1. In the terminated two-port shown below, the input impedance is $Z_1$.
   
   a. At what frequencies is $Z_1 = R$ for all values of $R$?
   
   b. For what value of $R$ does $Z_1 = R$ hold at all frequencies? Why?

![Circuit Diagram](image)

2. What is the input impedance of the circuit shown below? What are its possible applications?

![Circuit Diagram](image)
3. (Extra credit) Find all node voltages in the circuit shown below.
1. In the terminated two-port shown below, the input impedance is $Z_1$.

a. At what frequencies is $Z_1 = R$ for all values of $R$?

b. For what value of $R$ does $Z_1 = R$ hold at all frequencies? Why?

\[ Z_1 = \frac{Z_{11} + \frac{1}{sC}}{Z_{12}} = \frac{1}{Z_{11} + \frac{1}{sC}} \]

1. \[ Z_{11} = \frac{1}{2} \left[ \frac{1}{sC} + sL \right] = Z_{22} \]

2. \[ Z_{12} = \frac{1}{2} \left[ \frac{1}{sC} - sL \right] = Z_{21} \]

\[ Z_1 = Z_{11} - \frac{Z_{12} Z_{21}}{Z_{22} + R} = R \left( \frac{Z_{11} + \frac{1}{sC}}{Z_{11} + sC} \right) \]

a. By inspection, $Z_{11} \to \infty$ for $s = 0$ or $s \to \infty$, so $Z_1 \to R$

b. If $\left( \frac{1}{sC} / R = R \right)$, or $L / C = R^2$

\[ Z_1(s) = R \forall s, \quad R = 1.732 \, k\Omega \]

1. \[ R = Z_{11} - \frac{Z_{12}^2}{Z_{11} + R} \]

2. \[ R^2 - Z_{11} = -Z_{12}^2 \]

\[ R^2 = sL, \quad 1/sC = 1/C \]
2. The input admittance of the active branch

\[ I = \frac{-V}{R_1 R_L} \frac{R_2}{V(1 + \frac{R_2}{R_L})} \]  

\[ V_{in} = \frac{R_2}{R_1 R_L} V \]

Negative conductance may cancel \( 1/R \rightarrow \) oscillator, high-\( Q \) filter

Overall

\[ Z_1 = \frac{1}{1/sL + sC + 1/R - R_2/R_1 R_L} \]
3. (Extra credit) Find all node voltages in the circuit shown below.

\[ E = 2V \]

\[ 1 \rightarrow 2/16 = 1/8 \ V \]

So the node voltages are

2, 1, 0.5, 0.25 and 0.125 V

Or: Resistance after node = 2R

So, at second node, \( V_2 = V_1/2 = E/2 \)

at 3rd node, \( V_3 = E/4 \), etc.