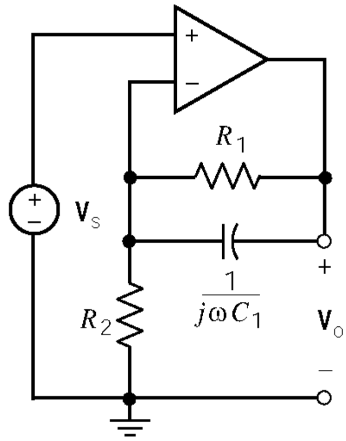
P 13.2-18
Solution:

Represent the circuit in the frequency domain. Apply KCL at the inverting input node of the op amp to get



$$\frac{\mathbf{V}_o - \mathbf{V}_s}{R_1} + j\omega C_1\left(\mathbf{V}_o - \mathbf{V}_s\right) - \frac{\mathbf{V}_s}{R_2} = 0$$

or

$$\left(R_1 + R_2 + j\omega C_1 R_1 R_2\right)\mathbf{V}_s = \left(R_2 + j\omega C_1 R_1 R_2\right)\mathbf{V}_o$$

so

$$\mathbf{H} = \frac{\mathbf{V}_o}{\mathbf{V}_s} = \frac{R_1 + R_2 + j\omega C_1 R_1 R_2}{R_2 + j\omega C_1 R_1 R_2} = \frac{R_1 + R_2}{R_2} \times \frac{1 + j\omega C_1 \dfrac{R_1 R_2}{R_1 + R_2}}{1 + j\omega C_1 R_1}$$

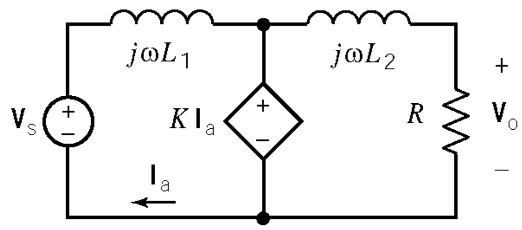
With the given values

$$\mathbf{H} = \frac{\mathbf{V}_o}{\mathbf{V}_s} = \frac{7}{2} - \frac{1 + \dfrac{j\omega}{7}}{1 + \dfrac{j\omega}{2}}$$

P 13.2-21

Solution:

Represent the circuit in the frequency domain. Apply KVL to the left mesh to get



$$\mathbf{V}_s = j\omega L_1 \mathbf{I}_a + K\mathbf{I}_a \quad \Rightarrow \quad \mathbf{I}_a = \frac{\mathbf{V}_s}{K + j\omega L_1}$$

Voltage division gives

$$\mathbf{V}_o = \frac{R}{R + j\omega L_2} K\mathbf{I}_a = \frac{R}{R + j\omega L_2} K\left(\frac{\mathbf{V}_s}{K + j\omega L_1}\right) = \frac{RK}{\left(R + j\omega L_2\right)\left(K + j\omega L_1\right)}\mathbf{V}_s$$

The network function of the circuit is

$$\mathbf{H}=\frac{\mathbf{V}_o}{\mathbf{V}_s}=\frac{1}{\left(1+j\omega\frac{L_2}{R}\right)\left(1+j\omega\frac{L_1}{K}\right)}$$

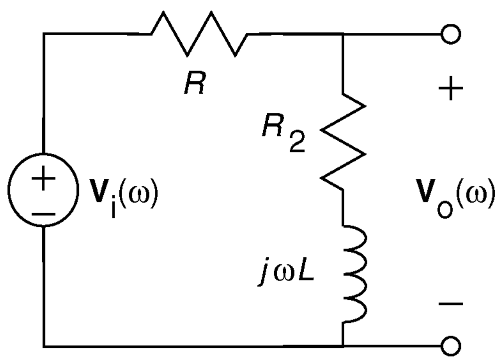
Comparing this network function to the specified network function gives

$$\frac{L_2}{R}=\frac{1}{30}\ \text{ and }\ \frac{L_1}{K}=\frac{1}{60}\quad\text{or}\quad\frac{L_2}{R}=\frac{1}{60}\ \text{ and }\ \frac{L_1}{K}=\frac{1}{30}$$

These equations do not have a unique solution. One solution is

$$L_1 = 0.07\text{ H},\quad L_2 = 0.16\text{ H},\quad R = 5\ \Omega \text{ and } K = 2\text{ V/A}$$

P 13.3-6
Solution:



$$\mathbf{H}(\omega)=\frac{\mathbf{V}_o(\omega)}{\mathbf{V}_i(\omega)}=\frac{R_2+j\omega L}{R+R_2+j\omega L}$$

$$=\left(\frac{R_2}{R+R_2}\right)\left(\frac{1+j\omega\frac{L}{R_2}}{1+j\omega\frac{L}{R+R_2}}\right)$$

$$\mathbf{H}(\omega)=\frac{(0.2)(1+j(0.2)\omega)}{1+j(0.04)\omega}\quad\Rightarrow\quad\begin{cases}k=0.2\\ z=\frac{1}{0.2}=5\\ p=\frac{1}{0.04}=25\end{cases}$$

