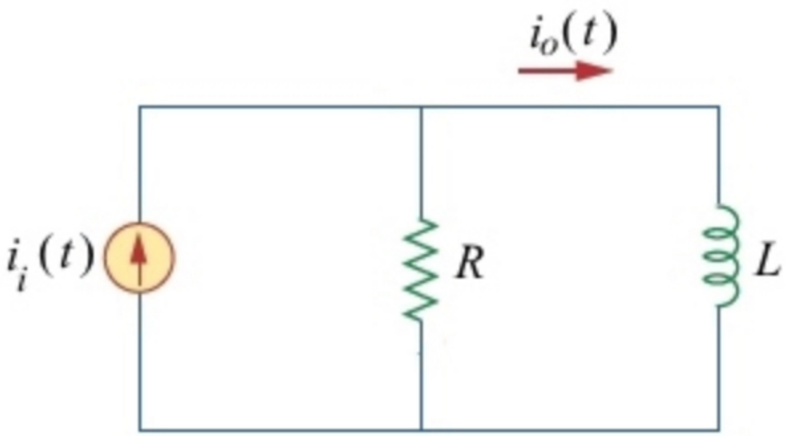
1.

value:
10.00 points

Identify the transfer function I_o/I_i of the *RL* circuit shown below. Express the transfer function using $\omega_o = R/L$.



→ ○ $H(\omega) = \frac{1}{1 + j\frac{\omega}{\omega_o}}$

○ $H(\omega) = \frac{1}{j + \frac{\omega_o}{\omega}}$

○ $H(\omega) = \frac{1}{1 + j\frac{\omega_o}{\omega}}$

○ $H(\omega) = \frac{j\omega}{1 + \frac{\omega}{\omega_o}}$

$$H(\omega) = \frac{I_o}{I_i} = \frac{\left(\frac{Rj\omega L}{R + j\omega L}\right)}{j\omega L} = \frac{1}{\left(1 + \frac{j\omega L}{R}\right)} \qquad \text{--(1)}$$

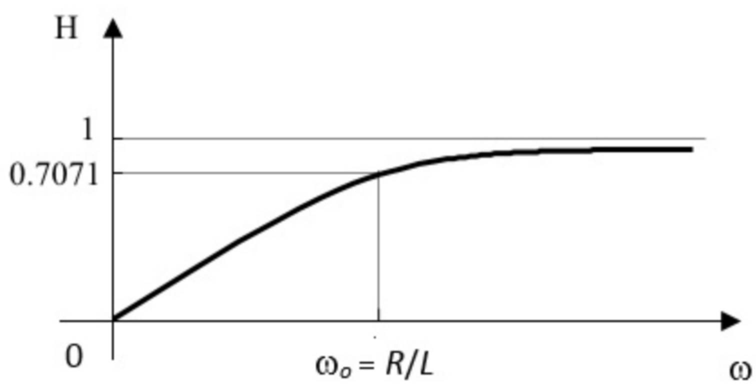
Given $\omega_o = R/L$.

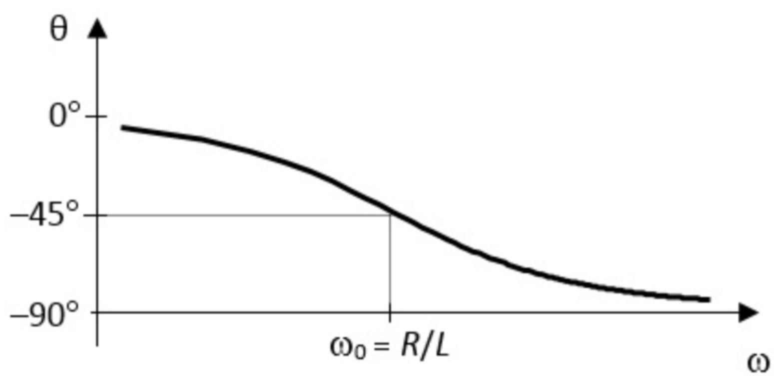
Eq.(1) becomes

$$H(\omega) = \frac{1}{1 + j\frac{\omega}{\omega_o}}$$

$$H = |H(\omega)| = \frac{1}{\sqrt{1 + \left(\frac{\omega}{\omega_o}\right)^2}} \text{ and } \theta = \angle H(\omega) = -\tan^{-1}\left(\frac{\omega}{\omega_o}\right)$$

This is a highpass filter. The sketches of H and θ are shown below.





