Department of Electrical Engineering
Indian Institute of Technology Bombay, Powai
EE111 : Introduction to Electrical Engineering
Solution to Assignment 10

1. $V = 250\text{V}$, $R_a = 0.12\Omega$, $R_f = 100\Omega$, $I_a = 80\text{A}$
   As motor, $E_{b1} = 250 - 80 \times 0.12 = 240.4\text{V}$
   As generator, $E_{b2} = 250 + 80 \times 0.12 = 259.6\text{V}$
   Since, $N \propto E_b$, ratio of speed $= \frac{259.6}{240.4} = 1.08$.

2. $I_{a1} = \frac{500\times10^3}{500} = 1000\text{A}$, $I_{a2} = \frac{250\times10^3}{500} = 500\text{A}$
   $E_{b1} = 500 + 1000 \times 0.015 = 515$ V
   $E_{b2} = 500 + 500 \times 0.015 = 507.5$ V
   %Reduction in speed $= \frac{515-507.5}{515} = 1.45\%$

3. $I_{a1} = 200\text{A}$, $V = 125\text{V}$
   $E_{b1} = 125 + 200 \times 0.04 + 2 = 135\text{V}$
   Since, $N \propto E_b$, $E_{b2} = 135 \times \frac{1000}{1200} = 112.5\text{V}$
   $R_{ext} = \frac{125}{200} = 0.625\Omega$
   $I_{a2} = \frac{E_{b2}-2}{R_a+R_{ext}} = 166\text{A}$

4. $E_b = 127\text{V}$, $V = 120\text{V}$
   $I_f = \frac{120}{15} = 8\text{A}$, $I_a = \frac{127-120}{0.02} = 350\text{A}$
   $I_L = 342\text{A}$

5. $I_L = \frac{50\times10^3}{250} = 200\text{A}$, $I_f = \frac{250}{50} = 5\text{A}$
   $I_{a1} = 205\text{A}$, $E_{b1} = 250 + 1 + 0.02 * 205 = 255.1\text{V}$

$I_{a2} = 195\text{A}$, $E_{b1} = 250 - 1 - 0.02 * 195 = 245.1\text{V}$

$N_2 = 400 \times \frac{245.1}{255.1} = 384.3\text{rpm}$

6. $V = 250\text{V}$, $I_f = \frac{250}{250} = 1\text{A}$ and $I_{L1} = 4A$

   $I_{a1} = 4 + 1 = 5\text{A}$, $E_{b1} = 250 - 5 \times 0.5 = 247.5\text{V}$

   $I_{L2} = 40\text{A}$, $I_{a2} = 40 + 1 = 41\text{A}$

   $E_{b2} = 250 - 41 \times 0.5 = 229.5\text{V}$

   $N_2 = 1000 \times \frac{229.5}{247.5} \times \frac{1}{0.96} = 965.9$ rpm

   $P_i = 40 \times 250 = 10000\text{W}$, $P_o = 229.5 \times 41 - 41^2 \times 0.5 - 250 = 8288.1\text{W}$

   %Efficiency=82.8%.

7. $E_b = 220 - 35 \times 0.3 = 209.5\text{V}$

   Slope of mag. line $= \frac{220-200}{1} = 20\text{V/A}$

   $209.5 = 200 + \Delta I_f \times 20$, gives $\Delta I_f = 0.475\text{A}$

   $I_f = 4.475\text{A}$, $\frac{220}{40+R_{ext}} = 4.475$, $R_{ext} = 9.16\Omega$.

9. P_o =10hp $= 7460\text{W}$. $P_i = \frac{7460}{0.85} = 8776.47\text{W}$

   $I_f = \frac{500}{400} = 1.25\text{A}$, $I_L = \frac{8776.47}{500} = 17.55\text{A}$

   $I_a = 16.302\text{A}$, $E_{b1} = 500 - 16.3 \times 0.25 = 495.93\text{V}$

   $P_{cu} = 16.3^2 \times 0.25 + 500 \times 1.25 = 691.42\text{W}$

   $P_{loss} = 1316.47\text{W}$, $P_{other1} = 625.04\text{W}$

   $\frac{E_{b2}}{E_{b1}} = \frac{N_2}{N_1} = 0.7$, gives $E_{b2} = 347.15\text{V}$

   $347.15 = 500 - 16.3 \times R_t$, gives $R_t = 9.37\Omega$, $R_{ext} = 9.12\Omega$

   $P_o = 8776.47 - 9.37 \times 16.3^2 - 500 \times 1.25 - 625.04 \times 0.7 = 5224.42\text{W}$

   %Efficiency = 59.52%.

10. $\frac{N_2}{N_1} = \frac{E_{b2}}{E_{b1}} \times \frac{I_{f1}}{I_{f2}} = \frac{800}{600}$

    $I_{f1} = 1A$, $I_{a1} = 20\text{A}$, $E_{b1} = 250 - 0.5 \times 20 = 240\text{V}$

    Since torque remains constant, $I_{f1}I_{a1} = I_{f2}I_{a2}$, $I_{a2} = \frac{20}{I_{f2}}$

    $(250 - 0.5 \times \frac{20}{I_{f2}} \frac{1}{I_{f2}} = 320$

    Solving the quadratic, the appropriate value of $I_{f2} = 0.738\text{A}$

    This results in $R_{ext} = 88.3\Omega$