11

9.17

Generate Bode magnitude and phase plots (straight-line approximations) for the following voltage transfer functions

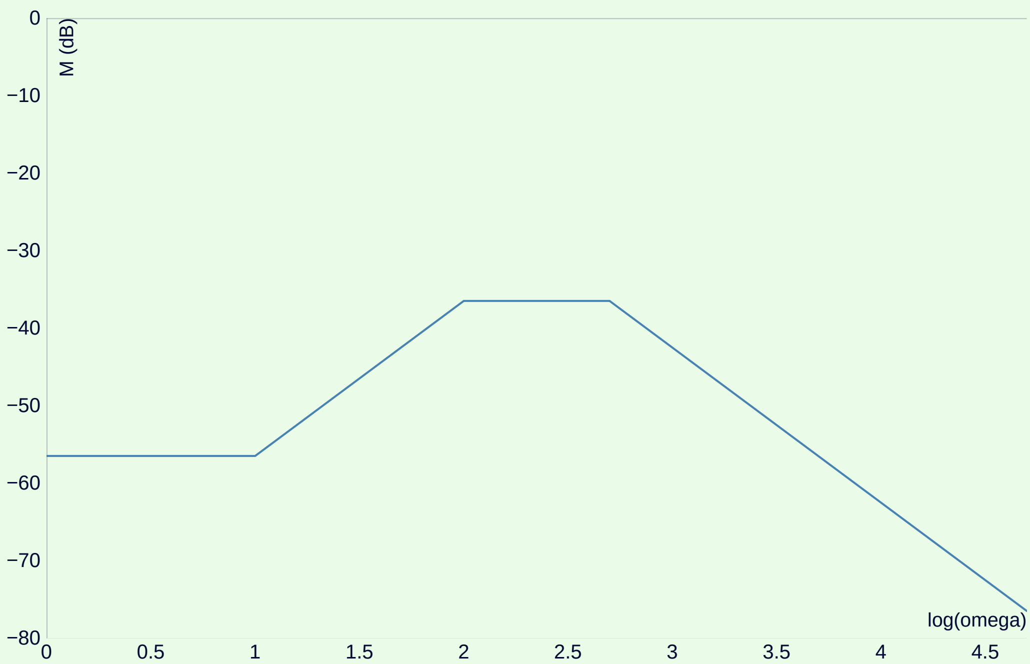
a

$\mathbf{H}(\omega) = \frac{30(10+j\omega)}{(200+j2\omega)(1000+j2\omega)}$

Answer

$\mathbf{H}(\omega) = \frac{30(10+j\omega)}{(200+j2\omega)(1000+j2\omega)}$
$= \frac{\frac{3}{2000}(1+\frac{1}{10}j\omega)}{(1+\frac{1}{100}j\omega)(1+\frac{1}{500}j\omega)}$

