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 $\bar{V}_o$

$$V_+ = \frac{29 \text{ k}\Omega}{29 + 2.2 \text{ k}\Omega} V_i = (9.290 \text{ mV}, \quad \bar{V}_o = \left(1 + \frac{29 \text{ k}\Omega}{2.2 \text{ k}\Omega}\right) V_+ = 14.182 V_+ = 131.751 \text{ mV}$$

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

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

$$V_o' = \left(1 + \frac{29 \text{ k}\Omega}{2.2 \text{ k}\Omega}\right) V_{OS} = 14.182 \times V_{OS} = 0.142 \text{ mV}$$

$$V_o = \bar{V}_o + V_o' = 131.893 \text{ mV}$$

- 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.

$$V_o'' = -\left(1 + \frac{29 \text{ k}\Omega}{2.2 \text{ k}\Omega}\right) (R_1||R_2) I_B = -14.182 \times 2.045 \text{k}\Omega \times I_B = -0.290 \text{ mV}$$

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 $I_B$.

$$V_o''' = (29 \text{ k}\Omega) I_B = 0.290 \text{ mV}$$

$$V_o = \bar{V}_o + V_o' + V_o'' = 131.751 \text{ mV}$$
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, $\bar{V}_o$

$$V_+ = \frac{24 \text{ k}\Omega}{24 + 3.3 \text{ k}\Omega} V_i = 0.879 V_i \quad \bar{V}_o = \left(1 + \frac{24 \text{ k}\Omega}{3.3 \text{ k}\Omega}\right) V_+ = 8.273 V_+ = 7.272 V_i$$

- 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 7.272 which is less than 40, so we get the specified gain.
  $V_o = 7.272 \times (20 \text{ mV}) \cos(2\pi ft)$, and peak-peak voltage is $2 \times \max(V_o)$.
  Answer: 290.9 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 7.272 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 \( \zeta \)?

  \[
  \omega_c = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{8.4 \text{ mH} \cdot 16.4 \mu \text{F}}} = 2694.253 \text{ rad/s}, \quad f_c = 2\pi \omega_c = 16928.137 \text{ Hz}
  \]

  and,

  \[
  \zeta = \frac{R}{2\sqrt{LC}} = \frac{243 \text{ k}\Omega}{2 \sqrt{16.4 \mu \text{F}} \cdot 8.4 \text{ mH}} = 5.369
  \]

- 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.