For the circuit above, $V_i = 10 \text{ mV}$:

- What is $V_o$ if the amplifier is ideal?
- What is $V_o$ if the offset voltage, $V_{OS} = 10 \mu \text{V}$?
- What is $V_o$ if the bias current, $I_B = 10 \text{ nA}$?

- What is $V_o$ if the amplifier is ideal?
  Represent ideal as $\vec{V}_o$

  \[
  V_+ = \frac{26 \text{ k}\Omega}{26 + 1.8 \text{ k}\Omega} V_i = (9.350 \text{ mV}), \quad \vec{V}_o = \left(1 + \frac{26 \text{ k}\Omega}{1.8 \text{ k}\Omega}\right) V_+ = 15.444 \text{ V}_+ = 144.401 \text{ mV}
  \]

- What is $V_o$ if the offset voltage, $V_{OS} = 10 \mu \text{V}$?
  Use superposition to get ($V_o'$) then add to ideal $V_{OS}$:

  \[
  V_o' = \left(1 + \frac{26 \text{ k}\Omega}{1.8 \text{ k}\Omega}\right) V_{OS} = 15.444 \times V_{OS} = 0.154 \text{ mV}
  \]

  \[
  V_o = \vec{V}_o + V_o' = 144.555 \text{ mV}
  \]

- What is $V_o$ if the bias current, $I_B = 10 \text{ nA}$?
  First, use superposition to get ($V_o''$) for $I_B$ into $V_-$. Current travels through parallel resistors.

  \[
  V_o'' = -(1 + \frac{26 \text{ k}\Omega}{1.8 \text{ k}\Omega}) (R_1 \parallel R_2) I_B = -15.444 \times 1.683 \text{ k}\Omega \times I_B = -0.260 \text{ mV}
  \]

Next, use superposition to get ($V_o'''$) for $I_B$ into $V_-$. Current through $R_1$, since FB keeps $V_-$ at ground. Note that this resistor configuration cancels $I_B$.

\[
V_o''' = (26 \text{ k}\Omega) I_B = 0.260 \text{ mV}
\]

\[
V_o = \vec{V}_o + V_o' + V_o''' = 144.401 \text{ mV}
\]
The op amp is ideal, except $f_T (= \text{Gain-Bandwidth})$ is 120 kHz.

\[
\begin{array}{c}
\text{2.3 kΩ} \\
\text{25 kΩ} \\
\text{Vi} \\
\text{2.3 kΩ} \\
\text{25 kΩ} \\
\text{Vo}
\end{array}
\]

For the circuit above, $V_i = (20 \text{ mV}) \cos(2\pi ft)$:

- What is the peak-to-peak amplitude of $V_o$ if $f = 3 \text{ kHz}$?
- What is the peak-to-peak amplitude of $V_o$ if $f = 30 \text{ kHz}$?

First, analyse ideal gain, $\hat{V}_o$

\[
V_+ = \frac{25 \text{kΩ}}{25 + 2.3 \text{kΩ}} V_i = 0.916 V_i \\
\hat{V}_o = \left(1 + \frac{25 \text{kΩ}}{2.3 \text{kΩ}}\right) V_+ = 11.870 V_+ = 10.873 V_i
\]

- What is the peak-to-peak amplitude of $V_o$ if $f = 3 \text{ kHz}$?
  
  Given Gain-Bandwidth, maximum possible gain is $G = (G \cdot BW)/f = 120/3 = 40$. We specify a gain of 10.873 which is less than 40, so we get the specified gain. $V_o = 10.873 \times (20 \text{ mV}) \cos(2\pi ft)$, and peak-peak voltage is $2 \times \max(V_o)$. 
  Answer: 434.9 mV.

- What is the peak-to-peak amplitude of $V_o$ if $f = 30 \text{ kHz}$?
  
  Given Gain-Bandwidth, maximum possible gain is $G = (G \cdot BW)/f = 120/30 = 4$. We specify a gain of 10.873 which is greater than 4, so we only get a gain of 4. $V_o = 4 \times (20 \text{ mV}) \cos(2\pi ft)$, and peak-peak voltage is $2 \times \max(V_o)$.
  Answer: 160.0 mV.
For the circuit above:

- **What type of filter is this?** (high pass, low pass, band pass, band stop)
- Sketch the amplitude of $\frac{V_o}{V_i}$ as a function of frequency. Label the passband, stopband and roll-off rate.
- What is the cut-off frequency ($f_c$) and damping constant ($\zeta$)?

**What type of filter is this?** (high pass, low pass, band pass, band stop)

This is a low pass filter

- What is the cut-off frequency ($f_c$) and damping constant ($\zeta$)?

$$\omega_c = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{7.1 \, \text{mH} \cdot 11.6 \, \mu\text{F}}} = 3484.511 \, \text{rad/s}, \quad f_c = 2\pi \omega_c = 21893.370 \, \text{Hz}$$

and,

$$\zeta = \frac{R}{2} \sqrt{\frac{C}{L}} = \frac{246 \, \text{k}\Omega}{2} \sqrt{\frac{11.6 \, \mu\text{F}}{7.1 \, \text{mH}}} = 4.972$$

- Sketch the amplitude of $\frac{V_o}{V_i}$ as a function of frequency. Label the passband, stopband and roll-off rate.

$\frac{V_o}{V_i}$ starts near 1.0. After $f_c$, graph decreases at 40 dB/decade.