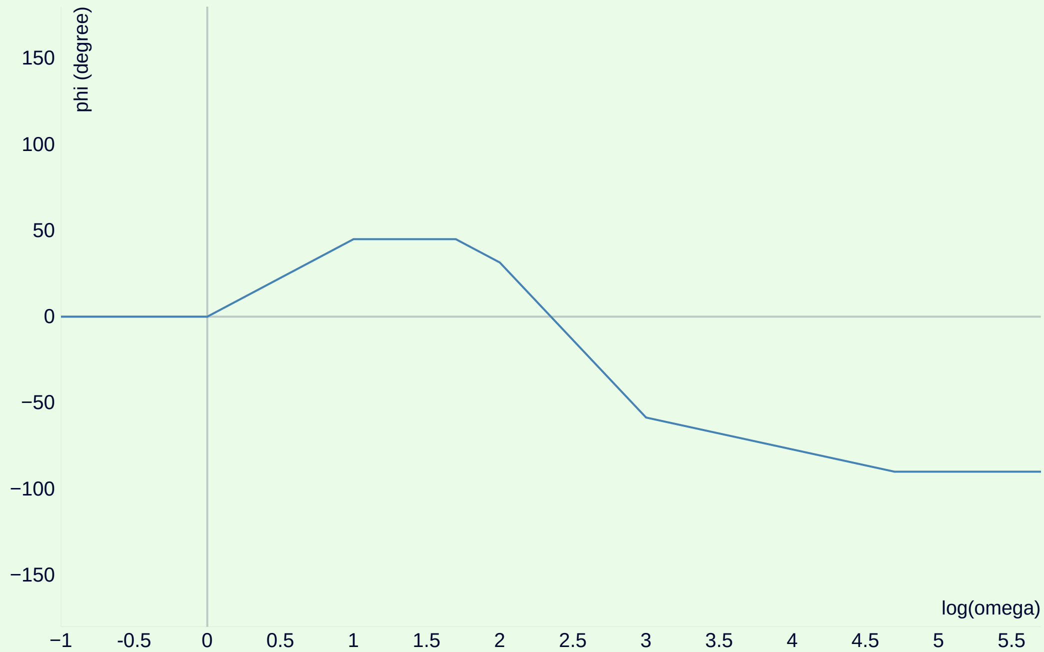
ω	$\log\omega$	M	$\frac{dM}{d\omega}^+ \frac{dB}{decade}$
0	$-\infty$	$20\log\left(\frac{3}{2000}\right)$	0
10	1	$20\log\left(\frac{3}{2000}\right)$	20
100	2	$20(\log\left(\frac{3}{2000}\right)+1)$	0
500	2.6990	$20(\log\left(\frac{3}{2000}\right)+1)$	-20



Component	$0.1\omega_c$	$10\omega_c$
$1+\frac{1}{10}j\omega$	1	100

Component	$0.1\omega_c$	$10\omega_c$
$\left(1+\frac{1}{100}j\omega\right)^{-1}$	10	1000
$\left(1+\frac{1}{500}j\omega\right)^{-1}$	50	5000

ω	$\log\omega$	ϕ°	$\frac{d\phi}{d\omega}^{+}\ \frac{\circ}{decade}$
0	$-\infty$	0	0
1	0	0	45
10	1	45	0
50	1.6990	45	-45
100	2	$45(1-\log 2)$	-90
1000	3	$45(-1-\log 2)$	-45
5000	4.6990	-90	0



b

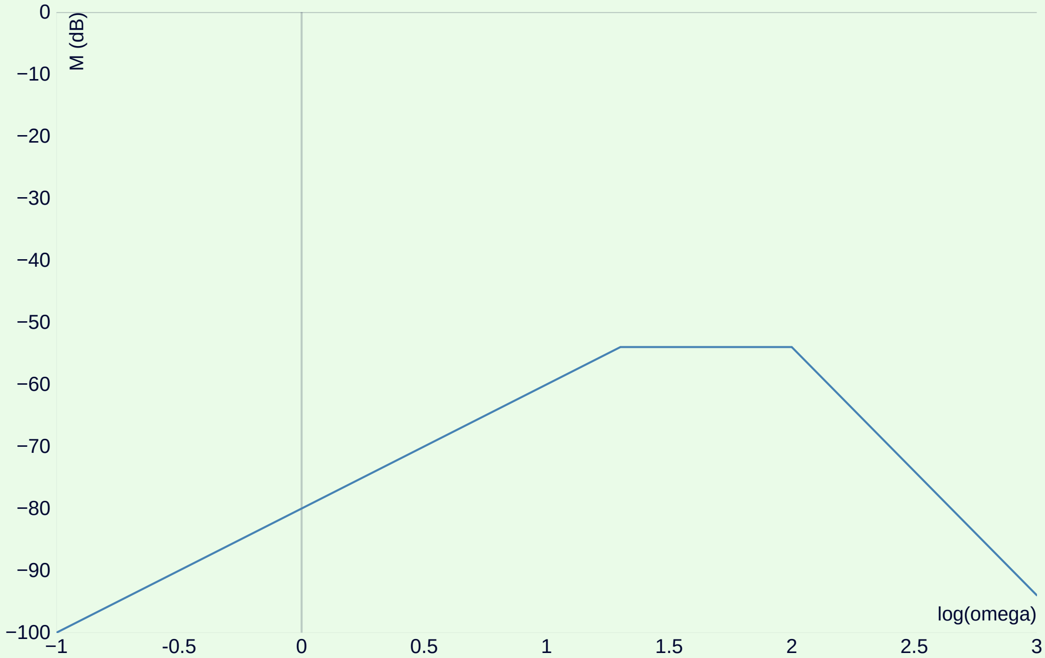
$$\mathbf{H}(\omega) = \frac{j100\omega}{(100+j5\omega)(100+j\omega)^2}$$

