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 $\bar{V}_o$

  $$V_+ = \frac{27 \text{ k} \Omega}{27 + 2.7 \text{ k} \Omega} V_i = (9.090 \text{ mV}, \quad \bar{V}_o = \left(1 + \frac{27 \text{ k} \Omega}{2.7 \text{ k} \Omega}\right) V_+ = 11.000 V_+ = 99.990 \text{ mV}$$

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

  $$V_o' = \left(1 + \frac{27 \text{ k} \Omega}{2.7 \text{ k} \Omega}\right) V_{OS} = 11.000 \times V_{OS} = 0.110 \text{ mV}$$
  $$V_o = \bar{V}_o + V_o' = 100.100 \text{ mV}$$

- 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.

  $$V_o'' = -(1 + \frac{27 \text{ k} \Omega}{2.7 \text{ k} \Omega}) (R_1 \parallel R_2) I_B = -11.000 \times 2.455 \text{ k} \Omega \times I_B = -0.270 \text{ mV}$$

  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 $I_B$.

  $$V_o''' = (27 \text{ k} \Omega) I_B = 0.270 \text{ mV}$$

  $$V_o = \bar{V}_o + V_o' + V_o''' = 99.990 \text{ mV}$$
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, $\bar{V}_o$

\[
V_+ = \frac{26 \text{ k}\Omega}{26 + 3.9 \text{ k}\Omega} V_i = 0.870 V_i \quad \bar{V}_o = \left(1 + \frac{26 \text{ k}\Omega}{3.9 \text{ k}\Omega}\right) V_+ = 7.667 V_+ = 6.670 V_i
\]

- 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 6.670 which is less than 40, so we get the specified gain.
  
  $V_o = 6.670 \times (20 \text{ mV}) \cos(2\pi ft)$, and peak-peak voltage is $2 \times \text{max}(V_o)$.

  Answer: 266.8 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 6.670 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)

  This is a low pass filter

- 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 ($\zeta$)?

  $\omega_c = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{7.3 \text{ mH} \cdot 19.4 \mu \text{F}}} = 2657.282 \text{ rad/s}, \quad f_c = 2\pi \omega_c = 16695.846 \text{ Hz}$

  and,

  $\zeta = \frac{R}{2 \sqrt{\frac{C}{L}}} = \frac{257 \text{ k} \Omega}{2 \sqrt{\frac{19.4 \mu \text{F}}{7.3 \text{ mH}}}} = 6.624$

- 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.