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 $\bar{V}_o$

\[
V_+ = \frac{29 \text{ k}\Omega}{29 + 2.3 \text{ k}\Omega} V_i = (9.270 \text{ mV}, \quad \bar{V}_o = \left(1 + \frac{29 \text{ k}\Omega}{2.3 \text{ k}\Omega}\right) V_+ = 13.609 V_+ = 126.155 \text{ mV}
\]

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

Use superposition to get ($V_o'$) then add to ideal $V_{OS}$:

\[
V_o' = \left(1 + \frac{29 \text{ k}\Omega}{2.3 \text{ k}\Omega}\right) V_{OS} = 13.609 \times V_{OS} = 0.136 \text{ mV}
\]

\[
V_o = \bar{V}_o + V_o' = 126.291 \text{ mV}
\]

- 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.

\[
V_o'' = \left(1 + \frac{29 \text{ k}\Omega}{2.3 \text{ k}\Omega}\right) (R_1 \parallel R_2) I_B = -13.609 \times 2.131 \text{ k}\Omega \times I_B = -0.290 \text{ mV}
\]

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 $I_B$.

\[
V_o''' = (29 \text{ k}\Omega) I_B = 0.290 \text{ mV}
\]

\[
V_o = \bar{V}_o + V_o' + V_o''' = 126.155 \text{ mV}
\]
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, $\bar{V}_o$

$$V_+ = \frac{21 \text{k} \Omega}{21 + 3.4 \text{k} \Omega} V_i = 0.861 V_i\quad \bar{V}_o = \left(1 + \frac{21 \text{k} \Omega}{3.4 \text{k} \Omega}\right) V_+ = 7.176 V_+ = 6.179 V_i$$

- 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 6.179 which is less than 40, so we get the specified gain.
  $V_o = 6.179 \times (20 \text{ mV}) \cos(2\pi ft)$, and peak-peak voltage is $2 \times max(V_o)$.
  Answer: 247.2 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 6.179 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 \( (\zeta) \)?

\[
\omega_c = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{8.6 \text{ mH} \cdot 17.0 \mu \text{F}}} = 2615.329 \text{ rad/s}, \quad f_c = 2\pi\omega_c = 16432.253 \text{ Hz}
\]

and,

\[
\zeta = \frac{R}{2} \sqrt{\frac{C}{L}} = \frac{209 \text{ k}\Omega}{2} \sqrt{\frac{17.0 \mu \text{F}}{8.6 \text{ mH}}} = 4.646
\]

- 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.