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 $\bar{V}_o$

$$V_+ = \frac{25 \text{kΩ}}{25 + 2.6 \text{kΩ}} V_i = (9.060 \text{ mV}, \quad \bar{V}_o = \left(1 + \frac{25 \text{kΩ}}{2.6 \text{kΩ}}\right) V_+ = 10.615 V_+ = 96.172 \text{ mV}$$

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

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

$$V_o' = \left(1 + \frac{25 \text{kΩ}}{2.6 \text{kΩ}}\right) V_{OS} = 10.615 \times V_{OS} = 0.106 \text{ mV}$$

$$V_o = \bar{V}_o + V_o' = 96.278 \text{ mV}$$

- 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.

$$V_o'' = - \left(1 + \frac{25 \text{kΩ}}{2.6 \text{kΩ}}\right) (R_1 \parallel R_2) I_B = -10.615 \times 2.355 \text{kΩ} \times I_B = -0.250 \text{ mV}$$

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 $I_B$.

$$V_o''' = (25 \text{kΩ}) I_B = 0.250 \text{ mV}$$

$$V_o = \bar{V}_o + V_o' + V_o''' = 96.172 \text{ mV}$$
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, $\bar{V}_o$

$$V_+ = \frac{30 \text{k}\Omega}{30 + 2.1 \text{k}\Omega} V_i = 0.935 V_i \quad \bar{V}_o = \left(1 + \frac{30 \text{k}\Omega}{2.1 \text{k}\Omega}\right) V_+ = 15.286 V_+ = 14.292 V_i$$

- 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 14.292 which is less than 40, so we get the specified gain.
  $V_o = 14.292 \times (20 \text{ mV}) \cos(2\pi ft)$, and peak-peak voltage is $2 \times \max(V_o)$.
  Answer: 571.7 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 14.292 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

- 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 \( \zeta \)?

\[
\omega_c = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{6.7 \text{ mH} \cdot 10.7 \mu \text{F}}} = 3734.829 \text{ rad/s}, \quad f_c = 2\pi\omega_c = 23466.132 \text{ Hz}
\]

and,

\[
\zeta = \frac{R}{2\sqrt{C\frac{1}{L}}} = \frac{298 \text{ k}\Omega}{2\sqrt{\frac{10.7 \mu \text{F}}{6.7 \text{ mH}}}} = 5.954
\]

- 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.