✓ **Answer**

$$\mathbf{H}(\omega) = \frac{j100\omega}{(100+j5\omega)(100+j\omega)^2}$$

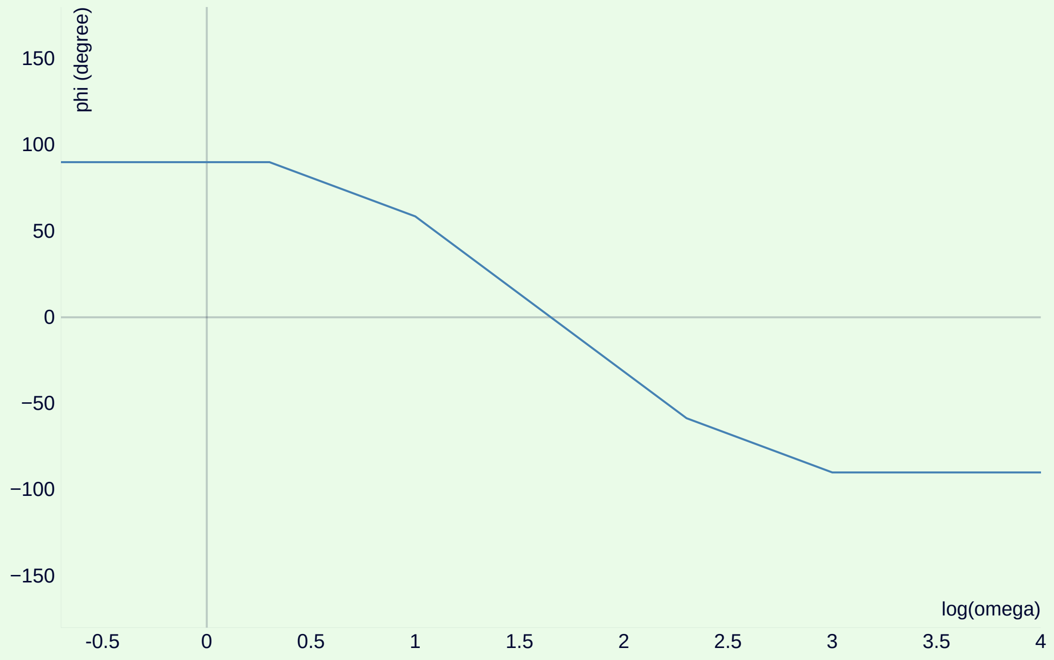
$$= \frac{1}{10000}\frac{j\omega}{\left(1+\frac{1}{20}j\omega\right)\left(1+\frac{1}{100}j\omega\right)^2}$$

ω	$\log\omega$	M	$\frac{dM}{d\omega} + \frac{dB}{decade}$
1	0	$20(-4)$	20
20	1.3010	$20\left(\log(2)-3\right)$	0
100	2	$20\left(\log(2)-3\right)$	-40



Component	$0.1\omega_c$	$10\omega_c$
$\left(1+\frac{1}{20}j\omega\right)^{-1}$	2	200
$\left(1+\frac{1}{100}j\omega\right)^{-1}$	10	1000

