SCR

1) Assume a firing angle of 50 degrees. Determine the voltages (DC and AC) at V1 and V2.

\[
\begin{align*}
V_1 & \approx \frac{1}{\pi} \left( \int_0^{0.8272} (-0.7) \cdot dt + \int_{0.8272}^{\pi} 169.7 \sin(t) \cdot dt \right) \\
V_1 & \approx \frac{1}{\pi} (-0.579 + 169.7 \cos(0)) \\
V_1 & \approx -0.1843 + 54.01 (1 + \cos(50^\circ)) \\
V_1 & \approx 88.55V
\end{align*}
\]

note: The voltage is large enough that the 0.7V drop from the diode for 50 degrees doesn't have much effect on the output. You could also use

\[
V_1 \approx \left( \frac{1 + \cos \theta}{\pi} \right) V_p
\]

\[
V_1 \approx 88.74V
\]
AC:

\[ \text{max}(V_1) = 169.7 - 1.4 = 168.3V \]
\[ \text{min}(V_1) = -0.7V \]
\[ V_{1pp} = 169V_{pp} \]

At V2:

\[ \omega = 120Hz = 754 \frac{\text{rad}}{\text{sec}} \]
\[ L \rightarrow j\omega L = j75.4\Omega \]
\[ C \rightarrow \frac{1}{j\omega C} = -j0.66\Omega \]

\( R \) in parallel with \( C \) is

\[ \left( \frac{1}{5} + \frac{1}{-j0.66} \right)^{-1} = 0.0864 - j0.6571\Omega \]

By voltage division

\[ V_{2pp} = \left( \frac{0.0864 - j0.6571}{(0.0864 - j0.6571) + j75.4} \right) V_{1pp} \]

\[ V_{2pp} = 1.486 \angle -172^0 \]

All we care about is the amplitude

\[ V_2 = 1.486V_{pp} \]
2) (Not Assigned). Use a transistor as a switch to turn on and off a full-wave rectified sine wave.

- NPN transistors act as switches to ground: (+Vcc = on, 0V = off)
- PNP transistors act as switches to power: (+Vcc = off, 0V = on)

For a resistive load, this results in ...

Looks good: Adding in C and L
V2(DC) = 83V (approx)
V2(AC) = 1.22Vpp (approx)
3) Determine the firing angle, $C$, and $L$ so that

The DC voltage at the load is 50V

\[ V_1 \approx \left( \frac{1 + \cos \theta}{\pi} \right) V_p \]

\[ 50 \approx \left( \frac{1 + \cos \theta}{\pi} \right) 169 \]

\[ \theta = 94.04^0 \]

The ripple at the load is 1Vpp

\[
\text{max } (V_1) = 169.7 \cdot \sin (94.04^0) - 1.4V \\
\text{max}(V_1) = 167.9V \\
\text{min}(V_1) = -0.7V \\
V_{1pp} = 168.6V_{pp}
\]

Pick $L$ to make the ripple 20x smaller (somewhat arbitrary)

\[ |j\omega L| = 20R \]

\[ \omega L = 100 \]

\[ L = \frac{100}{754} = 132.6mH \]

This should result in a ripple at $V_2$ that is 20x smaller

\[ V_2 = \frac{168.6}{20} = 8.42V_{pp} \]

To bring the ripple down to 1Vpp, add a capacitor which is 8.42 times smaller than $R$

\[ \frac{1}{\omega C} = \frac{1}{8.42} \cdot 5\Omega \]

\[ \frac{1}{\omega C} = 0.5932 \]

\[ C = 2235\mu F \]
4) For the following op-amp circuit with a gain of 'only' 2000:

![Op-amp Circuit Diagram]

a) Write the voltage node equations

\[
\begin{align*}
\frac{V_p - 2}{1k} + \frac{V_p}{2M} &= 0 \\
\frac{V_m}{2M} + \frac{V_m}{1k} + \frac{V_m - Y}{2k} &= 0 \\
\frac{Y - V_3}{75} + \frac{Y - V_m}{2k} + \frac{Y}{1k} &= 0
\end{align*}
\]

\[V_3 = 2000(V_p - V_m)\]

b) Solve for the voltages at Vp, Vm, and Y

Multiply each equation by 1000 and separate terms

\[
\begin{align*}
1.005V_p &= 2 \\
1.5005V_m - 0.5Y &= 0 \\
14.8333Y - 13.333V_3 - 0.5V_m &= 0 \\
V_3 - 2000V_p + 2000V_m &= 0
\end{align*}
\]

Place in matrix form

\[
\begin{bmatrix}
1.005 & 0 & 0 & 0 \\
0 & 1.5005 & 0 & -0.5 \\
0 & -0.5 & -13.333 & 14.8333 \\
-2000 & 2000 & 1 & 0
\end{bmatrix}
\begin{bmatrix}
V_p \\
V_m \\
V_3 \\
Y
\end{bmatrix}
= 
\begin{bmatrix}
2 \\
0 \\
0 \\
0
\end{bmatrix}
\]

Solve

\[
A = \begin{bmatrix}
1.005, 0, 0, 0 ; 0, 1.5005, 0, -0.5 ; 0, -0.5, -13.333, 14.8333 ; -2000, 2000, 1, 0
\end{bmatrix}
\]

A = 

\[
\begin{bmatrix}
1.005 & 0 & 0 & 0 \\
0 & 1.5005 & 0 & -0.5
\end{bmatrix}
\]
\[
\begin{bmatrix}
0. & -0.5 & -13.333 & 14.8333 \\
\end{bmatrix}
\]

\[\rightarrow \mathbf{B} = [2;0;0;0] \]

\[\mathbf{B} = \\
2. \\
0. \\
0. \\
0.
\]

\[\rightarrow \mathbf{V} = \text{inv}(A) \times \mathbf{B} \]

\[\mathbf{V} = \\
1.9900498 \; \text{Vp} \\
1.9867705 \; \text{Vm} \\
6.5585677 \; \text{V3} \\
5.9622982 \; \text{Y}
\]
5) For the following op-amp circuit
   - a) Write the voltage node equations
   - b) Solve for the voltages at \( V_p, V_m, \) and \( Y \)

Assume an ideal op-amp.

\[
V_p = 2V \\
V_p = V_m \\
\left( \frac{V_m}{1k} \right) + \left( \frac{V_m - Y}{2k} \right) = 0
\]

Solving
\[
Y = \left( 1 + \frac{2k}{1k} \right) 2V \\
Y = 6V
\]

The previous answer was 5.9622V. About the same
6) Assume ideal op-amps. Write the voltage node equations for the following circuit

![Circuit Diagram]

The impedance of a capacitor is \( \frac{1}{C_s} \)

\[
V_3 = V_2 \\
\left( \frac{V_1-V_0}{R} \right) + \left( \frac{V_1-V_2}{R} \right) + \left( \frac{V_1-V_4}{1/C_s} \right) = 0 \\
\left( \frac{V_2-V_1}{R} \right) + \left( \frac{V_2}{1/C_s} \right) = 0 \\
\left( \frac{V_2}{R_b} \right) + \left( \frac{V_3-V_4}{R_a} \right) = 0
\]