For the circuit above, $V_i = 10 \text{ mV}$:

- What is $V_o$ if the amplifier is ideal?

  Represent ideal as $\bar{V}_o$

  $$V_+ = \frac{21 \text{k}\Omega}{21 + 2.4 \text{k}\Omega} V_i = (8.970 \text{ mV}), \quad \bar{V}_o = \left(1 + \frac{21 \text{k}\Omega}{2.4 \text{k}\Omega}\right) V_+ = 9.750 V_+ = 87.457 \text{ mV}$$

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

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

  $$V_o' = \left(1 + \frac{21 \text{k}\Omega}{2.4 \text{k}\Omega}\right) V_{OS} = 9.750 \times V_{OS} = 0.098 \text{ mV}$$

  $$V_o = \bar{V}_o + V_o' = 87.555 \text{ mV}$$

- 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.

  $$V_o' = -\left(1 + \frac{21 \text{k}\Omega}{2.4 \text{k}\Omega}\right) (R_1 || R_2) I_B = -9.750 \times 2.154 \text{k}\Omega \times I_B = -0.210 \text{ mV}$$

  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 $I_B$.

  $$V_o'' = (21 \text{k}\Omega) I_B = 0.210 \text{ mV}$$

  $$V_o = \bar{V}_o + V_o' + V_o'' = 87.457 \text{ mV}$$
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, $V_o$

$$V_+ = \frac{27 \text{k\Omega}}{27 + 2.0 \text{k\Omega}} V_i = 0.931 V_i \quad V_o = \left(1 + \frac{27 \text{k\Omega}}{2.0 \text{k\Omega}}\right) V_+ = 14.500 V_+ = 13.499 V_i$$

- 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 13.499 which is less than 40, so we get the specified gain.
  $V_o = 13.499 \times (20 \text{ mV}) \cos(2\pi ft)$, and peak-peak voltage is $2 \times max(V_o)$.
  Answer: 540.0 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 13.499 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 ($\zeta$)?

  \[
  \omega_c = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{4.3 \text{ mH} \cdot 10.0 \mu F}} = 4822.428 \text{ rad/s}, \quad f_c = 2\pi \omega_c = 30299.575 \text{ Hz}
  \]

  and,

  \[
  \zeta = \frac{R}{2} \sqrt{\frac{C}{L}} = \frac{272 \text{ k}\Omega}{2} \sqrt{\frac{10.0 \mu F}{4.3 \text{ mH}}} = 6.559
  \]

- 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.