Department of Electrical Engineering
Indian Institute of Technology Bombay, Powai
EE111 : Introduction to Electrical Engineering
Solution to Assignment 6

1. $E_p \approx V_p \approx 520V$
   $520 = 4.44 \times f \times N_p \times A_c \times B$ gives $B = 0.976 \mathrm{Wb/m^2}$.
   $V_s = V_p \frac{N_s}{N_p} = 1300\mathrm{V}$.

2. $8 \times N_p = 250$ gives $N_p = 32$
   $8 \times N_s = 3000$ gives $N_s = 375$
   $8 = 4.44 \times f \times B \times A_c$ gives $A_c = 0.01$ sq. m.

3. $R_2' = 0.009 \times \left(\frac{4400}{220}\right)^2 = 3.6\Omega$
   $X_2' = 0.015 \times \left(\frac{4400}{220}\right)^2 = 6\Omega$
   $R_{1eq} = 7.05\Omega$, $X_{1eq} = 11.2\Omega$
   Conversely, $R_{2eq} = 0.0176\Omega$, $X_{2eq} = 0.028\Omega$
   Rated current in primary $= \frac{50 \times 10^3}{4400} = 11.36\mathrm{A}$
   Copper loss $= 11.36^2 \times 7.05 = 910\mathrm{W}$

4. $I_s = 80\angle{-36.87^\circ}$ A
   Referred to secondary, $I_s' = 20\angle{-36.87^\circ}$ A
   $I_p = I_o + I_s' = 25\angle{-45^\circ} - 20\angle{-36.87^\circ} = 5.291\angle{-73.56^\circ}$

5. $V_s = 500\angle 0^\circ\mathrm{V}$, $I_L = 200\angle{-36.87^\circ}$ A
   $V_s' = 500 \times 19.5 = 9750\angle 0^\circ$ V
   $R_2' = 0.06 \times (19.5)^2 = 22.81\Omega$

$X_2' = 0.25 \times (19.5)^2 = 95.06\Omega$

$I_L' = 10.25\angle{-36.87^\circ}$ A

$V_o = V_s' + I_L' \times (R_2' + jX_2') = 10541\angle 3.47^\circ$ V

$I_o = 1.25\angle{-60^\circ}$ A

$I_p = I_o + I_s' = 11.41\angle{-39.33^\circ}$ A

$V_p = V_o + I_p \times (R_1 + jX_1) = 11543.71\angle 6.67^\circ$ V

Power factor angle $= 6.67 - (-39.33) = 46^\circ$, $P.f = 0.694$

Percentage efficiency $= \frac{500\times200\times0.8}{|V_p|\times|I_p|\times0.694} \times 100 = 85.71\%$

6. $R = 0.01$ p.u, $X = 0.05$ p.u

   Voltage regulation for 0.8 p.f lag $= 0.01 \times 0.8 + 0.05 \times \sin(\cos^{-1}(0.8)) = 3.8\%$

   Voltage regulation for 0.8 p.f lead $= 0.01 \times 0.8 - 0.05 \times \sin(\cos^{-1}(0.8)) = -2.19\%$

   Voltage regulation for UPF $= 0.01 \times 1.0 - 0.05 \times 0 = 1\%$

8. $R_1 = 10\Omega$, $R_2 = 0.016\Omega$, $X_{1eq} = 34\Omega$

   $R_2' = 10.88\Omega$, $R_{1eq} = 20.88\Omega$

   Rated current in primary $= \frac{30\times10^3}{6000} = 5$ A

   $V_p^{sc} = 5 \times (R_{1eq} + jX_{1eq}) = 200\angle{-58.44^\circ}$ V

   P.f = 0.52 lag.

9. Let full load Cu loss be x and iron loss be denoted by y

   At half load and 0.8 p.f,

   $0.25x + y = 500 \times 10^3 \times 0.8 \times (1 - 0.985)/0.985 = 6091.37$ W

   At full load and UPF,

   $x + y = 1000 \times 10^3 \times (1 - 0.988)/0.988 = 12145.75$ W

   Solving, $x = 8072.50$ W and $y = 4073.25$ W

   For maximum efficiency, Cu loss = Iron loss = 4073.25 W.

   This maxmimum efficiency will occur at p times full load where

   $p^2 \times 8072.50 = 4073.25$, $p = 0.71$

   Maximum efficiency = 98.86 %.

10. $V_{sc} = 60$ V, $I_{sc} = 4$ A, $P_{sc} = 100$ W

    $P_{sc} = I_{sc}^2 R_{1eq}$, gives $R_{1eq} = 6.25\Omega$

    $Z_{sc} = \frac{V_{sc}}{I_{sc}} = 15\Omega$

    $X_{1eq} = \sqrt{Z_{sc}^2 - R_{1eq}^2} = 13.63\Omega$

Full load current in the hv side $= \frac{10\times10^3}{2000} = 5$ A

$I_L = 5\angle{-36.87^\circ}$ A, $V_s' = 2000\angle 0^\circ$ V

$V_p = V_s' + I_L \times (R_{1eq} + jX_{1eq})$ gives $|V_p| = 2066$ V

11. Let full load Cu loss be x and iron loss be denoted by y

    At half load and UPF,

    $0.25x + y = 300 \times 10^3 \times (1 - 0.92)/0.92 = 26086.96$ W

    At full load and UPF,

    $x + y = 600 \times 10^3 \times (1 - 0.92)/0.92 = 52173.91$ W

    Solving, $x = 34782.6$ W and $y = 17391.31$ W

    At 60% load and UPF,

    Effeciency $= \frac{0.6\times600\times10^3}{0.6\times600\times10^3+17931.31+0.36\times34782.6} = 92.32\%$