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 $\bar{V}_o$

  $$V_+ = \frac{30 \text{ k}\Omega}{30 + 1.1 \text{ k}\Omega} V_i = (9.650 \text{ mV}, \quad \bar{V}_o = \left(1 + \frac{30 \text{ k}\Omega}{1.1 \text{ k}\Omega}\right) V_+ = 28.273 \text{ V}_+ = 272.834 \text{ mV}$$

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

  $$V'_o = \left(1 + \frac{30 \text{ k}\Omega}{1.1 \text{ k}\Omega}\right) V_{OS} = 28.273 \times V_{OS} = 0.283 \text{ mV}$$
  $$V_o = \bar{V}_o + V'_o = 273.117 \text{ mV}$$

- 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.

  $$V'_o = -\left(1 + \frac{30 \text{ k}\Omega}{1.1 \text{ k}\Omega}\right) (R_1 || R_2) I_B = -28.273 \times 1.061 \text{ k}\Omega \times 10^{-9} \text{ A} = -0.300 \text{ mV}$$

  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 $I_B$.

  $$V''_o = (30 \text{ k}\Omega) I_B = 0.300 \text{ mV}$$
  $$V_o = \bar{V}_o + V'_o + V''_o = 272.834 \text{ mV}$$
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, $\bar{V}_o$

$$V_+ = \frac{28 \text{ k}\Omega}{28 + 3.8 \text{ k}\Omega} V_i = 0.881 V_i \quad \bar{V}_o = \left(1 + \frac{28 \text{ k}\Omega}{3.8 \text{ k}\Omega}\right) V_+ = 8.368 V_+ = 7.372 V_i$$

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

$V_o = 7.372 \times (20 \text{ mV}) \cos(2\pi ft)$, and peak-peak voltage is $2 \times max(V_o)$.

Answer: 294.9 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 7.372 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 ($\zeta$)?

  \[
  \omega_c = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{8.9 \text{ mH} \cdot 18.8 \mu \text{F}}} = 2444.703 \text{ rad/s}, \quad f_c = 2\pi \omega_c = 15360.200 \text{ Hz}
  \]

  and,

  \[
  \zeta = \frac{R}{2 \sqrt{C}} \frac{\sqrt{C}}{L} = \frac{285 \text{ k}\Omega}{2 \sqrt{\frac{18.8 \mu \text{F}}{8.9 \text{ mH}}}} = 6.549
  \]

- 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.