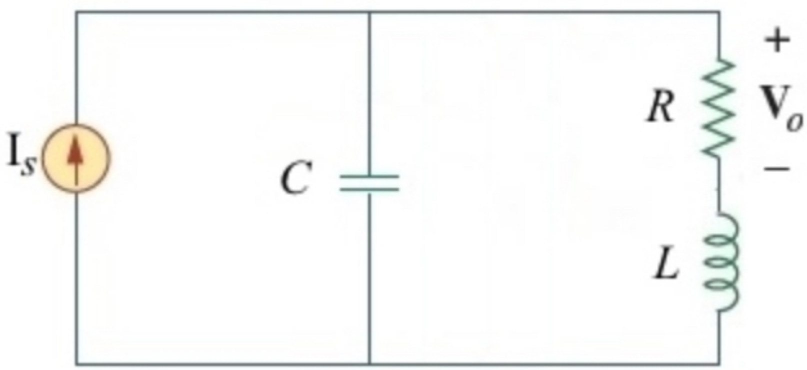
The transfer function I_o/I_i of the *RL* circuit is given by

$$H(\omega) = \frac{1}{1 + j\frac{\omega}{\omega_o}}$$

2.

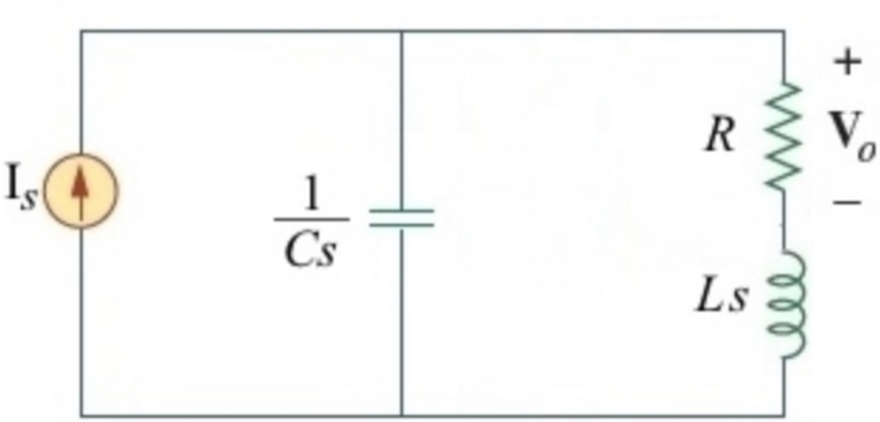
value:
10.00 points

For the circuit shown below, find H(*s*) = V_o/I_s.



- $H(s) = \frac{Ls}{(LCs^2 + 1)}$
- $H(s) = \frac{Ls}{(LCs^2 + RCs + 1)}$
- $H(s) = \frac{(Rs + L)}{(RCs^2 + LCs + 1)}$
- → $H(s) = \frac{R}{(LCs^2 + RCs + 1)}$

Let the capacitor be represented by 1/(*Cs*) and the inductor by *Ls*. Then, convert the circuit into the *s*-domain.



By current division, we can represent I_o as

$$I_o = \left(\frac{1}{Cs}\right)\left(\frac{I_s}{\left(\frac{1}{Cs}\right) + R + Ls}\right)$$

which leads to $V_o = (R)I_o$.

$$I_o = \frac{I_s}{(1 + RCs + LCs^2)} \quad \text{or} \quad V_o = \frac{(R)I_s}{(LCs^2 + RCs + 1)}$$

Therefore, H(*s*) can be written as

$$H(s) = \frac{V_o}{I_s} = \frac{R}{(LCs^2 + RCs + 1)}$$

The transfer function H(*s*) is given by

$$H(s) = \frac{R}{(LCs^2 + RCs + 1)}$$

3.

value:
10.00 points

A ladder network has a voltage gain of

$$H(\omega) = \frac{30}{(1 + j\omega)(10 + j\omega)}$$

Identify the gain H_{dB}.

