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 $\bar{V}_o$
  \[ V_+ = \frac{28\, \text{k}\Omega}{28 + 1.9\, \text{k}\Omega} V_i = (9.360\, \text{mV}), \quad \bar{V}_o = \left(1 + \frac{28\, \text{k}\Omega}{1.9\, \text{k}\Omega}\right) V_+ = 15.737\, V_+ = 147.298\, \text{mV} \]

- What is $V_o$ if the offset voltage, $V_{OS} = 10\, \mu\text{V}$?
  Use superposition to get $(V_o')$ then add to ideal $V_{OS}$:
  \[ V_o' = \left(1 + \frac{28\, \text{k}\Omega}{1.9\, \text{k}\Omega}\right) V_{OS} = 15.737 \times V_{OS} = 0.157\, \text{mV} \]
  \[ V_o = \bar{V}_o + V_o' = 147.455\, \text{mV} \]

- 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.
  \[ V_o' = -\left(1 + \frac{28\, \text{k}\Omega}{1.9\, \text{k}\Omega}\right) (R_1\parallel R_2)I_B = -15.737 \times 1.779\, \text{k}\Omega \times I_B = -0.280\, \text{mV} \]
  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 $I_B$.
  \[ V_o'' = (28\, \text{k}\Omega) I_B = 0.280\, \text{mV} \]
  \[ V_o = \bar{V}_o + V_o' + V_o'' = 147.298\, \text{mV} \]
The op amp is ideal, except $f_T (= \text{Gain-Bandwidth})$ is $120 \text{ kHz}$.

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, $\bar{V}_o$

$$V_+ = \frac{24 \text{k}\Omega}{24 + 3.4 \text{k}\Omega} V_i = 0.876 V_i \quad \bar{V}_o = \left(1 + \frac{24 \text{k}\Omega}{3.4 \text{k}\Omega}\right) V_+ = 8.059 V_+ = 7.060 V_i$$

- 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 7.060 which is less than 40, so we get the specified gain.
$V_o = 7.060 \times (20 \text{ mV}) \cos(2\pi ft)$, and peak-peak voltage is $2 \times max(V_o)$.
Answer: $282.4 \text{ mV}$.

- 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 7.060 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: $160.0 \text{ mV}$.
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 ($\zeta$)?

  \[
  \omega_c = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{7.8 \text{ mH} \cdot 16.8 \mu\text{F}}} = 2762.473 \text{ rad/s}, \quad f_c = 2\pi\omega_c = 17356.766 \text{ Hz}
  \]

  and,

  \[
  \zeta = \frac{R}{2} \sqrt{\frac{C}{L}} = \frac{243 \text{ k}\Omega}{2} \sqrt{\frac{16.8 \mu\text{F}}{7.8 \text{ mH}}} = 5.639
  \]

- 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.