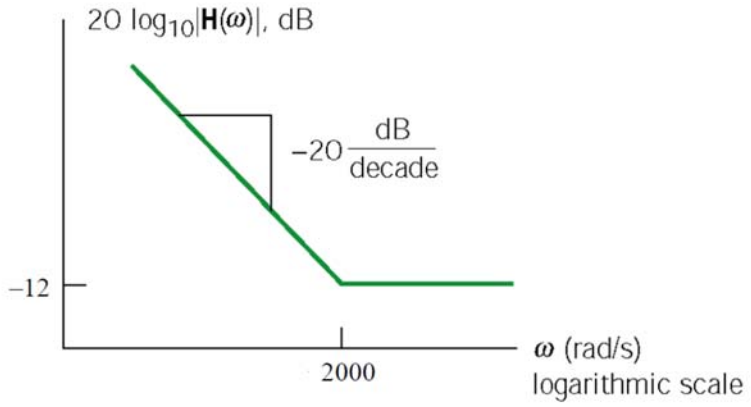
P 13.3-11
Solution:

$$\mathbf{H}(\omega)=-\frac{\frac{1}{j\omega C_2}}{R_1\left\|\frac{1}{j\omega C_1}\right.}=-\frac{1+j\omega R_1C_1}{j\omega R_1C_2}=-\frac{1}{R_1C_2}\frac{(1+j\omega R_1C_1)}{j\omega}$$

$$\mathbf{H}(\omega) \simeq \begin{cases} -\dfrac{1}{R_1 C_2}\left(\dfrac{1}{j\omega}\right) & \omega < \dfrac{1}{R_1 C_1} \\ -\dfrac{1}{R_1 C_2}\left(R_1 C_1\right) = -\dfrac{C_1}{C_2} & \omega > \dfrac{1}{R_1 C_1} \end{cases}$$

With the given values:

$$20\log\left(\frac{C_1}{C_2}\right) = 20\log\left(0.25\right) = -12 \text{ dB}, \quad \frac{1}{R_1 C_1} = 2000 \text{ rad/s}$$



P 13.4-2

Solution: For the parallel resonant *RLC* circuit we have

$$\left|\mathbf{H}(\omega)\right| = \frac{k}{\sqrt{1+Q^2\left(\dfrac{\omega}{\omega_0}-\dfrac{\omega_0}{\omega}\right)^2}}$$

so

$$R = k = \left|\mathbf{H}(\omega_0)\right| = \frac{8}{20{\cdot}10^{-3}} = 400\ \Omega \ \text{ and } \ \omega_0 = 1000 \ \text{ rad/s}$$

At $\omega = 897.6$ rad/s, $\left|\mathbf{H}(\omega)\right| = \dfrac{4}{20.10^{-3}} = 200$, so

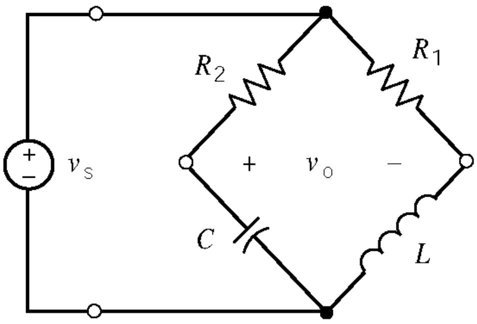
$$200 = \frac{400}{\sqrt{1+Q^2\left(\dfrac{897.6}{1000}-\dfrac{1000}{897.6}\right)^2}} \quad \Rightarrow \quad Q = 8$$

Then

$$\left.\begin{array}{l}\dfrac{1}{\sqrt{LC}} = \omega_0 = 1000 \\ 400\sqrt{\dfrac{C}{L}} = Q = 8\end{array}\right\} \Rightarrow \begin{array}{l} C = 20\ \mu\text{F} \\ L = 50\ \text{mH}\end{array}$$

P 13.6-1

Solution:



