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 $\bar{V}_o$

$$V_+ = \frac{21 \text{ k}\Omega}{21 + 2.7 \text{ k}\Omega} V_i = (8.860 \text{ mV}, \quad \bar{V}_o = \left(1 + \frac{21 \text{ k}\Omega}{2.7 \text{ k}\Omega}\right) V_+ = 8.778 \times V_+ = 77.773 \text{ mV}$$

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

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

$$V_o' = \left(1 + \frac{21 \text{ k}\Omega}{2.7 \text{ k}\Omega}\right) V_{OS} = 8.778 \times V_{OS} = 0.088 \text{ mV}$$

$$V_o = \bar{V}_o + V_o' = 77.861 \text{ mV}$$

- 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.

$$V_o' = -\left(1 + \frac{21 \text{ k}\Omega}{2.7 \text{ k}\Omega}\right) (R_1 \parallel R_2) I_B = -8.778 \times 2.392 \text{ k}\Omega \times I_B = -0.210 \text{ mV}$$

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 $I_B$.

$$V_o'' = (21 \text{ k}\Omega) I_B = 0.210 \text{ mV}$$

$$V_o = \bar{V}_o + V_o' + V_o'' = 77.773 \text{ mV}$$
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, $\bar{V}_o$

$$V_+ = \frac{28 \text{ k}\Omega}{28 + 3.5 \text{ k}\Omega} V_i = 0.889 V_i \quad \bar{V}_o = \left(1 + \frac{28 \text{ k}\Omega}{3.5 \text{ k}\Omega}\right) V_+ = 9.000 V_+ = 8.001 V_i$$

- What is the peak-to-peak amplitude of $V_o$ if $f = 3 \text{ kHz}$?
  Given Gain-Bandwidth, maximum possible gain is $G = (G \cdot \text{BW})/f = 120/3 = 40$. We specify a gain of 8.001 which is less than 40, so we get the specified gain. $V_o = 8.001 \times (20 \text{ mV}) \cos(2\pi ft)$, and peak-peak voltage is $2 \times \text{max}(V_o)$.
  Answer: 320.0 mV.

- What is the peak-to-peak amplitude of $V_o$ if $f = 30 \text{ kHz}$?
  Given Gain-Bandwidth, maximum possible gain is $G = (G \cdot \text{BW})/f = 120/30 = 4$. We specify a gain of 8.001 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 $2 \times \text{max}(V_o)$.
  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 \( \zeta \)?

\[
\omega_c = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{4.3 \text{ mH} \cdot 17.3 \mu F}} = 3666.424 \text{ rad/s}, \quad f_c = 2\pi \omega_c = 23036.339 \text{ Hz}
\]

and,

\[
\zeta = \frac{R}{2} \sqrt{\frac{C}{L}} = \frac{278 \text{ k}\Omega}{2} \sqrt{\frac{17.3 \mu F}{4.3 \text{ mH}}} = 8.817
\]

- 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.