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 $\bar{V}_o$

\[
V_+ = \frac{26 \, \text{k}\Omega}{26 + 1.1 \, \text{k}\Omega} \quad V_i = (9.590 \, \text{mV}), \quad \bar{V}_o = \left(1 + \frac{26 \, \text{k}\Omega}{1.1 \, \text{k}\Omega}\right) V_+ = 24.636 \, V_+ = 236.259 \, \text{mV}
\]

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

\[
V_o' = \left(1 + \frac{26 \, \text{k}\Omega}{1.1 \, \text{k}\Omega}\right) V_{OS} = 24.636 \times V_{OS} = 0.246 \, \text{mV}
\]

\[
V_o = \bar{V}_o + V_o' = 236.505 \, \text{mV}
\]

- 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.

\[
V_o'' = - \left(1 + \frac{26 \, \text{k}\Omega}{1.1 \, \text{k}\Omega}\right) (R_1 \parallel R_2) I_B = -24.636 \times 1.055 \, \text{k}\Omega \times I_B = -0.260 \, \text{mV}
\]

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 $I_B$.

\[
V_o''' = (26 \, \text{k}\Omega) I_B = 0.260 \, \text{mV}
\]

\[
V_o = \bar{V}_o + V_o' + V_o''' = 236.259 \, \text{mV}
\]
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, $\bar{V}_o$

$$V_+ = \frac{29 \text{ k}\Omega}{29 + 3.0 \text{ k}\Omega} V_i = 0.906 V_i \quad \bar{V}_o = \left(1 + \frac{29 \text{ k}\Omega}{3.0 \text{ k}\Omega}\right) V_+ = 10.667 V_+ = 9.664 V_i$$

- 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 9.664 which is less than 40, so we get the specified gain.
  $V_o = 9.664 \times (20 \text{ mV}) \cos(2\pi ft)$, and peak-peak voltage is $2 \times max(V_o)$.
  Answer: 386.6 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 9.664 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 ($\zeta$)?

\[
\omega_c = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{6.9 \text{ mH} \cdot 15.1 \mu \text{F}}} = 3098.040 \text{ rad/s}, \quad f_c = 2\pi \omega_c = 19465.152 \text{ Hz}
\]

and,

\[
\zeta = \frac{R}{2} \sqrt{\frac{C}{L}} = \frac{287 \text{ k}\Omega}{2} \sqrt{\frac{15.1 \mu \text{F}}{6.9 \text{ mH}}} = 6.713
\]

- 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.