ω	$\log\omega$	ϕ°	$\frac{d\phi}{d\omega} + \frac{\circ}{decade}$
0	$-\infty$	90	0
2	0.3010	90	-45
10	1	$90-45\log(5)$	-90
200	2.3010	$90-45\log(2000)$	-45
1000	3	-90	0



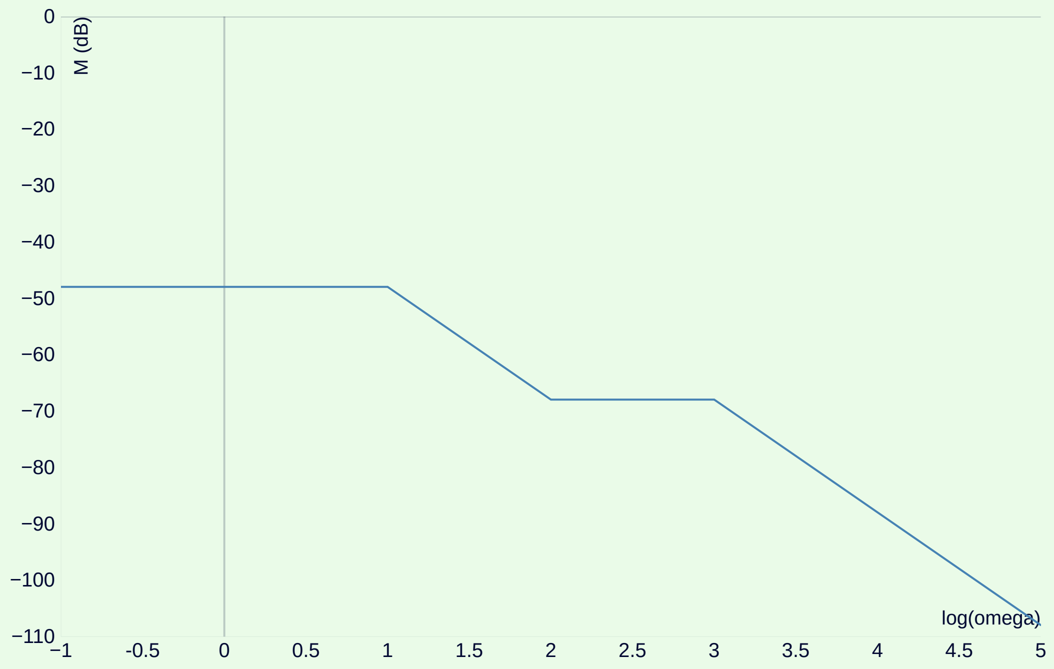
c

$$\mathbf{H}(\omega) = \frac{(200+j2\omega)}{(50+j5\omega)(1000+j\omega)}$$

✓ **Answer**

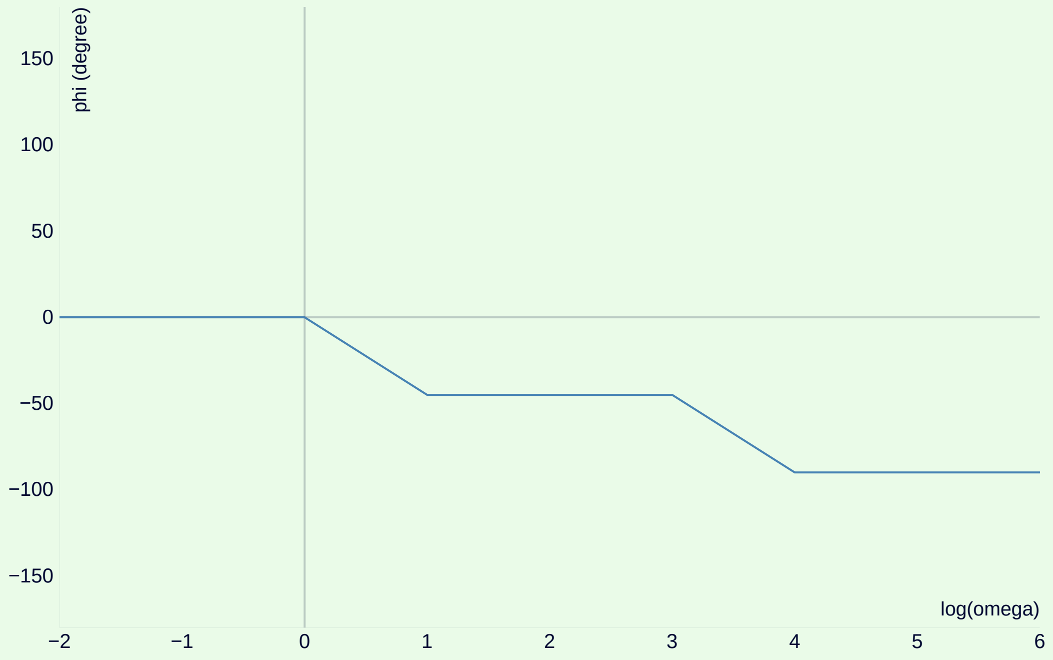
$$\mathbf{H}(\omega) = \frac{(200+j2\omega)}{(50+j5\omega)(1000+j\omega)}$$
$$= \frac{1}{250}\,\frac{1+\frac{1}{100}j\omega}{\left(1+\frac{1}{10}j\omega\right)\left(1+\frac{1}{1000}j\omega\right)}$$

ω	$\log\omega$	M	$\frac{dM}{d\omega}+\frac{dB}{decade}$
0	$-\infty$	$20\left(\log\left(\frac{1}{250}\right)\right)$	0
10	1	$20\left(\log\left(\frac{1}{250}\right)\right)$	-20
100	2	$20\left(\log\left(\frac{1}{250}\right)-1\right)$	0
1000	3	$20\left(\log\left(\frac{1}{250}\right)-1\right)$	-20



Component	$0.1\omega_c$	$10\omega_c$
$\left(1+\frac{1}{10}j\omega\right)^{-1}$	1	100
$1+\frac{1}{100}j\omega$	10	1000
