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, $V_{OS} = 10 \mu V$?
- 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 $\bar{V}_o$

  $$V_+ = \frac{25 \text{ k}\Omega}{25 + 2.4 \text{ k}\Omega} V_i = (9.120 \text{ mV}, \quad \bar{V}_o = \left(1 + \frac{25 \text{ k}\Omega}{2.4 \text{ k}\Omega}\right) V_+ = 11.417 V_+ = 104.123 \text{ mV}$$

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

  $$V'_o = \left(1 + \frac{25 \text{ k}\Omega}{2.4 \text{ k}\Omega}\right) V_{OS} = 11.417 \times V_{OS} = 0.114 \text{ mV}$$

  $$V_o = \bar{V}_o + V'_o = 104.237 \text{ mV}$$

- 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.

  $$V'_o = -\left(1 + \frac{25 \text{ k}\Omega}{2.4 \text{ k}\Omega}\right) \left(\frac{R_1}{R_1} R_2\right) I_B = -11.417 \times 2.190 \text{ k}\Omega \times I_B = -0.250 \text{ mV}$$

  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 $I_B$.

  $$V''_o = (25 \text{ k}\Omega) I_B = 0.250 \text{ mV}$$

  $$V_o = \bar{V}_o + V'_o + V''_o = 104.123 \text{ mV}$$
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, \( \tilde{V}_o \)

\[
V_+ = \frac{27 \text{k}\Omega}{27 + 3.4 \text{k}\Omega} V_i = 0.888 V_i \quad \tilde{V}_o = \left(1 + \frac{27 \text{k}\Omega}{3.4 \text{k}\Omega}\right) V_+ = 8.941 V_+ = 7.940 V_i
\]

- 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 7.940 which is less than 40, so we get the specified gain.
  \( V_o = 7.940 \times (20 \text{ mV}) \cos(2\pi ft) \), and peak-peak voltage is \( 2 \times \max(V_o) \).
  Answer: 317.6 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 7.940 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 \( \zeta \)?

  \[
  \omega_c = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{6.7 \text{ mH} \cdot 16.9 \mu\text{F}}} = 2971.798 \text{ rad/s}, \quad f_c = 2\pi\omega_c = 18671.967 \text{ Hz}
  \]

  and,

  \[
  \zeta = \frac{R}{2} \sqrt{\frac{C}{L}} = \frac{267 \text{k} \Omega}{2} \sqrt{\frac{16.9 \mu\text{F}}{6.7 \text{ mH}}} = 6.705
  \]

- 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.