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 $\bar{V}_o$

  $$V_+ = \frac{26 \text{ k}\Omega}{26 + 2.6 \text{ k}\Omega} V_i = (9.090 \text{ mV}, \quad \bar{V}_o = \left(1 + \frac{26 \text{ k}\Omega}{2.6 \text{ k}\Omega}\right) V_+ = 11.000 V_+ = 99.990 \text{ mV}$$

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

  $$V'_o = \left(1 + \frac{26 \text{ k}\Omega}{2.6 \text{ k}\Omega}\right) V_{OS} = 11.000 \times V_{OS} = 0.110 \text{ mV}$$
  
  $$V_o = \bar{V}_o + V'_o = 100.100 \text{ mV}$$

- 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.

  $$V'_o = -\left(1 + \frac{26 \text{ k}\Omega}{2.6 \text{ k}\Omega}\right) (R_1 \parallel R_2) I_B = -11.000 \times 2.364 \text{ k}\Omega \times I_B = -0.260 \text{ mV}$$

  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 $I_B$.

  $$V''_o = (26 \text{ k}\Omega) I_B = 0.260 \text{ mV}$$
  
  $$V_o = \bar{V}_o + V'_o + V''_o = 99.990 \text{ mV}$$
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, $\bar{V}_o$

$$V_+ = \frac{23 \text{ k}\Omega}{23 + 3.4 \text{ k}\Omega} V_i = 0.871 V_i \quad \bar{V}_o = \left(1 + \frac{23 \text{ k}\Omega}{3.4 \text{ k}\Omega}\right) V_+ = 7.765 V_+ = 6.763 V_i$$

- 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 6.763 which is less than 40, so we get the specified gain.
  $V_o = 6.763 \times (20 \text{ mV}) \cos(2\pi ft)$, and peak-peak voltage is $2 \times \text{max}(V_o)$.
  Answer: 270.5 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 6.763 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 $2 \times \text{max}(V_o)$.
  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 ($\zeta$)?

$$\omega_c = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{7.0 \text{ mH} \cdot 17.2 \mu F}} = 2881.952 \text{ rad/s}, \quad f_c = 2\pi\omega_c = 18107.459 \text{ Hz}$$

and,

$$\zeta = \frac{R}{2} \sqrt{\frac{C}{L}} = 229 \text{ k}\Omega \cdot \frac{2}{2} \sqrt{\frac{17.2 \mu F}{7.0 \text{ mH}}} = 5.676$$

- 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.