$\left(1+\frac{1}{1000}j\omega\right)^{-1}$	100	10000

ω	$\log\omega$	ϕ°	$\frac{d\phi}{d\omega}^{+}\frac{\circ}{decade}$
0	$-\infty$	0	0
1	0	0	-45
10	1	-45	0
100	2	-45	0
1000	3	-45	-45
10000	4	-90	0



9.23

Determine the voltage transfer function $\mathbf{H}(\omega)$ corresponding to the Bode magnitude plot shown in **Fig. P9.23**. The phase of $\mathbf{H}(\omega)$ is 180° at $\omega = 0$.

✓ **Answer**

$\mathbf{H}(\omega) = -20\frac{(1+\frac{1}{10}j\omega)(1+\frac{1}{100}j\omega)}{j\omega}$

9.35

For the circuit shown below

a

Obtain an expression for $\mathbf{H}(\omega) = \frac{\mathbf{V}_0}{\mathbf{V}_i}$ in standard form

✓ **Answer**

$\begin{bmatrix} iL\omega + R & -iL\omega \\ -iL\omega & iL\omega + R \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \end{bmatrix} = \begin{bmatrix} v_i \\ 0 \end{bmatrix}$

$v_o = i_2 R$

$\mathbf{H}(\omega) = \frac{L\omega}{2L\omega - iR} = \frac{L}{R}\frac{i\omega}{1+\frac{2L}{R}i\omega}$

