Note the above calculation has two errors in the last two lines. These errors are:

a. next to last line: should be $I_2 = 0.138 \angle -141.35^\circ$.

b. last line: should be $V_2 = -I_2 R = 1.656 \angle -38.65^\circ$.

7. The ohmic values of circuit parameters of a transformer, having turns ration of $N_1/N_2 = 5$, are $R_1 = 0.5 \Omega$, $R_2 = 0.021 \Omega$, $X_1 = 3.2 \Omega$, $X_2 = 0.12 \Omega$, $R_e = 350 \Omega$, and $X_m = 982 \Omega$. ($R_1$, $X_1$, $R_e$, and $X_m$ are given referred to the primary side; $R_2$ and $X_2$ are given referred to the secondary). Draw the approximate equivalent circuit of the transformer, with all quantities referred to (a) the primary and (b) the secondary. Show the numerical values of the circuit parameters.
The “exact” equivalent circuit parameters of a 150-kVA, 2400volt/2400volt transformer are $R_1 = 0.2 \, \Omega$, $R_2 = 2 \, \text{m} \Omega$, $X_1 = 0.45 \, \text{m} \Omega$, $X_2 = 4.5 \, \text{m} \Omega$, $R_c = 10 \, \text{k} \Omega$, and $X_m = 1.55 \, \text{k} \Omega$. ($R_1$, $X_1$, $R_c$, and $X_m$ are given referred to the primary side; $R_2$ and $X_2$ are given referred to the secondary). Using the circuit referred to the primary, determine the (a) percent voltage regulation and (b) efficiency of the transformer operating at rated load (150 kVA) with 0.8 lagging power factor. Assume that $V_2 = 240$ volts and note that percent voltage regulation is given by $(V_{\text{no-load}} - V_{\text{load}})/V_{\text{load}}$ (where these are voltage magnitudes).

Note that in the below solution, “a” refers to the turns ratio $N_1/N_2$. 
9. Using the “approximate equivalent circuit #1”, shown below, repeat the calculations of problem 8 and compare the results (note again that “a” is the turns ration N1/N2).

See Figs. 2-3(a) and 2-4. Given V2 = 240 V, a = 10, and \( \theta_2 = \cos^{-1} 0.8 = -36.8^\circ \).

\[
a \cdot V_2 = 2400/0^\circ \quad V
\]

\[
I_2 = \frac{150 \times 10^3}{240} = 625 \quad A \quad \text{and} \quad \frac{I_2}{a} = 62.5/-36.8^\circ = 50 - j37.5 \quad A
\]

Also, \( a^2R_2 = 0.2 \ \Omega \) and \( a^2X_2 = 0.45 \ \Omega \), so that

\[
E_1 = (2400 + j0) + (50 - j37.5)(0.2 + j0.45)
\]

\[
= 2427 + j15 = 2427/0.35^\circ \quad V
\]

\[
I_m = \frac{2427/0.35^\circ}{1550/90^\circ} = 1.56/-89.65^\circ = 0.0095 - j1.56 \quad A
\]

\[
I_c = \frac{2427 + j15}{10 \times 10^3} = 0.2427 + j0 \quad A
\]

Therefore

\[
I_0 = I_c + I_m = 0.25 - j1.56 \quad A
\]

\[
I_1 = I_0 + (I_2/a) = 50.25 - j39.06 = 63.65/-37.85^\circ \quad A
\]

\[
V_1 = (2427 + j15) + (50.25 - j39.06)(0.2 + j0.45)
\]

\[
= 2455 + j30 = 2455/0.7^\circ \quad V
\]

\( (a) \) percent regulation = \( \frac{V_{approx} - V_{load}}{V_{load}} \times 100 \)

\[
= \frac{V_1 - a \cdot V_2}{a \cdot V_2} \times 100 = \frac{2455 - 2400}{2400} \times 100 = 2.3\%
\]

\( (b) \) efficiency = \( \frac{\text{output}}{\text{input}} = \frac{\text{output}}{\text{output} + \text{losses}} \)

output = \( (150 \times 10^3)0.8 = 120 \text{ kW} \)

losses = \( I_1^2R_1 + I_2^2R_2 + I_3^2R_2 \)

\[
= (63.65)^2(0.2) + (0.2427)^2(10 \times 10^3) + (2427)^2(2 \times 10^{-3}) = 2.18 \text{ kW}
\]

Hence

\[
\text{efficiency} = \frac{120}{122.18} = 0.982 = 98.2\%
\]
10. The coefficient of coupling for coupled coils is defined as

\[ k = \frac{M}{\sqrt{L_{11}L_{22}}} \]

(a) Show that the idea case of no-leakage flux results in \( k=1 \).
(b) Determine for the actual case, where leakage flux exists, whether \( k>1 \) or \( k<1 \).
(c) The coupled circuit below has a coefficient of coupling of 1. Determine the energy stored in the mutually coupled inductors at time \( t=5 \) msec, where \( L_{11}=2.653 \text{ mH} \) and \( L_{22}=10.61 \text{ mH} \).