I_f \Rightarrow I_F = \frac{V_t}{R_f} = \frac{230}{115} = 2\ A \Rightarrow I_t = I_a + I_f = 202\ A$

$P_{out} = \tau_m \omega_r = 298.42(125.66) = 37.4999\ kW$

$P_{in} = V_t I_t = 230(202) = 46.46\ kW$

$\eta = \frac{P_{out}}{P_{in}} = \frac{37.4999}{46.46} = \boxed{0.8071 = 80.71\ \%}$

4.38)



$V_t = 120\ V$
$I_a = 8\ A$
$\omega_r = 1800\ rpm = 188.49\ rad/s$
$R_a = 0.08\ \Omega$

a) $V_t = E_a + R_a I_a \Rightarrow E_a = V_t - R_a I_a = 120 - 0.08(8) = 119.36\ V \Rightarrow K_a \phi_p = \frac{E_a}{\omega_r} = \frac{119.36}{188.49} = 0.633\ \frac{V\cdot s}{rad}$

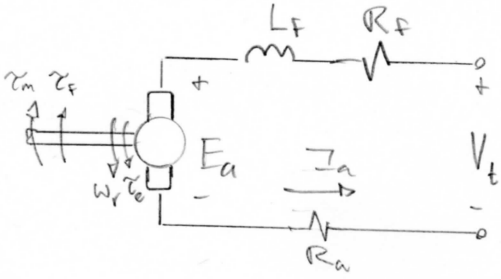
$K_a = \phi \therefore K_a \phi_p|_{break} = \frac{5}{100}(0.633) = 0.03166\ \frac{N\cdot s}{rad}$

$\tau_e = K_a \phi_p I_a \Rightarrow \tau_e|_{start} = 0.633(8) = 5.07\ N\cdot m$

$\tau_e|_{break} = \tau_e|_{start} = 5.07 = K_a \phi_p I_a \Rightarrow \boxed{I_a|_{break} = \frac{5.07}{0.03166} = 160\ A}$

b) $E_a = V_t - R_a I_a = 120 - 0.08(160) = 107.2\ V \Rightarrow \omega_r = \frac{E_a}{K_a \phi_p} = \frac{107.2}{0.03166} = \boxed{3385\ rad/s = 32331\ rpm}$

4.39)



$V_t = 600\ V$

$R_f = 0.5\ \Omega$

$\omega_r = 500\ rpm = 52.36\ rad/s$

$I_a = 75\ A$

a) $\tau_e = L_{af} I_f I_a \quad I_f = I_a \Rightarrow \tau_e = L_{af} I_a^2$

$$\sqrt{\frac{\tau_e}{L_{af}}} = I_a \Rightarrow \sqrt{\frac{\tau_e}{2L_{af}}} = I_{a,1/2} \Rightarrow I_{a,1/2} = \frac{1}{\sqrt{2}}\sqrt{\frac{\tau_e}{L_{af}}} = \frac{I_a}{\sqrt{2}} = \boxed{53.03\ A}$$

b) $E_a = V_t - I_a R_t$, $E_a = L_{af} I_a \omega_r \Rightarrow L_{af} = \frac{E_a}{I_a \omega_r}$

$E_{a,1/2} = V_t - \frac{I_a}{\sqrt{2}} R_t$, $E_{a,1/2} = L_{af} \frac{I_a}{\sqrt{2}} \omega_{r,1/2} \Rightarrow L_{af} = \frac{\sqrt{2}\, E_{a,1/2}}{I_a \omega_r}$

$$\frac{E_a}{I_a \omega_r} = \frac{\sqrt{2}\, E_{a,1/2}}{I_a \omega_r}$$

$E_{a,1/2} = \frac{E_a}{\sqrt{2}} \Rightarrow \omega_r = \frac{E_a}{L_{af} I_a}$

$$\omega_{r,1/2} = \frac{E_{a,1/2}}{L_{af} I_{a,1/2}} = \frac{E_a \sqrt{2}}{\sqrt{2} L_{af} I_a} = \frac{E_a}{L_{af} I_a} = \omega_r = \boxed{52.36\ \frac{rad}{sec}}$$