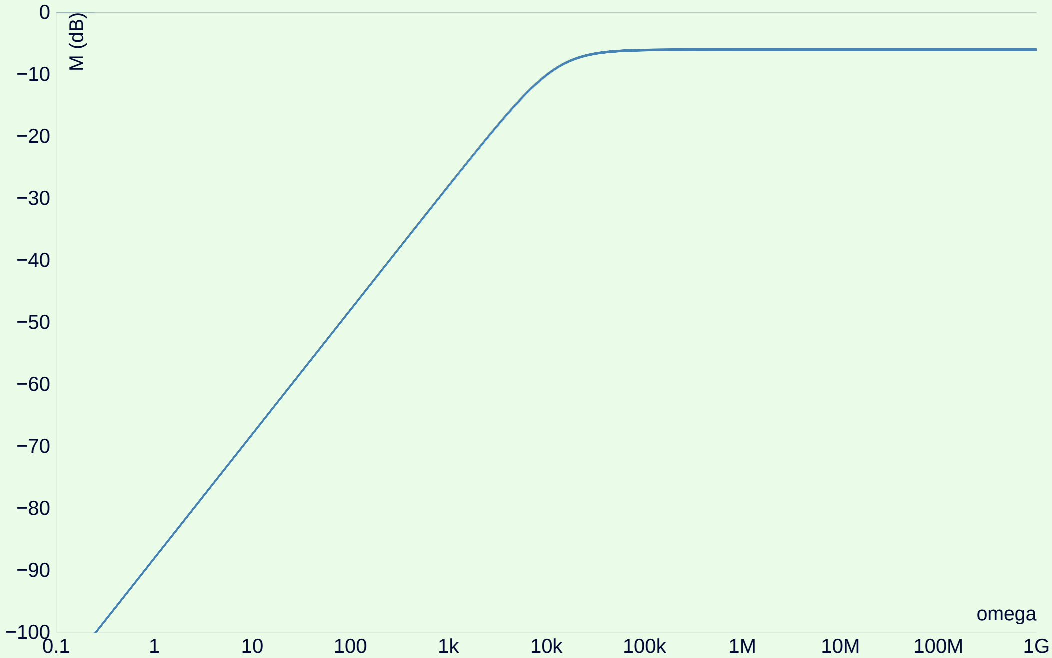
b

Generate spectral plots for the magnitude and phase of $\mathbf{H}(\omega)$, given that $R = 50\Omega$ and $L = 2\,mH$.

