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 $ar{V}_o$

  \[
  V_+ = \frac{28 \text{k}\Omega}{28 + 2.5 \text{k}\Omega} V_i = (9.180 \text{ mV}), \quad \bar{V}_o = \left(1 + \frac{28 \text{k}\Omega}{2.5 \text{k}\Omega}\right) V_+ = 12.200 \text{ V}_+ = 111.996 \text{ mV}
  \]

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

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

  \[
  V'_o = \left(1 + \frac{28 \text{k}\Omega}{2.5 \text{k}\Omega}\right) V_{OS} = 12.200 \times V_{OS} = 0.122 \text{ mV}
  \]

  $V_o = \bar{V}_o + V'_o = 112.118 \text{ mV}$

- 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.

  \[
  V'_o = -\left(1 + \frac{28 \text{k}\Omega}{2.5 \text{k}\Omega}\right) (R_1||R_2) I_B = -12.200 \times 2.295 \text{k}\Omega \times I_B = -0.280 \text{ mV}
  \]

  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 $I_B$.

  \[
  V''_o = (28 \text{k}\Omega) I_B = 0.280 \text{ mV}
  \]

  $V_o = \bar{V}_o + V'_o + V''_o = 111.996 \text{ mV}$
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, $\bar{V}_o$

$$V_+ = \frac{29 \text{ k}\Omega}{29 + 3.3 \text{ k}\Omega} V_i = 0.898 V_i$$
$$\bar{V}_o = \left(1 + \frac{29 \text{ k}\Omega}{3.3 \text{ k}\Omega}\right) V_+ = 9.788 V_+ = 8.790 V_i$$

- 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 8.790 which is less than 40, so we get the specified gain.
  $V_o = 8.790 \times (20 \text{ mV}) \cos(2\pi ft)$, and peak-peak voltage is $2 \times \max(V_o)$.
  Answer: 351.6 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 8.790 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)
  - 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 ($\zeta$)?

  $$\omega_c = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{8.2 \text{ mH} \cdot 16.5 \mu F}} = 2718.636 \text{ rad/s}, \quad f_c = 2\pi\omega_c = 17081.336 \text{ Hz}$$

  and,

  $$\zeta = \frac{R}{2} \sqrt{\frac{C}{L}} = \frac{293 \text{ k}\Omega}{2} \sqrt{\frac{16.5 \mu F}{8.2 \text{ mH}}} = 6.572$$

- 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.