ECE 431. SP 2020. HW 7. soln.

7.1 No load: $E_a = k_f \omega I_f$ $\omega = 1850 \cdot \frac{2\pi}{60} = 193.73$ rad/s.

$I_f = \frac{V_t}{R_f} = \frac{250}{200} = 1.25$ A.

$k_f = \frac{E_a}{\omega I_f} = \frac{250}{193.73 \times 1.25} = 1.032 \frac{V \cdot s}{A \cdot rad}$

a) $I_a = I_t - I_f = 290 - 1.25 = 288.75$ A

$E_a = V_t - I_a R_a = 250 - 288.75 \times 50 \times 10^{-3} = 235.5625$ V.

$\omega_{load} = \frac{E_a}{k_f I_f} = 182.606$ rad/s $= 1743.8$ rpm.

$P = E_a I_a = 68.02$ kW

$T = \frac{P}{\omega_{load}} = 372.49$ Nm.

b) $I_f = \frac{V_{t\,new}}{R_f} = \frac{200}{200} = 1$ A

$T = \frac{E_a I_a}{\omega} = k_f I_f I_a \Rightarrow I_a = \frac{T}{k_f I_f} = \frac{372.49}{1.032 \times 1} = 360.94$ A

$E_a = k_f \omega I_f = V_t - I_a R_a \Rightarrow \omega = \frac{V_t - I_a R_a}{k_f I_f} = 176.31$ rad/s $= 1683.6$ rpm

$I_t = I_a + I_f = 361.94$ A

c) $T_o = 372.49$ Nm. $\omega_o = 182.606$ rad/s

$T = T_o \left(\frac{\omega}{\omega_o}\right)^2 = k_f I_f I_a = k_f I_f \left(\frac{V_t - k_f I_f \omega}{R_a}\right)$

Solve for ω: $\omega = 177.311$ rad/s $= 1693.2$ rpm.

$I_t = I_f + I_a = I_f + \frac{V_t - k_f I_f \omega}{R_a} = 1 + \frac{200 - 1.032 \times 1 \times 177.311}{50 \times 10^{-3}} = 341.3$ A

7.2 no load: $230 = 15 + 180 I_{sh} \Rightarrow I_{sh} = 1.194\ A.$

$R_{sh} = 192.56\ \Omega$

a) $I_{start} = \frac{V_t}{R + R_a // R_{sh}} \Rightarrow R = \frac{1}{I_{start}} (V_t - (R_a // R_{sh}) I_{start})$

$= \frac{1}{8} (230) - 5 // 192.56$

$= 23.88\ \Omega$

b) unload $\Rightarrow I_a = 0$

$I_f = I_{sh} = \frac{V_t}{R + R_{sh}} = \frac{230}{23.88 + 192.56} = 1.063\ A$

$E_a = V_t - I_{sh} R = 230 - 1.063 \times 23.88 = 204.62\ V.$

$n = \frac{E_a}{15 + 180 I_{sh}} \cdot 1500 = \frac{204.62}{15 + 180 \times 1.063} \cdot 1500 = 1487.5\ rpm$

$w = 155.77\ rad/s.$

7.3. a) $I_f = \frac{V_t}{R_{sh}} = \frac{240}{300} = 0.8A$

$E_a = K w = 0.9 w$, $K_f = \frac{K}{I_f} = \frac{0.9}{0.8} = 1.125\ \frac{V.s}{A.rad}$

$T_e = \frac{E_a I_a}{w} = K I_a = 0.001 w^2 = T_{load} \Rightarrow 0.001 w^2 = 0.9 \left(\frac{240 - 0.9w}{0.2} \right)$

$\therefore w = 251.10\ rad/s = 2397.8\ rpm.$

$I_a = \frac{V_t - K w}{R_a} = \frac{240 - 0.9 \times 251.10}{0.2} = 70.05\ A$

$I_t = I_a + I_f = 70.05 + 0.8 = 70.85\ A$

$T = K I_a = 0.9 \times 70.05 = 63.045\ Nm.$

b) $I_{f\,new} = \frac{V_t}{R_{sh} + R} = \frac{240}{300 + 30} = 0.727\ A$

$E_a = K_f I_{f\,new} w = 1.125 \times 0.727\ w = 0.818\ w$

$T_e = T_m \Rightarrow 0.001 w^2 = 0.818 \left(\frac{240 - 0.818 w}{0.2} \right)$

$\therefore w_{new} = 271.338\ rad/s = 2591.1\ rpm.$

$I_{a\,new} = \frac{240 - 0.818 w}{0.2} = 90.228\ A$

$I_{t\,new} = I_{a\,new} + I_{f\,new} = 90.955 A$

$T_{new} = 0.818 I_a = 73.823\ Nm$

c) $I_f = 0.8\ A$, $E_a = 0.9\ w$

$T_e = T_m \Rightarrow 0.001 w^2 = 0.9 \left(\frac{120 - 0.9w}{0.2}\right)$

$\therefore w = 129.211\ rad/s = 1233.9\ rpm.$

$I_a = \frac{120 - 0.9w}{0.2} = 18.551\ A$

$I_t = I_a + I_f = 19.351\ A$

$T = 0.9 I_a = 16.70\ Nm.$

7.4 a) $E_a = k_f w$, $P = E_a I_a$, $T = \frac{P}{w} \Rightarrow T = k_f I_a$

$T_{load} = F \cdot d = gM \cdot d = 9.81 \times 200 \times \frac{0.5}{2} = 490.5\ Nm$

assuming 490.5Nm can be provided.

$I_a = \frac{T}{k_f} = \frac{490.5}{9} = 54.5\ A.$

$E_a = V_a - I_a R_a = 600 - 54.5 \times 0.3 = 583.65\ V$

$w = \frac{E_a}{k_f} = \frac{583.65}{9.0} = 64.85\ rad/s$

$P = Tw = 490.5 \times 64.85 = 31.8\ kw > P_{rate} = 15\ kw.$

$\therefore$ not safe.

b). ① $w = \frac{E_a}{k_f} = \frac{V_a - I_a R_a}{k_f} = \frac{V_a - T/k_f \cdot R_a}{k_f} = \frac{600 - \frac{T 0.3}{9}}{9}$

② $Tw = 15000$

solving ①, ② $\Rightarrow T = 227.885\ Nm \quad w = 65.823\ rad/s$

$I_a = \frac{T}{k_f} = \frac{227.885}{9} = 25.32\ A$

$D = \frac{2T}{gM} = \frac{2 \times 227.885}{9.81 \times 200} = 0.232\ m.$

$E_a = V_a - I_a R_a = 600 - 25.32 \times 0.3 = 592.4\ V.$