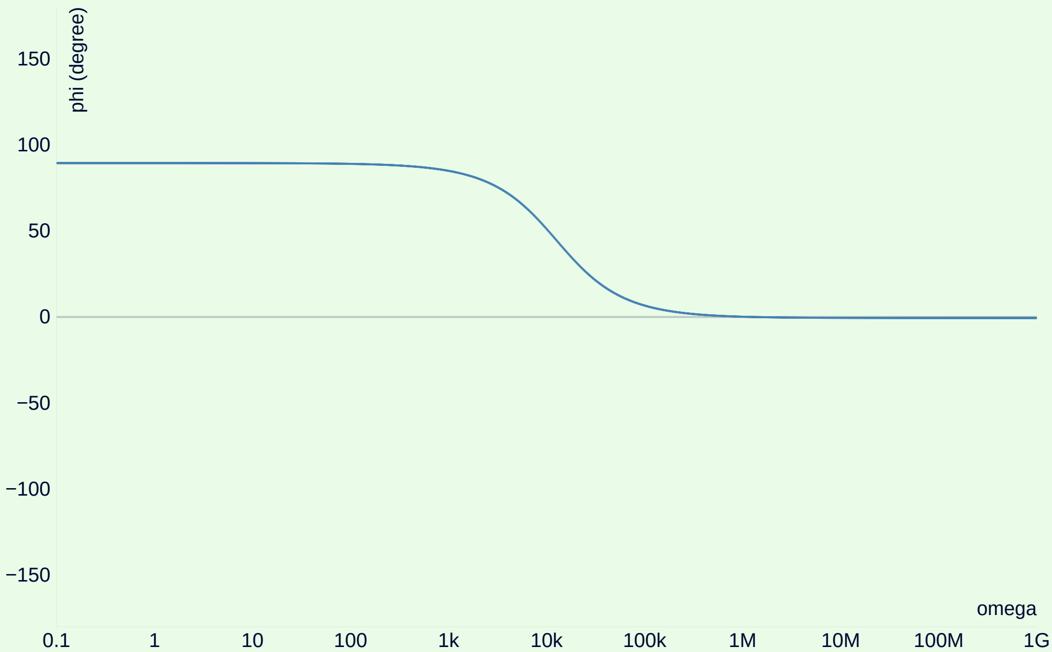
✓ **Answer**

$M(\omega) = \frac{L}{R}\frac{\omega}{\sqrt{1+\frac{4L^2}{R^2}\omega^2}}$

$M(\omega)[dB] = 20\log\left(\frac{L\omega}{R}\right) - 10\log\left(1+\frac{4L^2}{R^2}\omega^2\right)$



$\phi(\omega) = -\arctan(R, 2L\omega)$



c

Determine the cutoff frequency ω_c and the slope of the magnitude (in dB) when $\frac{\omega}{\omega_c} \ll 1$

✓ **Answer**

$\omega_c = \frac{2L}{R}$

$20 \ \frac{dB}{decade}$

9.27

A series RLC circuit is drive by an ac source with a phasor voltage $\mathbf{V}_s = 10\angle 30^{\circ} V$. If the circuit resonates at $10^3 \ rad/s$ and the average power absorbed by the resistor at resonsnace is $2.5W$, determine the values of R, L, and C, given that $Q = 5$

✓ **Answer**

$2.5 = \frac{10^2}{2R} \implies R = 20$

$Q = \frac{\omega_0 L}{R} = \frac{1}{\omega_0 CR} = 5$

$L = \frac{1}{10} = 0.1 \ H$

$C = 10 \ \mu F$

9.37

For the op-amp circuit

a

Obtain an expression for $\mathbf{H}(\omega) = \mathbf{V}_0/\mathbf{V}_s$ in standard form

✓ **Answer**

$\mathbf{H}(\omega) = \frac{R_2+R_1-\frac{i}{\omega C}}{R_1-\frac{i}{\omega C}} = \frac{1+C(R_2+R_1)i\omega}{1+R_1 Ci\omega}$