- ○ $H_{dB} = 20\log_{10}|3| - 20\log_{10}|1 + j\omega| - 20\log_{10}|10 + j\omega|$
- → ○ $H_{dB} = 20\log_{10}|3| - 20\log_{10}|1 + j\omega| - 20\log_{10}|1 + j\omega/10|$
- ○ $H_{dB} = 20\log_{10}|3| - 40\log_{10}|1 + j\omega|$
- ○ $H_{dB} = 20\log_{10}|3| - 20\log_{10}|1 + j\omega| + 20\log_{10}|1 + j\omega/10|$

The given H(ω) can be rewritten as follows:

$$H(\omega) = \frac{3}{(1 + j\omega)(1 + j\omega/10)}$$

Therefore, $H_{dB} = 20\log_{10}|3| - 20\log_{10}|1 + j\omega| - 20\log_{10}|1 + j\omega/10|$.

The value of gain H_{dB} is given below.
$H_{dB} = 20\log_{10}|3| - 20\log_{10}|1 + j\omega| - 20\log_{10}|1 + j\omega/10|$.

4.

value:
10.00 points

A ladder network has a voltage gain of

$$\mathbf{H}(\omega) = \frac{30}{(1 + j\omega)(10 + j\omega)}$$

Identify the phase ϕ.

→ ○ $\phi = -\tan^{-1}(\omega) - \tan^{-1}(\omega/10)$

○ $\phi = \tan^{-1}(\omega) - \tan^{-1}(\omega/10)$

○ $\phi = \tan^{-1}(\omega) + \tan^{-1}(10\omega)$

○ $\phi = -\tan^{-1}(\omega) - \tan^{-1}(10\omega)$

The phase can be written as

$$\angle H(\omega) = \angle 20 - \angle(1 + j\omega) - \angle(1 + j\omega\,/\,10)$$
$$= 0 - \angle(1 + j\omega) - \angle(1 + j\omega\,/\,10)$$

Therefore, $\phi = -\tan^{-1}(\omega) - \tan^{-1}(\omega/10)$.

The value of phase ϕ is given below.

$\phi = -\tan^{-1}(\omega) - \tan^{-1}(\omega/10)$

5.

value:
10.00 points

Given

$$H(\omega) = \frac{175(j\omega + 1)}{j\omega(-\omega^2 + 10j\omega + 25)}$$

Identify the gain H_{dB}.

→ ○ $H_{dB} = 20\log_{10}|7| + 20\log_{10}|1 + j\omega| - 20\log_{10}|j\omega| - 20\log_{10}|1 + 2j\omega/5 + (j\omega/5)^2|$

○ $H_{dB} = 20\log_{10}|1 + j\omega| - 20\log_{10}|j\omega| - 20\log_{10}|1 + 2j\omega/5 + (j\omega/5)^2|$

○ $H_{dB} = 20\log_{10}|7| - 20\log_{10}|j\omega| - 20\log_{10}|1 + 2j\omega/5 + (j\omega/5)^2|$

○ $H_{dB} = 20\log_{10}|7| + 20\log_{10}|1 + j\omega| - 20\log_{10}|1 + 2j\omega/5 + (j\omega/5)^2|$

H(ω) can be rewritten as

$$H(\omega) = \frac{175}{25}\frac{(1 + j\omega)}{j\omega\left(1 + \frac{10}{25}j\omega + \left(\frac{j\omega}{5}\right)^2\right)}$$

Therefore, H_{dB} is calculated as follows:

