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 $\bar{V}_o$

$$V_+ = \frac{23 \text{ k}\Omega}{23 + 2.6 \text{ k}\Omega} V_i = (8.980 \text{ mV}, \quad \bar{V}_o = \left(1 + \frac{23 \text{ k}\Omega}{2.6 \text{ k}\Omega}\right) V_+ = 9.846 \text{ V}_+ = 88.417 \text{ mV}$$

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

$$V_o' = \left(1 + \frac{23 \text{ k}\Omega}{2.6 \text{ k}\Omega}\right) V_{OS} = 9.846 \times V_{OS} = 0.098 \text{ mV}$$  
  $$V_o = \bar{V}_o + V_o' = 88.515 \text{ mV}$$

- 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.

$$V_o'' = -\left(1 + \frac{23 \text{ k}\Omega}{2.6 \text{ k}\Omega}\right) (R_1 \parallel R_2) I_B = -9.846 \times 2.336 \text{ k}\Omega \times \text{ I}_B = -0.230 \text{ mV}$$

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 $I_B$.

$$V_o''' = (23 \text{ k}\Omega) I_B = 0.230 \text{ mV}$$

$$V_o = \bar{V}_o + V_o' + V_o''' = 88.417 \text{ mV}$$
The op amp is ideal, except $f_T (= \text{Gain-Bandwidth})$ is 120 kHz.

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, $\tilde{V}_o$

$$V_+ = \frac{23 \text{ k}\Omega}{23 + 2.3 \text{ k}\Omega} V_i = 0.909 V_i \quad \tilde{V}_o = \left( 1 + \frac{23 \text{ k}\Omega}{2.3 \text{ k}\Omega} \right) V_+ = 11.000 V_+ = 9.999 V_i$$

- 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 9.999 which is less than 40, so we get the specified gain.
  $V_o = 9.999 \times (20 \text{ mV}) \cos(2\pi ft)$, and peak-peak voltage is $2 \times max(V_o)$.
  Answer: 400.0 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 9.999 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)
  
  This is a low pass filter

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

\[
\omega_c = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{5.5 \text{ mH} \cdot 11.6 \mu\text{F}}} = 3959.038 \text{ rad/s}, \quad f_c = 2\pi \omega_c = 24874.849 \text{ Hz}
\]

and,

\[
\zeta = \frac{R}{2} \sqrt{\frac{1}{C}} = \frac{232 \text{ kΩ}}{2} \sqrt{\frac{11.6 \mu\text{F}}{5.5 \text{ mH}}} = 5.327
\]

- 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.