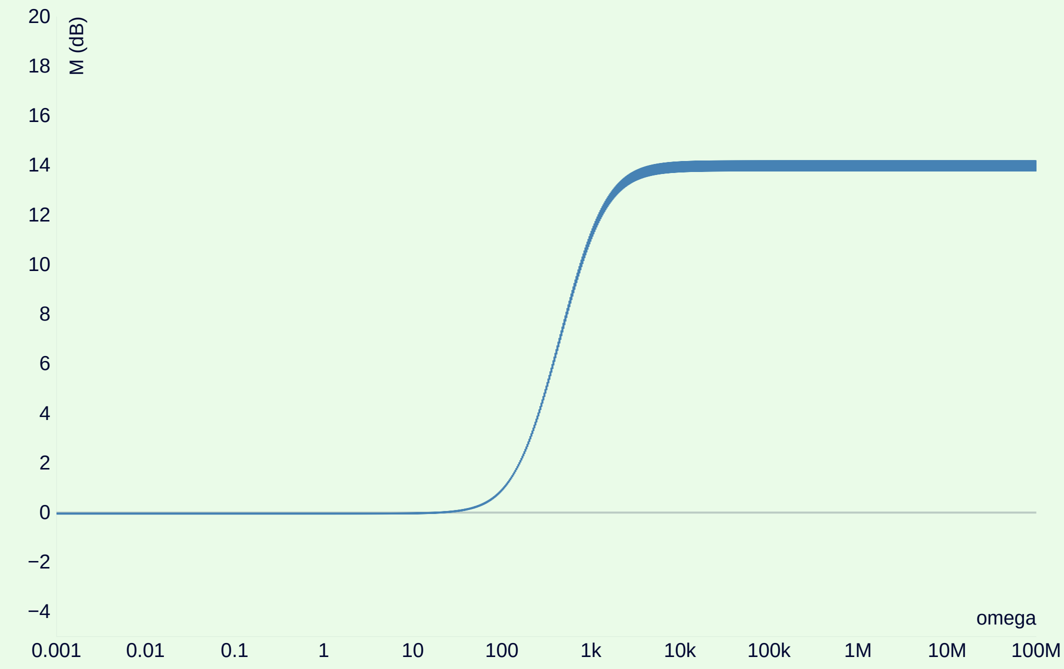
b

Generate spectral plots for the magnitude and phase of $\mathbf{H}(\omega)$, given that $R_1 = 1 \ k\Omega, R_2 = 4 \ k\Omega, C = 1 \ \mu F$

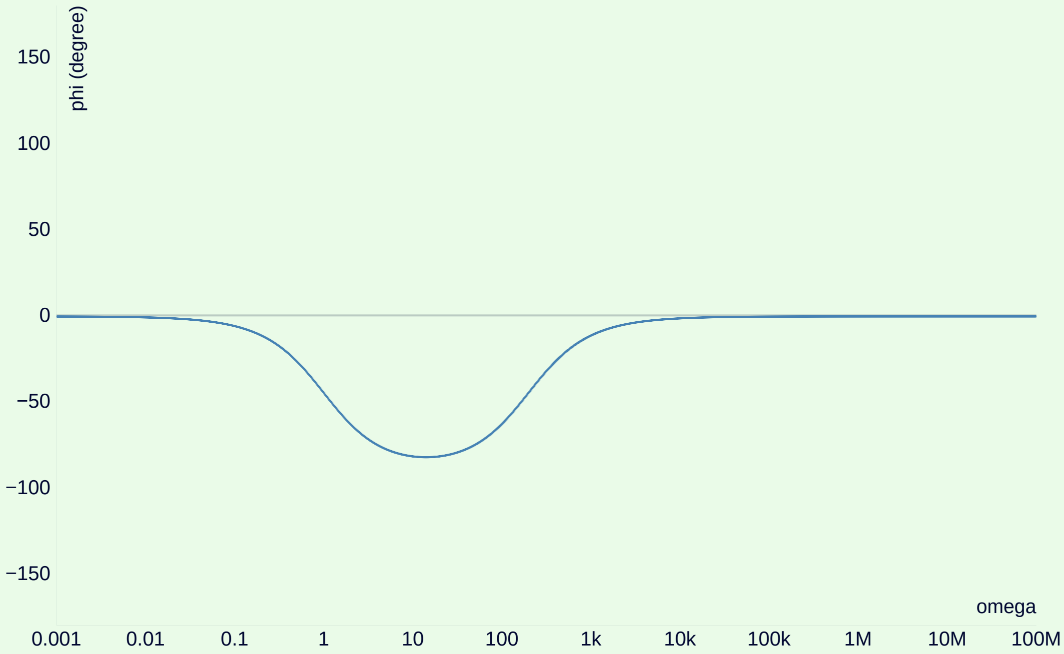
✓ **Answer**

$M(\omega) = \frac{\sqrt{1+C^2(R_2+R_1)^2\omega^2}}{\sqrt{1+R_1^2 C^2\omega^2}}$

$M(\omega)[dB] = 10 \left(\log(1 + C^2(R_1 + R_2)^2\omega^2) - \log(1 + C^2 R_1^2\omega^2)\right)$



$$\phi(\omega) = \arctan(C(R_2 + R_1)\omega) - \arctan(CR_1\omega)$$



c

What type of filter is it? What is its maximum gain?

✓ **Answer**

This is a high-pass filter, as it boosts the high frequencies while doing nothing with the low frequencies.