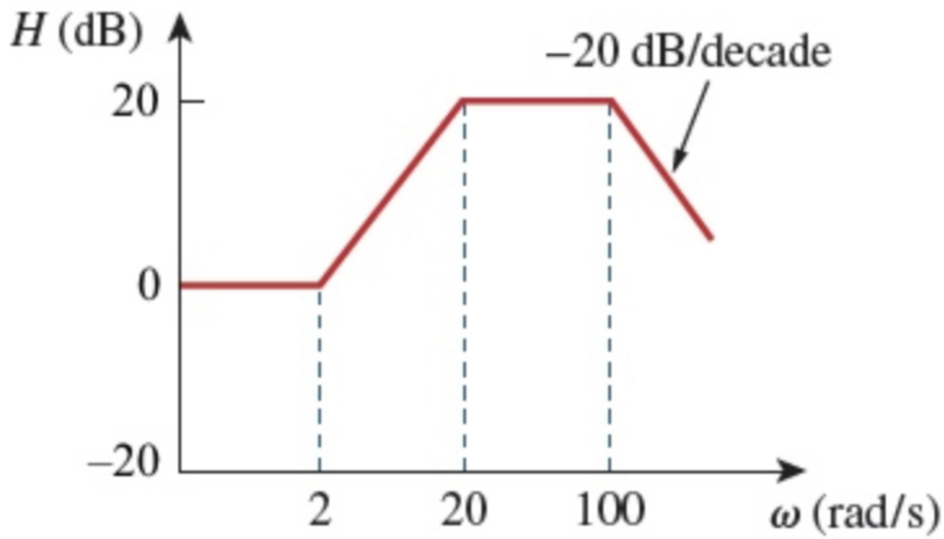
$H_{dB} = 20\log_{10}|7| + 20\log_{10}|1 + j\omega| - 20\log_{10}|j\omega| - 20\log_{10}|1 + 2j\omega/5 + (j\omega/5)^2|$

$H_{dB} = 20\log_{10}|7| + 20\log_{10}|1 + j\omega| - 20\log_{10}|j\omega| - 20\log_{10}|1 + 2j\omega/5 + (j\omega/5)^2|$

6.

value:
10.00 points

Find the transfer function H(ω) with the Bode magnitude plot shown below.



- $H(\omega) = \dfrac{(2 + j\omega)}{(20 + j\omega)(100 + j\omega)}$
- $H(\omega) = \dfrac{100(2 + j\omega)}{(20 + j\omega)(100 + j\omega)}$
- $H(\omega) = \dfrac{100(2 + j\omega)}{(20 + j\omega)(10 + j\omega)}$
- → $H(\omega) = \dfrac{1000(2 + j\omega)}{(20 + j\omega)(100 + j\omega)}$

$0 = 20 \log_{10} k \quad \rightarrow \quad k = 1$

A zero of slope +20 dB/dec at $\omega = 2 \quad \rightarrow \quad 1 + j\omega / 2$

A pole of slope –20 dB/dec at $\omega = 20 \quad \rightarrow \quad \frac{1}{1 + j\omega/20}$

A pole of slope –20 dB/dec at $\omega = 100 \quad \rightarrow \quad \frac{1}{1 + j\omega/100}$

Hence,

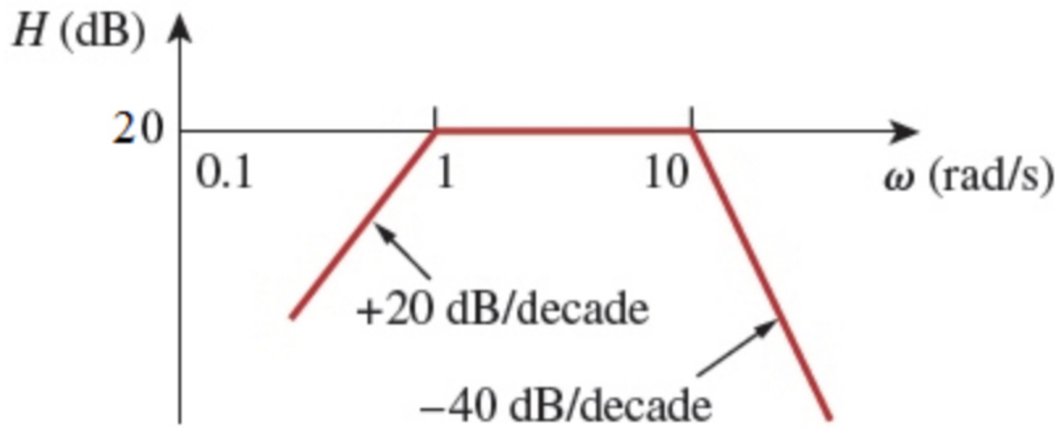
$$\mathbf{H}(\omega) = \frac{1(1 + j\omega/2)}{(1 + j\omega/20)(1 + j\omega/100)} = \frac{1000(2 + j\omega)}{(20 + j\omega)(100 + j\omega)}$$

The transfer function H(ω) is mentioned below.

$$\mathbf{H}(\omega) = \frac{1000(2 + j\omega)}{(20 + j\omega)(100 + j\omega)}$$

7. value: **10.00 points**

The Bode magnitude plot of H(ω) is shown below. Identify H(ω).



