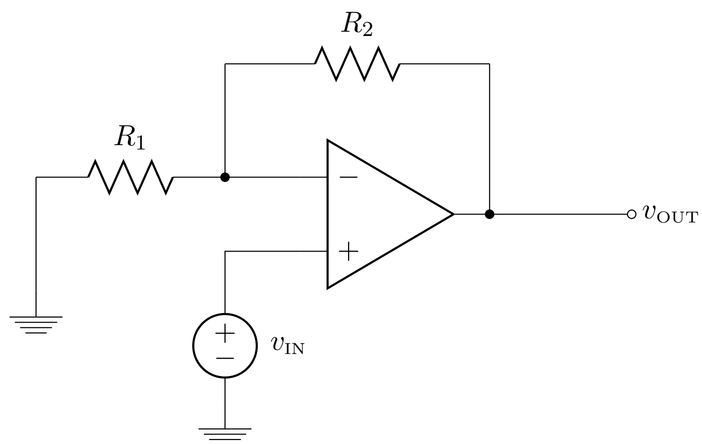
Problem 1. A non-inverting op amp configuration is shown below. The op amp has the following characteristics:

- DC open-loop gain $A_0 = 40\text{dB}$.
- Open-loop 3dB cut-off frequency $f_c = 1\text{MHz}$.
- Slew rate $\text{SR} = 2\text{V}/\,\mu\text{s}$.
- Rail voltages at $\pm 5\text{V}$.
- $R_1 = 1\text{k}\Omega$ and $R_2 = 1\text{k}\Omega$, so the ideal closed-loop gain is $2\text{V}/\,\text{V}$.



(A) Calculate the unity-gain frequency (f_t) of this amplifier circuit. Give your answer in Hz.

(B) Calculate the 3dB cut-off frequency for the **closed-loop** circuit.

(C) Sketch the magnitude response (i.e. Bode plot) for this op amp, showing both the open-loop and closed-loop responses. Identify the unity-gain frequency.

(D) Calculate the full-power bandwidth (FPBW) for this op amp.

(E) If the circuit amplifies an input signal described by the equation

$$v_{\text{IN}} = V_{\text{IN}} \sin\left(2\pi f t\right),$$

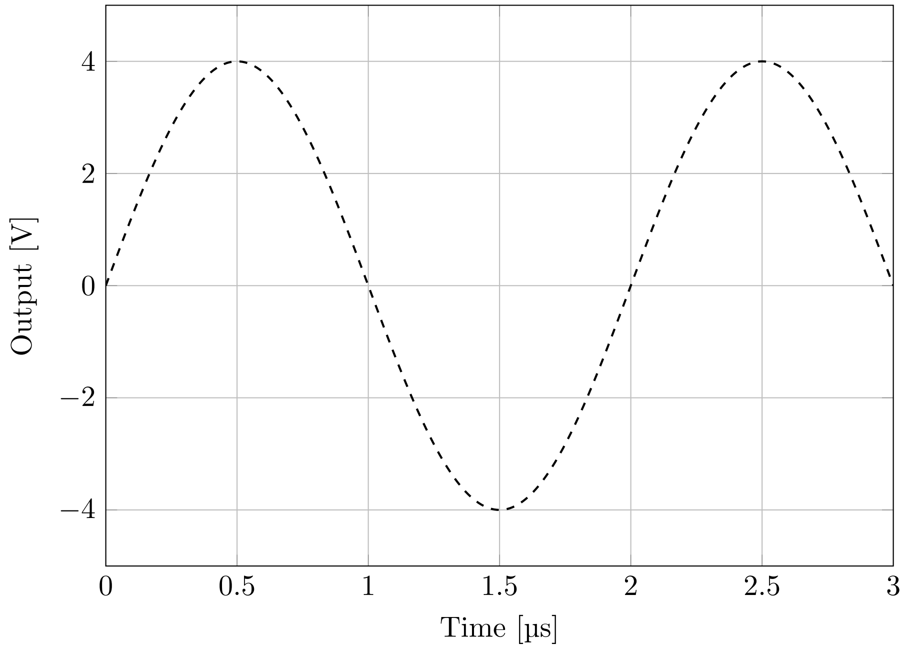
answer these subquestions:

