For the circuit above, $V_i = 10$ mV:

- What is $V_o$ if the amplifier is ideal?

- What is $V_o$ if the offset voltage, $V_{OS} = 10 \mu$V?

- What is $V_o$ if the bias current, $I_B = 10$ nA?

- What is $V_o$ if the amplifier is ideal?

Represent ideal as $\bar{V}_o$

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

- What is $V_o$ if the offset voltage, $V_{OS} = 10 \mu$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, $I_B = 10$ nA?

First, use superposition to get ($V_o''$) for $I_B$ into $V_+$. Current travels through parallel resistors.

\[
V_o' = -\left(1 + \frac{23 \, \text{k\Omega}}{2.6 \, \text{k\Omega}}\right) (R_1||R_2) I_B = -9.846 \times 2.336 \, \text{k\Omega} \times I_B = -0.230 \, \text{mV}
\]

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, $\bar{V}_o$

$$V_+ = \frac{27 \text{k}\Omega}{27 + 3.2 \text{k}\Omega} V_i = 0.894 V_i \quad \bar{V}_o = \left(1 + \frac{27 \text{k}\Omega}{3.2 \text{k}\Omega}\right) V_+ = 9.438 V_+ = 8.438 V_i$$

- 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 8.438 which is less than 40, so we get the specified gain.
  $V_o = 8.438 \times (20 \text{ mV}) \cos(2\pi ft)$, and peak-peak voltage is $2 \times max(V_o)$.
  Answer: 337.5 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 8.438 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 \( (\zeta) \)?**

\[
\omega_c = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{5.7 \text{ mH} \cdot 15.9 \mu\text{F}}} = 3321.728 \text{ rad/s}, \quad f_c = 2\pi\omega_c = 20870.596 \text{ Hz}
\]

and,

\[
\zeta = \frac{R}{2\sqrt{C/L}} = \frac{269 \text{ k}\Omega}{2\sqrt{\frac{15.9 \mu\text{F}}{5.7 \text{ mH}}}} = 7.104
\]

- 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.