→ ○ $H(\omega) = \frac{1000j\omega}{(1 + j\omega)(10 + j\omega)^2}$

○ $H(\omega) = \frac{0.001j\omega}{(1 + j\omega)(10 + j\omega)^2}$

○ $H(\omega) = \frac{100j\omega}{(1 + j\omega)(10 + j\omega)}$

○ $H(\omega) = \frac{100j\omega}{(1 + j\omega)(10 + j\omega)^2}$

The initial slope indicates we have $j\omega$ in the numerator. Our approach to plotting requires the plot of $j\omega$ to cross 0dB at $\omega = 1$ rad/s. Since the plot crosses at 20dB, it indicates that the overall gain is 20dB or

$20 = 20\log_{10}|\text{gain}|$, where the gain has to be 10.

A zero of slope +20dB/dec at the origin $\rightarrow$ $j\omega$

A pole of slope –20dB/dec at $\omega = 1$ $\rightarrow$ $\frac{1}{1 + j\omega}$

A pole of slope –40dB/dec at $\omega = 10$ $\rightarrow$ $\frac{1}{(1 + j\omega/10)^2}$

Hence,

$$\mathbf{H}(\omega) = \frac{10j\omega}{(1 + j\omega)(1 + j\omega/10)^2} = \frac{1000j\omega}{(1 + j\omega)(10 + j\omega)^2}$$

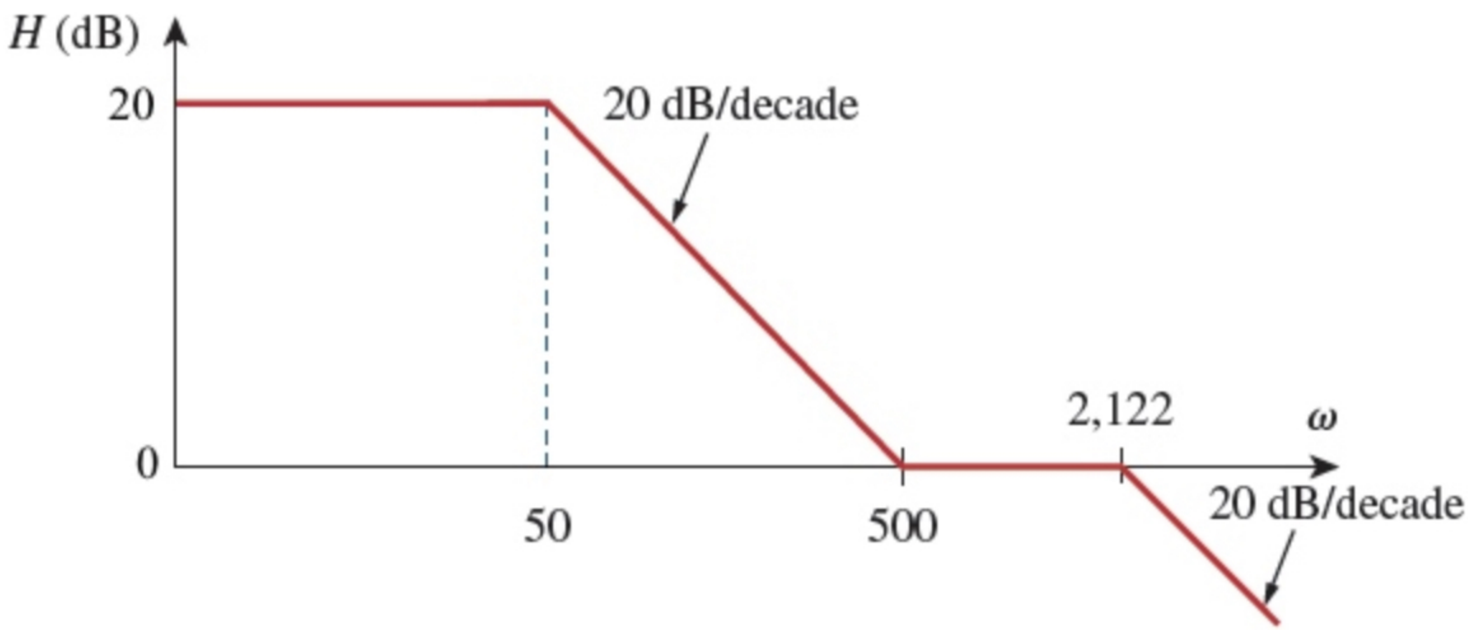
The transfer function H(ω) is mentioned below.