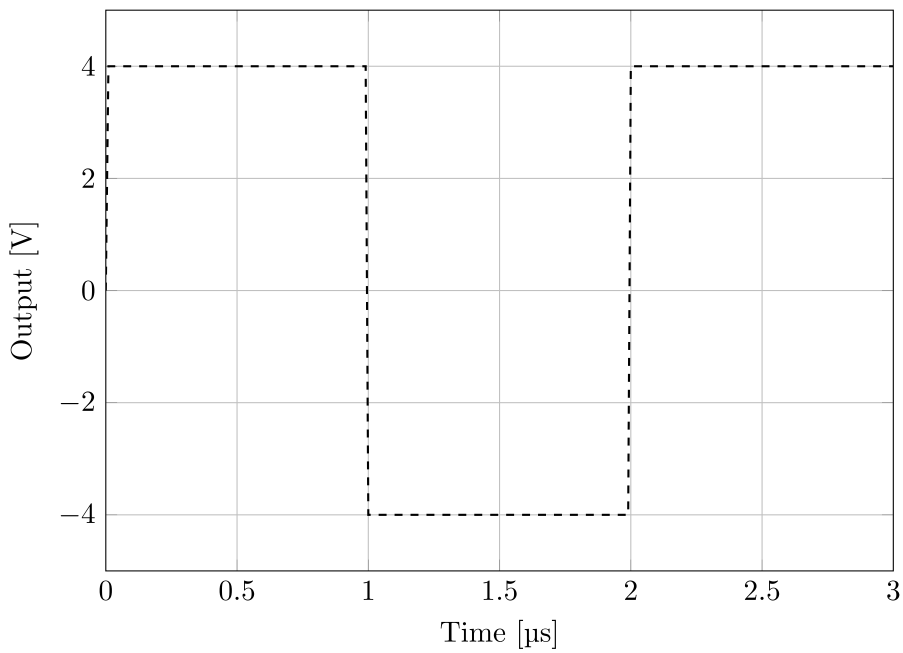
i. If $f = 1\text{MHz}$, what is the maximum possible amplitude V_{IN} with no slewing?

ii. If $V_{\text{IN}} = 1\text{V}$, what is the maximum possible f with no slewing?

(F) If v_{IN} is a square wave, is it possible to avoid slewing in the circuit's output?

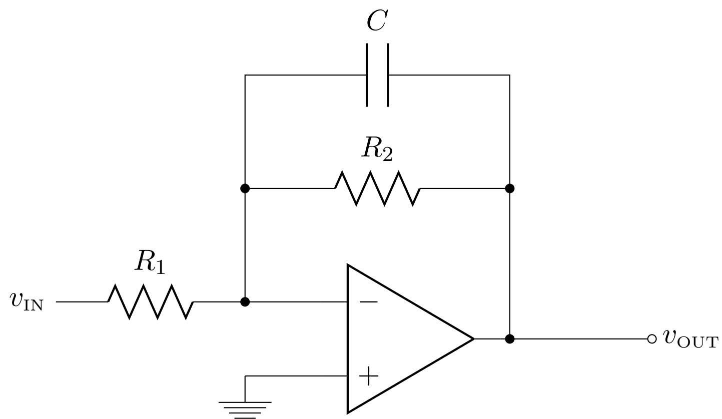
(G) Carefully study the axes and waveforms shown below. The waveforms are shown for the **ideal** behavior (with no slewing). If slewing is present, draw the resulting waveforms. You may assume that $v_{\text{OUT}} = 0$ at time $t = 0$.


4
2
0
−2
−4
Output [V]
0
0.5
1
1.5
2
2.5
3
Time [µs]


4
2
0
−2
−4
Output [V]
0
0.5
1
1.5
2
2.5
3
Time [µs]

Problem 2. An inverting Miller integrator circuit is shown below. The component values are

$$R_1 = 10\text{k}\Omega$$
$$R_2 = 10\text{k}\Omega$$
$$C = 10\mu\text{F}$$



(A) When operating at DC, the capacitor C can be viewed as an open circuit (i.e. as though it isn't there). What is the DC gain of this circuit?

(B) Using Laplace-transform analysis, show that the steady-state transfer function is given by

$$H(s) = \left(-\frac{R_2}{R_1}\right)\left(\frac{1}{1 + sR_2C}\right).$$

You may assume that the op amp is ideal.

(C) Since an integrator has transfer function of the form K/s, this circuit can only be considered an integrator for high-frequency signals. At low frequencies (close to DC), it is a unity-gain buffer. What is the cut-off frequency that separates the AC integrating mode from the DC buffering mode?

(D) The magnitude response of a linear system is

$$|H(f)| = \sqrt{H(j2\pi f)\,H(-j2\pi f)}.$$

If the circuit has an input sine wave with amplitude 100mV at frequency $f = 10\text{Hz}$, predict the amplitude of the output waveform.

(E) Suppose the op amp has an input bias current $I_{\text{bias}} = 1\mu\text{A}$ and an offset voltage of $V_{\text{ofs}} = 10\text{mV}$. What is the resulting DC offset that appears at the circuit's output? (Remember that the offset voltage is modeled as a DC input applied to the op amp's non-inverting terminal).