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 $\bar{V}_o$

\[
V_+ = \frac{22\text{ k}\Omega}{22 + 1.5\text{ k}\Omega} V_i = 9.360\text{ mV}, \quad \bar{V}_o = \left(1 + \frac{22\text{ k}\Omega}{1.5\text{ k}\Omega}\right) V_+ = 15.667 V_+ = 146.643\text{ mV}
\]

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

\[
V_o' = \left(1 + \frac{22\text{ k}\Omega}{1.5\text{ k}\Omega}\right) V_{OS} = 15.667 \times V_{OS} = 0.157\text{ mV}
\]

\[
V_o = \bar{V}_o + V_o' = 146.800\text{ mV}
\]

- 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.

\[
V_o'' = -\left(1 + \frac{22\text{ k}\Omega}{1.5\text{ k}\Omega}\right) (R_1 \parallel R_2)I_B = -15.667 \times 1.404\text{ k}\Omega \times I_B = -0.220\text{ mV}
\]

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 $I_B$.

\[
V_o''' = (22\text{ k}\Omega) I_B = 0.220\text{ mV}
\]

\[
V_o = \bar{V}_o + V_o' + V_o''' = 146.643\text{ mV}
\]
The op amp is ideal, except $f_T$ (= Gain-Bandwidth) is $120$ kHz.

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

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

First, analyse ideal gain, $V_o$

$$V_+ = \frac{29 \, \text{k}\Omega}{29 + 2.3 \, \text{k}\Omega} V_i = 0.927 V_i \quad V_o = \left(1 + \frac{29 \, \text{k}\Omega}{2.3 \, \text{k}\Omega}\right) V_+ = 13.609 V_+ = 12.616 V_i$$

- What is the peak-to-peak amplitude of $V_o$ if $f = 3$ kHz?
  Given Gain-Bandwidth, maximum possible gain is $G = (G \cdot BW)/f = 120/3 = 40$.
  We specify a gain of $12.616$ which is less than $40$, so we get the specified gain.
  $V_o = 12.616 \times (20$ mV$) \cos(2\pi ft)$, and peak-peak voltage is $2 \times \text{max}(V_o)$.
  Answer: $504.6$ mV.

- What is the peak-to-peak amplitude of $V_o$ if $f = 30$ kHz?
  Given Gain-Bandwidth, maximum possible gain is $G = (G \cdot BW)/f = 120/30 = 4$.
  We specify a gain of $12.616$ which is greater than $4$, so we only get a gain of $4$.
  $V_o = 4 \times (20$ mV$) \cos(2\pi ft)$, and peak-peak voltage is $2 \times \text{max}(V_o)$.
  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 \((\zeta)\)?

\[
\omega_c = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{4.9 \text{ mH} \cdot 11.7 \mu \text{F}}} = 4176.467 \text{ rad/s}, \quad f_c = 2\pi\omega_c = 26240.967 \text{ Hz}
\]

and,

\[
\zeta = \frac{R}{2} \sqrt{\frac{C}{L}} = \frac{293 \text{ k}\Omega}{2} \sqrt{\frac{11.7 \mu \text{F}}{4.9 \text{ mH}}} = 7.159
\]

- 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.