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 $\bar{V}_o$

\[
V_+ = \frac{26 \text{ k}\Omega}{26 + 2.8 \text{ k}\Omega} V_i = (9.030 \text{ mV}, \quad \bar{V}_o = \left(1 + \frac{26 \text{ k}\Omega}{2.8 \text{ k}\Omega}\right) V_+ = 10.286 V_+ = 92.883 \text{ mV}
\]

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

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

\[
V_o' = \left(1 + \frac{26 \text{ k}\Omega}{2.8 \text{ k}\Omega}\right) V_{OS} = 10.286 \times V_{OS} = 0.103 \text{ mV}
\]

\[
V_o = \bar{V}_o + V_o' = 92.986 \text{ mV}
\]

- 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.

\[
V_o'' = \left(1 + \frac{26 \text{ k}\Omega}{2.8 \text{ k}\Omega}\right) (R_1 \parallel R_2)I_B = -10.286 \times 2.528 \text{ k}\Omega \times I_B = -0.260 \text{ mV}
\]

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 $I_B$.

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

\[
V_o = \bar{V}_o + V_o' + V_o'' = 92.883 \text{ mV}
\]
The op amp is ideal, except $f_T$ (= 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, $\tilde{V}_o$

$$V_+ = \frac{28 \text{k}\Omega}{28 + 3.2 \text{k}\Omega} V_i = 0.897 V_i \quad \tilde{V}_o = \left(1 + \frac{28 \text{k}\Omega}{3.2 \text{k}\Omega}\right) V_+ = 9.750 V_+ = 8.746 V_i$$

- 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 8.746 which is less than 40, so we get the specified gain.
  $V_o = 8.746 \times (20 \text{ mV}) \cos(2\pi ft)$, and peak-peak voltage is $2 \times max(V_o)$.
  Answer: 349.8 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 8.746 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 ($\zeta$)?

    $$\omega_c = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{7.1 \text{ mH} \cdot 15.8 \mu F}} = 2985.673 \text{ rad/s,} \quad f_c = 2\pi \omega_c = 18759.144 \text{ Hz}$$

    and,

    $$\zeta = \frac{R}{2} \sqrt{\frac{C}{L}} = \frac{280 \text{ k}\Omega}{2} \sqrt{\frac{15.8 \mu F}{7.1 \text{ mH}}} = 6.604$$

  - 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.