Problem 1

Find the Thevenin equivalent of the circuit shown below with respect to the terminals \( a \) and \( b \).

\[
V_{TH} = \frac{50V}{R_{TH}} \quad R_{TH} = \frac{50V}{0.25mA} = 200 \Omega.
\]

\( V_{OC} \): use node voltage method

\[
\left\{ \begin{align*}
\frac{V_S - \Delta V_x}{R_1} &= \frac{\Delta V_x - \Delta V_a}{R_3} + \frac{\Delta V_x}{R_2} \\
\frac{\Delta V_x - \Delta V_a}{R_2} + \beta i_{R_2} &= \frac{\Delta V_a}{R_4}
\end{align*} \right.
\]

\[
\left\{ \begin{align*}
\left[ 1 + \frac{R_1}{R_2} + \frac{R_1}{R_3} \right] \Delta V_x &= \frac{R_1}{R_3} \Delta V_a = V_S \\
\left[ 1 + \beta \frac{R_2}{R_4} \right] \Delta V_x &= \left[ 1 + \frac{R_3}{R_4} \right] \Delta V_a
\end{align*} \right.
\]

\[
\left\{ \begin{align*}
2 \Delta V_x &= 0.5 \Delta V_a = V_S \\
5 \Delta V_x &= 1.5 \Delta V_a
\end{align*} \right.
\]

\( \Delta V_a = 50V \)

(\( \Delta V_x = 15V \))

Must find \( i_{sc} \) too, due to dependent source.

\( i_{sc} = i_{R_2} + \beta i_{R_2} \)

Need to find \( \Delta V_y \). Use NV.

\[
\frac{V_S - \Delta V_y}{R_1} = \frac{\Delta V_y}{R_2} + \frac{\Delta V_y - 0}{R_3}
\]

\[
\Delta V_y = \frac{V_S}{1 + \frac{R_2}{R_3} + \frac{R_2}{R_4}} = \frac{50V}{2} = 25V
\]

\[
i_{sc} = \frac{\Delta V_y}{R_3} + \beta \frac{\Delta V_y}{R_2} = \frac{25V}{2} + \frac{4(25V)}{2} = 62.5mA
\]
Put your final answers on this sheet and attach any additional sheets behind. You must include your work to get full credit.

Problem 2

For the op-amp circuit below, find $v_o$ in terms of $v_a$, $v_b$, and $v_c$. Assume that the op amps are ideal.

\[ v_o = 32 \, \Delta_j - 40 \, \Delta_jb + 9 \, \Delta_jc \]

1: \[ \frac{\Delta_j - \Delta_j}{R_1} = \frac{\Delta_j - \Delta_jx}{R_2} \quad \Delta_j = \Delta_jb \]

\[ \Delta_jx = (1 + \frac{R_2}{R_1}) \Delta_jb - \frac{R_2}{R_1} \Deltajc = 5 \, \Delta_jb - 4 \, \Deltajc \]

2: \[ \frac{\Delta_jx - \Delta_jc}{R_3} = \frac{\Delta_j - \Delta_j0}{R_4} \quad \Delta_j = \Deltajc \]

\[ \Delta_j0 = (1 + \frac{R_4}{R_3}) \Deltajc - \left( \frac{R_4}{R_3} \right) \Delta_jx = 9 \, \Deltajc - 5 \, \Delta_jx \]

\[ \Delta_j0 = -36 \, \Delta_ja + 40 \, \Delta_jb - 9 \, \Deltajc \]
Problem 3

In the circuit at right, the switch has been closed for a long time and then opens at $t = 0$.

The capacitor voltage equation for $t > 0$ is

$$v_c(t) = V_f - (V_f - V_i) \exp \left(-\frac{t}{RC}\right)$$

Determine the quantities for the transient equation:

$$V_f = \frac{20\text{V}}{}$$

$$V_i = \frac{16.67\text{V}}{}$$

$$\tau = RC = \frac{(2)\times(5)\times(1\mu\text{F})}{(2\text{mA})} = 2\text{ ms}.$$  

Find the time $t_1$ at which capacitor voltage is halfway between $V_i$ and $V_f$: $t_1 = 1.39\text{ ms}$.  

t < 0: Need to find $v_c$ to know initial condition.

circuit is open.  $v_c = v_i = V_i$.

Superposition:

$$v_c(t) = 10\text{V} + 6.67\text{V} e^{-\frac{t}{2\text{ms}}}$$

Halfway: $13.33\text{V} = 10\text{V} + 6.67\text{V} e^{-\frac{t}{2\text{ms}}}$

$$\Rightarrow t_1 = 2\text{ms} \ln \left[ \frac{1}{2} \right] = 1.39\text{ ms}.$$
Problem 4

In the circuit at right, the switch has been open for a long time and then closes at \( t = 0 \).

The inductor current equation for \( t > 0 \) is

\[
i_L(t) = I_f - (I_f - I_i) \exp \left(-\frac{t}{\tau}\right)
\]

Determine the quantities for the transient equation:

\( I_f = 25 \text{ mA} \) \hspace{1cm} \( I_i = 5 \text{ mA} \)

\( \tau = L/R = 22.5 \mu s \)

Find the time \( t_1 \) at which inductor current is halfway between \( I_i \) and \( I_f \): \( t_1 = 15.6 \mu s \).

For \( t > 0 \), need Norton equivalent \((I_f = I_N)\):

\[
R_N = \frac{1}{1/R_1 + 1/R_2 + \frac{1}{2\pi f L}}
\]

Store current:

\[
i_s = \frac{V_s}{R_1} + I_s
\]

\[
i_s = \frac{20}{1/\mu s} + 5 \text{ mA} = 25 \text{ mA}
\]

\[
i_s = I_f
\]

\[
i_L = 25 \text{ mA} - (20 \text{ mA}) e^{-t/22.5 \mu s}
\]

Half-way:

\[
15 \text{ mA} = 25 \text{ mA} - (20 \text{ mA}) e^{-t/22.5 \mu s}
\]

\[
= 15 \mu s = 15.6 \mu s
\]