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 $\bar{V}_o$

\[
V_+ = \frac{29\, \text{k}\Omega}{29 + 2.4\, \text{k}\Omega} V_i = (9.240\, \text{mV}), \quad \bar{V}_o = \left(1 + \frac{29\, \text{k}\Omega}{2.4\, \text{k}\Omega}\right) V_+ = 13.083\, V_+ = 120.887\, \text{mV}
\]

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

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

\[
V_o' = \left(1 + \frac{29\, \text{k}\Omega}{2.4\, \text{k}\Omega}\right) V_{OS} = 13.083 \times V_{OS} = 0.131\, \text{mV}
\]

\[
V_o = \bar{V}_o + V_o' = 121.018\, \text{mV}
\]

- 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.

\[
V_o' = -\left(1 + \frac{29\, \text{k}\Omega}{2.4\, \text{k}\Omega}\right) (R_1 \parallel R_2) I_B = -13.083 \times 2.217\, \text{k}\Omega \times I_B = -0.290\, \text{mV}
\]

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 $I_B$.

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

\[
V_o = \bar{V}_o + V_o' + V_o'' = 120.887\, \text{mV}
\]
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, $\bar{V}_o$

$$V_{+} = \frac{25 \text{k}\Omega}{25 + 3.1 \text{k}\Omega} V_i = 0.890 V_i \quad \bar{V}_o = \left( 1 + \frac{25 \text{k}\Omega}{3.1 \text{k}\Omega} \right) V_{+} = 9.065 V_{+} = 8.068 V_i$$

- 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 8.068 which is less than 40, so we get the specified gain.
  $V_o = 8.068 \times (20 \text{ mV}) \cos(2\pi ft)$, and peak-peak voltage is $2 \times \max(V_o)$.
  Answer: 322.7 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 8.068 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 \( \zeta \)?

\[
\omega_c = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{8.4 \text{ mH} \cdot 15.3 \mu\text{F}}} = 2789.425 \text{ rad/s}, \quad f_c = 2\pi \omega_c = 17526.107 \text{ Hz}
\]

and,

\[
\zeta = \frac{R}{2} \sqrt{\frac{C}{L}} = \frac{253 \text{ k\Omega}}{2} \sqrt{\frac{15.3 \mu\text{F}}{8.4 \text{ mH}}} = 5.399
\]

- 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.