**Problem 1:** 10 Points

Design constraint #1: Power supplied to resistors is 60W.

R₁, R₂, R₃ in series ⇒ have same current I (goes from top to bottom since 24V is + at top...)

\[ P_{\text{total}} = 60 = I^2 R_1 + I^2 R_2 + I^2 R_3 = I^2 (R_1 + R_2 + R_3) \]

\[ I = \frac{24V}{R_1 + R_2 + R_3} \]

\[ P_{\text{total}} = 60 = \frac{24^2}{(R_1 + R_2 + R_3)^2} \]

\[ (R_1 + R_2 + R_3) = \frac{576}{60} \]

\[ R_1 + R_2 + R_3 = 9.6 \ \Omega \]

Design constraint 2:

\[ V_2 - \text{Common} = 5V = 24 \cdot \frac{R_2}{R_1 + R_2 + R_3} \]

\[ R_2 = 2 \Omega \]

\[ \text{Common} - V_3 = 12V = 24 \cdot \frac{R_3}{R_1 + R_2 + R_3} \]

\[ R_3 = 4.8 \Omega \]
\[ V_1 - \text{Common} = 12 = 24 \ \frac{R_1 + R_2}{R_1 + R_2 + R_3} = 24 \left( \frac{R_1 + 2}{R_1 + R_2 + R_3} \right) = 9.6 \]

\[ R_1 = 2.8 \ \Omega \]

10 Points for correct answers
8 Points for minor math errors
5 Points for a significant error (or multiple math errors)
0 Points for multiple significant errors

Problem 2: 10 Points

There are many ways to solve this!
I used current division - first simplifying R's

\[ \frac{25 \Omega}{6 \Omega} + \frac{16 \Omega}{20 \Omega} + \frac{12 \Omega}{32 \Omega} = 60 \Omega / 80 \]

\[ I_0 = \frac{15A \cdot 40 \Omega}{40 + 60 \Omega} = 6A \]

\[ V_0 = 32 \Omega \cdot 6A = 192 \text{ V} \]

Do KVL around outside loop 3 (clockwise)

\[-V_g + (15A)(8 \Omega) + (6A)(60 \Omega) = 0 \quad V_g = 480 \text{ V} \]
10 Points for both answers correct
8 Points for math, sign, smaller error
6 Points for a significant error (or multiple math errors)
4 Points for 2 significant errors
2 Points for 3 or more

Problem 30: 20 Points

Above, I have labeled the reference node, the other nodes, values for other nodes if known, and the only unknown node voltage \( V_1 \).

KCL @ \( V_1 \):

\[
\frac{V_1 - 20}{25000} + \frac{V_1 + V_1 - 10}{250} + \frac{V_1 - 10}{500} + 11 \times 10^{-3} = 0
\]

Solve to find \( V_1 = -5 \) V

\( I_x = \frac{V_1}{250} = -20 \) mA
20 Points for correct answer
18 Points for math + minor error
16 Points for multiple math + minor errors
20 - 5n points for n significant errors
10 points if right answer, but not node voltage method (must at least have KCL @ V1)
0 points for "I x not shown" lame excuse

Problem 4: 20 Points

I have labeled the reference node, nodes with known voltages, and the two unknown node voltages V1 and V2.

KCL @ V1: Can't be done! The voltage $\pm 10$ prevents it!

KCL @ V2: Make a supernode (as shown) around source

KCL @ supernode:

$$\frac{V_1 - 15}{10} + \frac{V_1}{2} + \frac{V_2}{20} + \frac{V_2}{40} = 0$$

Inside supernode:

$$V_1 - V_2 = 5 V_\Delta$$
Extra equation defining controlling current in terms of node voltages:

\[ V_\Delta = V_1 \]

Solve these 3 equations in 3 unknowns to get:

\[ V_\Delta = 5 \text{V} \]

Same grading as Problem 4. It's ok if simplifications were made before doing node voltage analysis.

**Problem 5: 20 Points**

I first observe the above about the circuit.

Doing KVL involving \( V_T \) and the 40Ω resistor (clockwise starting at \( V_T \))

\[ V_T + (40 \Omega)(1 \text{A}) - 520 \text{V} - (4 \Omega)(0 \text{A}) = 0 \]

\[ V_T = 480 \text{V} \]
Turn off sources to find $R_T$.

What does an attached circuit see?

16 Ω Cannot carry current - has no effect
260 Ω is in parallel with wire - becomes wire

$R_T = 50 \, \Omega$

20 points for both answers correct
(10 points for each $V_T$ and $R_T$)

$V_T$: 8 points for minor/maths error
5 points for major or multiple maths error
0 points for more than 2 major errors

$R_T$: Same grading
Turning off sources wrong is a major error
Problem 6: 20 Points

Since no independent sources are present,

\[ V_T = 0 \]

Find \( R_T \) by applying test voltage,

\[ R_T = \frac{V_{\text{TEST}}}{I_{\text{TEST}}} \]

\[ \text{Do node-voltage analysis with indicated ground node:} \]

KCL@ \( V_1 \)

KCL@ \( V_{\text{TEST}} \)

Supernode around source:

\[ -2I_\Delta + I_\Delta + \frac{V_{\text{TEST}}}{10} - I_{\text{TEST}} = 0 \]

Inside supernode:

\[ V_{\text{TEST}} - V_1 = 300 I_\Delta \]

Definition of controlling current \( I_\Delta \):

\[ I_\Delta = \frac{V_1}{700} \]

Subs above in 2nd above:

\[ V_{\text{TEST}} - 700I_\Delta = 300I_\Delta \Rightarrow I_\Delta = \frac{V_{\text{TEST}}}{1000} \]
Subs in KCL:
\[-20 \left( \frac{V_{\text{TEST}}}{1000} \right) + \frac{V_{\text{TEST}}}{10} = I_{\text{TEST}} \]

\[-20 V_{\text{TEST}} + 100 V_{\text{TEST}} = I_{\text{TEST}} \cdot 1000 \]

\[80 V_{\text{TEST}} = 1000 I_{\text{TEST}} \]

\[\frac{V_{\text{TEST}}}{I_{\text{TEST}}} = R_T = \frac{1000}{80} = 12.5 \Omega \]

20 Points for correct answer
18 for minor math error
20 - 5n for each major error
15 for multiple math errors