1. Consider the high-pass RC filter circuit:

When $v_{in}(t) = V_{in}e^{i\omega t}$, the Thevenin equivalent circuit would consist of an ideal voltage source $V_{Th}$ in series with an impedance $Z_{Th}$, both of which depend on the frequency, $\omega$.

(a) With no additional load across the resistor, calculate $V_{out}$. How does $V_{out}$ behave in the low-frequency ($\omega \ll 1/RC$) and high-frequency ($\omega \gg 1/RC$) limits?

(b) Calculate the Thevenin equivalent impedance $Z_{Th}$ for the circuit where the impedance of the resistor is $R$ and the impedance of the capacitor is $i/\omega C$. How does $Z_{Th}$ behave in the low-frequency and high-frequency limits?

2. Consider the following low-pass filter circuit:

(a) Assuming $v_{in}(t) = V_{in}e^{i\omega t}$ and $v_{out} = V_{out}e^{i\omega t}$, solve for the magnitude of $V_{out}$ in terms of $V_{in}$, $R$, $L$, and $C$.

(b) In principle, this circuit could have a resonance if $R$ is too big. Assuming that $R$ is large enough that it can be ignored, estimate the resonant frequency, $\omega_0$.

(c) If this circuit is intended to form a low-pass filter, what value of $R$ would be needed to provide a gain of $-3$ db at the frequency calculated in part (b)?

(d) At high frequencies, how many deci-Bells per decade of frequency does this circuit attenuate? Compare this with the result for a first-order RC or RL low-pass filter.
3. Using the nodes listed on the circuit in the previous question and using the component values

\[
L = 10 \mu\text{H} \\
C = 2.53 \text{ nF} \\
R = 44.4 \Omega
\]

use SPICE to calculate the magnitude of the voltage gain as follows:

- The AC voltage source is described using
  \[
  \text{Vxxx} \ <\text{N+}> <\text{N}-> <\text{DC offset}> \text{ AC}
  \]
  where you should set the DC offset to zero in this case.

- The magnitude of the voltage across the resistor is graphed using
  \[
  \text{.PRINT AC VM(2)}
  \]

- The frequency response is analysed using the \text{.AC} command:
  \[
  \text{.AC DEC 10 1K 10MEG}
  \]
  which will calculate the response at ten points per decade between the frequencies of 1 kHz and 10 MHz.

(a) Write the SPICE netlist that describes this circuit.
(b) Hand in a plot of the voltage gain across \( R \) as a function of frequency. At what frequency (in Hz) is the gain approximately equal to \(-3 \text{ db}\)? How does this frequency compare with the calculation performed in question 2?
(c) Provide graphs of the voltage gain as a function of frequency when \( R = 50 \Omega \), \( R = 100\Omega \) and \( R = 1 \text{ k}\Omega \). Compare these frequencies with the results of the calculation performed in question 2.