Using voltage division twice gives

$$\mathbf{V}_o(\omega) = \frac{\dfrac{1}{j\omega C}}{R_2 + \dfrac{1}{j\omega C}} \mathbf{V}_s(\omega) - \frac{j\omega L}{R_1 + j\omega L} \mathbf{V}_s(\omega)$$

so

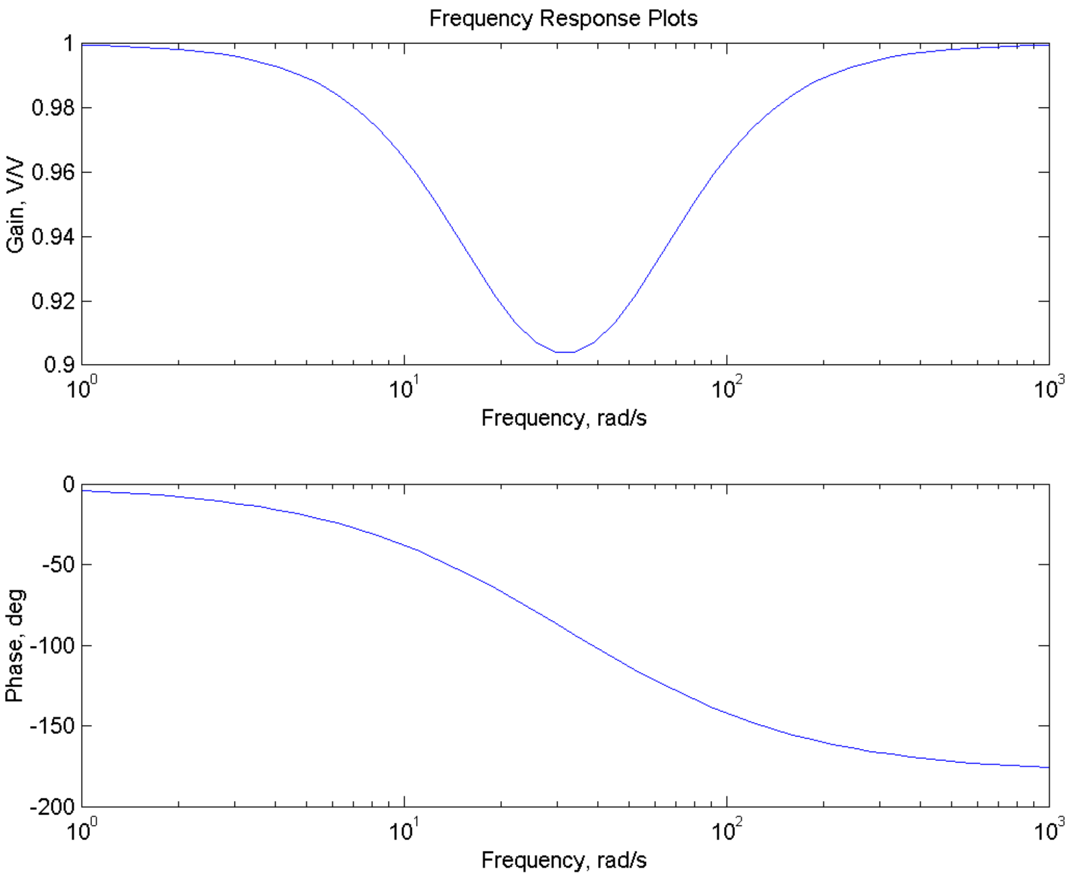
$$\mathbf{H}(\omega) = \frac{\mathbf{V}_o(\omega)}{\mathbf{V}_s(\omega)} = \frac{1}{1 + j\omega C R_2} - \frac{j\omega L}{R_1 + j\omega L}$$

Modify the MATLAB script given in Section 13.7 of the text:

```
% P13_7_1.m - plot the gain and phase shift of a circuit

%--------------------------------------------------------------
%    Create a list of logarithmically spaced frequencies.
%--------------------------------------------------------------

wmin=1;      % starting frequency, rad/s
wmax=1000;    % ending frequency, rad/s

w = logspace(log10(wmin),log10(wmax));

%--------------------------------------------------------------
%   Enter values of the parameters that describe the circuit.
%--------------------------------------------------------------
```

```
R1 = 10;   % Ohms
R2 = 20;   % Ohms
C = 0.001; % Farads
L = 0.5;   % Henries

%----------------------------------------------------------------
% Calculate the value of the network function at each frequency.
%   Calculate the magnitude and angle of the network function.
%----------------------------------------------------------------

for k=1:length(w)
   H(k) = 1/(1+j*R2*C*w(k)) - j*L*w(k)/(R1+j*L*w(k));
   gain(k) = abs(H(k));
   phase(k) = angle(H(k))*180/pi;
end

%----------------------------------------------------------------
%                Plot the frequency response.
%----------------------------------------------------------------

subplot(2,1,1), semilogx(w, gain)
xlabel('Frequency, rad/s'), ylabel('Gain, V/V')
title('Frequency Response Plots')
subplot(2,1,2), semilogx(w, phase)
xlabel('Frequency, rad/s'), ylabel('Phase, deg')
```

Here are the plots produced by MATLAB:


Frequency Response Plots
Gain, V/V
1
0.98
0.96
0.94
0.92
0.9
10^0
10^1
10^2
10^3
Frequency, rad/s
Phase, deg
0
-50
-100
-150
-200
10^0
10^1
10^2
10^3
Frequency, rad/s