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 $\bar{V}_o$

  \[
  V_+ = \frac{29 \text{ k}\Omega}{29 + 1.9 \text{ k}\Omega} V_i = (9.390 \text{ mV}, \quad \bar{V}_o = \left(1 + \frac{29 \text{ k}\Omega}{1.9 \text{ k}\Omega}\right) V_+ = 16.263 V_+ = 152.710 \text{ mV}
  \]

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

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

  \[
  V_o' = \left(1 + \frac{29 \text{ k}\Omega}{1.9 \text{ k}\Omega}\right) V_{OS} = 16.263 \times V_{OS} = 0.163 \text{ mV}
  \]

  \[
  V_o = \bar{V}_o + V_o' = 152.873 \text{ mV}
  \]

- 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.

  \[
  V_o' = -\left(1 + \frac{29 \text{ k}\Omega}{1.9 \text{ k}\Omega}\right) (R_1 \parallel R_2) I_B = -16.263 \times 1.783 \text{ k}\Omega \times I_B = -0.290 \text{ mV}
  \]

  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 $I_B$.

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

  \[
  V_o = \bar{V}_o + V_o' + V_o'' = 152.710 \text{ mV}
  \]
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, $\bar{V}_o$

$$V_+ = \frac{24 \text{ kΩ}}{24 + 3.8 \text{ kΩ}} V_i = 0.863 V_i \quad \bar{V}_o = \left(1 + \frac{24 \text{ kΩ}}{3.8 \text{ kΩ}}\right) V_+ = 7.316 V_+ = 6.314 V_i$$

- 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 6.314 which is less than 40, so we get the specified gain.
  $V_o = 6.314 \times (20 \text{ mV}) \cos(2 \pi ft)$, and peak-peak voltage is $2 \times max(V_o)$.
  Answer: 252.6 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 6.314 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)
- 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 ($\zeta$)?

- **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 ($\zeta$)?

  $$\omega_c = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{8.7 \, \text{mH} \cdot 19.1 \, \mu\text{F}}} = 2453.148 \, \text{rad/s}, \quad f_c = 2\pi \omega_c = 15413.261 \, \text{Hz}$$

  and,

  $$\zeta = \frac{R}{2} \sqrt{\frac{C}{L}} = \frac{245 \, \text{k}\Omega}{2} \sqrt{\frac{19.1 \, \mu\text{F}}{8.7 \, \text{mH}}} = 5.740$$

- 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.