Work the exam on the space provided below the problem. Work on one side of your paper only. Problems 1 through 4 are 20% each. Problem 5 is 10%. Take home problem is 10%.

(1) Determine the value of $V_S$ in the opamp circuit of Figure 1 so that $V_O = -2$ V.

![Circuit Diagram]

Figure 1: Circuit for problem 1.

\[
\begin{align*}
4\text{ At A} & \\
\frac{V_A - V_S}{15k} + \frac{V_A - 1}{30k} &= 0 \\
3V_A &= 2V_S + 1 \\
V_A &= \left[\frac{2V_S + 1}{3}\right] \quad (1)
\end{align*}
\]

\[
4\text{ At B} \\
V_B = V_A;\text { write a node equation} \\
\left[\frac{2V_S + 1}{3}\right] + \left[\frac{2V_S + 1}{3} - V_O\right] = 0
\]
11) continue

\[ 2V_3 + 1 + \frac{2V_2 + 1}{3} - V_0 = 0 \]

\[ 6V_3 + 3 + 2V_2 + 1 - 3V_0 = 0 \]

\[ 8V_3 = 3V_0 - 4 \]

\[ V_5 = \frac{3V_0 - 4}{8} \]

\[ V_0 = \frac{-10}{8} \]

\[ V = -1.25V \]
(2) You are given the circuit shown in Figure 2.
(a) Find the Thevenin equivalent circuit, with respect to terminals a-b.
(b) Draw the Thevenin equivalent circuit: include $V_{TH}$ and $R_{TH}$.
(c) What resistor placed between terminals a-b will give maximum power
   Transfer to this resistor? Determine the value of this power.

![Circuit Diagram]

Figure 2: Circuit for problem 2.

(a) First find $R_{TH}$.

\[
\frac{8 \Omega \parallel 12 \Omega}{20} = \frac{48 \Omega}{12} = 8 \Omega
\]

\[
R_{TH} = \frac{30 \Omega \parallel 10 \Omega}{40} = \frac{300 \Omega}{40} = 7.5 \Omega
\]

Using mesh:

\[
\begin{bmatrix}
20 & -8 \\
-8 & 43.2
\end{bmatrix}
\begin{bmatrix}
\lambda_1 \\
\lambda_2
\end{bmatrix}
= 
\begin{bmatrix}
500 \\
0
\end{bmatrix}
\]

\[
\lambda_1 = 2.7 \text{A} \quad \lambda_2 = 5 \text{A}
\]
\[ V_{ab} = 12x + 5.2x \]
\[ = 12 \times 27 + 5.2 \times 5 \]
\[ = 350 \text{V} \]

\[ V_{ab} = V_{TH} = 350 \text{V} \]

1b)

![Electrical Circuit Diagram]

1c) FOR max PWR X freq.

\[ V_0 = \frac{350}{2} = 175 \text{V} \]

\[ P_0 = \frac{V_0^2}{7.5} = \frac{175^2}{7.5} = 4083 \text{W} \]

\[ P_o = 4083 \text{W} \]
(3) You are given the circuit of Figure 3.

(a) Find the Norton equivalent circuit with respect to terminals a-b. You are required to find \( I_{\text{Norton}} \) by actually finding the short circuit current.

(b) Draw your Norton equivalent circuit showing the \( I_{\text{Norton}} \), \( R_{\text{TH}} \) and terminals a-b.

![Figure 3: Circuit for problem 3.](image)

(a) The circuit can be redrawn as follows:

\[
R_{\text{TH}} = \frac{30k \times 20k}{50k} = 12k
\]

Shorting \( a-b \) shorts out the 20k resistor. The circuit becomes (with a source transformation):

\[
I_N = -4 + 1.333 = -2.67 \text{ mA}
\]

(b) Norton Equivalent Circuit
(4) You are given the circuit of Figure 4.
(a) Give the value of the Thevenin voltage seen looking into terminals a-b.
(b) Determine the resistance $R_{\text{TH}}$ seen looking into terminals a-b.

![Circuit Diagram]

Figure 4: Circuit for problem 4.

(A) Since there are no independent sources, $V_{\text{TH}} = 0$. (It is a dead circuit).

(b) Apply a source, $V_s = 1\, V$, as shown in the diagram. Determine $I_s$. Then

$$ R_{\text{TH}} = \frac{V_s}{I_s} = \frac{1}{I_s} $$

For mesh $I_x$

\[-V_x + 8(I_x - I_s) + 5I_x + 2V_x = 0\]

\[13I_x - 8I_s + V_x = 0 \quad (1)\]

But $V_x = 2(I_s - I_x) = 2I_s - 2I_x \quad (2)$

Substitute (2) into (1)

\[13I_x - 8I_s + 2I_s - 2I_x = 0\]

\[11I_x - 6I_s = 0 \quad (3)\]
(4) Continue

For mesh \( I_0 \)

\[
-1 + 30 I_0 - 10 I_x = 0
\]

\[
-10 I_x + 30 I_0 = 1 \quad (4)
\]

\[
\begin{bmatrix}
11 & -6 \\
-10 & 30
\end{bmatrix}
\begin{bmatrix}
I_x \\
I_0
\end{bmatrix} =
\begin{bmatrix}
0 \\
1
\end{bmatrix}
\]

\( I_0 = 0.0407 \text{ A} \)

\( R_{TH} = \frac{1}{0.0407} \approx 24.5 \Omega \)

(c)
Find the voltage across each capacitor in the circuit shown in Figure 5.

\[
C_{ab} = \left(\frac{20 \times 80}{20 + 80}\right) \mu F = 16 \mu F
\]

\[
C_{cd} = 14 \mu F + 16 \mu F = 30 \mu F
\]

\[
C_{ce} = \frac{60 \times 30}{60 + 30} \mu F = 20 \mu F
\]

\[V_{30} = 180 \text{ V}\]

\[V_{60} = \left(\frac{180 \times 30}{60 + 30}\right) = 60 \text{ V}\]

\[V_{14} = 180 - V_{60} = 120 \text{ V}\]

\[V_{20} = \frac{V_{14} \times 80}{80 + 20} = 96 \text{ V}\]

\[V_{3b} = V_{14} - 96 = 24 \text{ V}\]