$$\mathbf{H}(\omega) = \frac{1000j\omega}{(1 + j\omega)(10 + j\omega)^2}$$

8.

value:
10.00 points

The magnitude plot shown below represents the transfer function of the preamplifier. Find *H*(*s*).



- ○ $H(s) = \dfrac{(s+500)}{(s+50)(s+2122)}$
- ○ $H(s) = \dfrac{42.44(s+500)}{(s+50)(s+2122)}$
- → ○ $H(s) = \dfrac{2122(s+500)}{(s+50)(s+2122)}$
- ○ $H(s) = \dfrac{4.244(s+500)}{(s+50)(s+2122)}$

$20 = 20\log_{10}|\text{gain}| \quad \rightarrow \quad \text{gain} = 10$

There is a pole at $\omega = 50$, which results in

$$\frac{1}{1 + j\omega/50}$$

There is a zero at $\omega = 500$, which results in

$$1 + j\omega / 500$$

There is another pole at $\omega = 2122$, which results in

$$\frac{1}{1 + j\omega/2122}$$

Thus,

$$\mathbf{H}(\omega) = \frac{10(1 + j\omega/500)}{(1 + j\omega/50)(1 + j\omega/2122)}$$

$$H(s) = \frac{2122(500 + s)}{(s + 50)(s + 2122)}$$

The transfer function $H(s)$ is mentioned below.

$$H(s) = \frac{2122(s + 500)}{(s + 50)(s + 2122)}$$

9.

value:
10.00 points

A series *RLC* network has $R = 4\ k\Omega$, $L = 80$ mH, and $C = 1\ \mu F$.

Calculate the impedance at twice the resonant frequency.

The impedance at twice the resonant frequency is 4.000 ± 2% + *j* 0.424 ± 2% kΩ

Explanation:

Calculate the value of ω_o.

$$\omega_o = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{(80 \times 10^{-3}\ \mathrm{H})(1 \times 10^{-6}\ \mathrm{F})}} = 3.536\ \mathrm{krad}/s$$

The impedance at twice the resonant frequency is calculated as follows:

$$Z(2\omega_o) = R + j\left(2\omega_o L - \frac{1}{2\omega_o C}\right)$$

$$Z(2\omega_o) = 4000\ \Omega + j\left(2 \times (3.536 \times 10^3\ \mathrm{rad/s}) \times (80 \times 10^{-3}\ \mathrm{H}) - \frac{1}{2 \times (3.536 \times 10^3\ \mathrm{rad/s}) \times (1 \times 10^{-6}\ \mathrm{F})}\right) = (4 + j(0.424))\,\mathrm{k}\Omega$$

The impedance at twice the resonant frequency is $Z(2\omega_o) = (4 + j(0.424))$ kΩ.

10.

value:
10.00 points

A series *RLC* network has $R = 4\ \text{k}\Omega$, $L = 80\ \text{mH}$, and $C = 1\ \mu\text{F}$.

Calculate the impedance at resonance.

The impedance at resonance is 4 kΩ.

Explanation:

At resonance, the impedance of the inductor is equal and opposite the impedance of the capacitor, and the impedances cancel.

Therefore, the impedance at resonance is calculated as

$$Z(\omega_o) = R = 4\ \text{k}\Omega$$

The impedance at resonance is 4 kΩ.