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 $\bar{V}_o$

$$V_+ = \frac{30 \text{ kΩ}}{30 + 1.8 \text{ kΩ}} V_i = (9.430 \text{ mV}), \quad \bar{V}_o = \left(1 + \frac{30 \text{ kΩ}}{1.8 \text{ kΩ}}\right) V_+ = 17.667 V_+ = 166.600 \text{ mV}$$

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

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

$$V_o' = \left(1 + \frac{30 \text{ kΩ}}{1.8 \text{ kΩ}}\right) V_{OS} = 17.667 \times V_{OS} = 0.177 \text{ mV}$$

$$V_o = \bar{V}_o + V_o' = 166.777 \text{ mV}$$

- 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.

$$V_o'' = -\left(1 + \frac{30 \text{ kΩ}}{1.8 \text{ kΩ}}\right) (R_1\parallel R_2) I_B = -17.667 \times 1.698 \text{ kΩ} \times I_B = -0.300 \text{ mV}$$

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 $I_B$.

$$V_o''' = (30 \text{ kΩ}) I_B = 0.300 \text{ mV}$$

$$V_o = \bar{V}_o + V_o' + V_o''' = 166.600 \text{ mV}$$
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, $\bar{V}_o$

$$V_+ = \frac{27 \text{ k}\Omega}{27 + 2.4 \text{ k}\Omega} V_i = 0.918 V_i \quad \bar{V}_o = \left(1 + \frac{27 \text{ k}\Omega}{2.4 \text{ k}\Omega}\right) V_+ = 12.250 V_+ = 11.245 V_i$$

- 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 11.245 which is less than 40, so we get the specified gain.

$V_o = 11.245 \times (20 \text{ mV}) \cos(2\pi ft)$, and peak-peak voltage is $2 \times \max(V_o)$.

Answer: 449.8 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 11.245 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 \( \zeta \)?

  \[
  \omega_c = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{8.8 \text{ mH} \cdot 12.0 \mu \text{F}}} = 3077.287 \text{ rad/s}, \quad f_c = 2\pi \omega_c = 19334.760 \text{ Hz}
  \]

  and,

  \[
  \zeta = \frac{R}{2} \sqrt{\frac{C}{L}} = \frac{271 \text{ k}\Omega}{2} \sqrt{\frac{12.0 \mu \text{F}}{8.8 \text{ mH}}} = 5.004
  \]

- 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.