1. Consider the parallel resonant circuit with $L = 1$ mH and phasor $I_S = I_m(\text{rms}) \angle 0^\circ$. Assume $R_s >> R$, so that $R_s$ and $V_s$ act as a source of constant current $I_s$.

   a) Calculate the value of the capacitor $C$ such that the resonant frequency $f_0 = 50$ kHz.

   b) Calculate the value of the resistor $R$ such that the bandwidth $B = 5$ kHz.

   c) Calculate the lower half-power frequency $f_1$ and upper half-power frequency $f_2$ in Hz. If possible, use the approximation $f_0 \pm B/2$. 
d) Calculate the $Q$ factor for the circuit.

e) Find theoretical expression for the magnitude for the phasor common voltage $|V_R|$ as a function of frequency $f$, and in terms of $I_m$. Evaluate at $f = f_o$ for $I_m = 0.1$ mA.

**Resonant Circuit with Loading**

2. Suppose the resonant circuit is modified so that a load resistor $R_L$ is connected across $R$. In a practical sense, resistor $R_L$ might represent the input resistance of some load on the RLC network.

![Resonant Circuit Diagram]

a) For $R_L = 3500 \, \Omega$, re-calculate the values of $Q$, $B$, and $|V_o(f_o)|$ for $I_m = 0.1$ mA.

b) In order to avoid deterioration of $Q$-value, should $R_L$ be large or small (compared to what)? Consider its effect on the resonant frequency, bandwidth, and $Q$ of the ideal parallel resonant circuit.
OPERATIONAL AMPLIFIER

3. Add an operational amplifier circuit to the resonant circuit from section 2 of this PreLab, so that the load $R_L$ is at the output of the Op Amp.

![Circuit Diagram]

**Hint**

a) Using an ideal Op Amp and $R_L = 3500 \, \Omega$, design a non-inverting amplifier circuit to go inside the box labeled “OP AMP Circuit” (hint provided on the right side). Choose $I_m = 0.1 \, mA$ and make $|V_o| = 5.0 \, V$ at $f_o$. Give a complete schematic of your design and carefully label all components. Show your calculations.

b) Now what are the new values of $f_o$, $B$ and $Q$?

FILTER DESIGN

4. Design your own filter: low pass, high pass, band pass or band stop (choose one), with the cutoff frequency / bandwidth of your choice.
   Attach hand calculations and hand-drawn Bode plots.
   Simulate your filter in Cadence and attach printouts.
   You may search literature or web for the filter design (include the reference) or you may ‘play’ with the Cadence until you are satisfied with your filter design. We are not pre-assigning the filter type; that will be done in the 300-level classes. The only requirement is that your filter should be different from any design already analyzed in class, homework or in the lab.
APPENDIX: SERIES RESISTANCE OF REAL INDUCTORS

Real inductors are constructed from a coil of fine wire wound on a magnetic core. The coil always exhibits some non-zero resistance $R_{\text{ind}}$ which is due to the series resistance of the wire in the many windings of the coil. We can model the real inductor by an ideal inductor $L$ in series with an ideal resistor $R_{\text{ind}}$, or we can convert the series connection to the parallel connection of a new inductor $L_P$ and resistor $R_P$, as shown below. In order for the two circuits to be equivalent, the impedance for the series circuit between terminals A-B must equal the impedance for the parallel circuit between A-B,

$\begin{align*}
R_{\text{ind}} + j\omega L &= \frac{R_P(j\omega L_P)}{R_P + j\omega L_P} \\
\end{align*}$

Equating the real and imaginary parts yields expressions for the parallel components:

$\begin{align*}
R_P &= \frac{R_{\text{ind}}^2 + \omega^2 L^2}{R_{\text{ind}}} \\
L_P &= \frac{R_{\text{ind}}^2 + \omega^2 L^2}{\omega^2 L} \\
\end{align*}$

Although $R_P$ and $L_P$ depend on frequency and thus are non-ideal elements, we can use the above expressions to estimate the effects of $R_{\text{ind}}$ in a real inductor used in a parallel RLC circuit. Note that $R_P$ will appear in parallel with the resistance $R$ in the RLC circuit, effectively reducing $R$ and degrading the $Q$ of the resonant circuit.