This is a non-inverting amplifier with a gain of $G = 1 + \frac{411}{120} = 343.5$. With such a large gain, it will saturate when $V_i = ±10 V / G = ±0.029 V$.

Times when $|V_i| < 0.029$, $V_o$ are

$T_1 = \pm \frac{0.1-0.029}{5 V/100 \text{ms}} = ±1.420 \text{ ms}$.

$T_2 = \pm \frac{0.1+0.029}{5 V/100 \text{ms}} = ±2.580 \text{ ms}$.

- Sketch $V_o$.
  - From start to $-2.580 \text{ ms}$, $V_o = -10 V$
  - From $-2.580 \text{ ms}$ to $-1.420 \text{ ms}$, $V_o$ transitions from $-10 V$ to $+10 V$
  - From $-1.420 \text{ ms}$ to $0 \text{ ms}$, $V_o = +10 V$
  - From $0 \text{ ms}$ to $+1.420 \text{ ms}$, $V_o = -10 V$
  - From $+1.420 \text{ ms}$ to $+2.580 \text{ ms}$, $V_o$ transitions from $-10 V$ to $+10 V$
  - From $+2.580 \text{ ms}$ to end, $V_o = +10 V$

- At what times does $V_o$ reach $±10 V$?
  - From start to $-2.580 \text{ ms}$, $V_o = -10 V$
  - From $-1.420 \text{ ms}$ to $0 \text{ ms}$, $V_o = +10 V$
  - From $0 \text{ ms}$ to $+1.420 \text{ ms}$, $V_o = -10 V$
  - From $+2.580 \text{ ms}$ to end, $V_o = +10 V$

- Does this circuit suffer from multiple transitions?
  - Yes
The diagram shows a voltage divider circuit with resistances 1.37 kΩ and 491 kΩ. The input voltage $V_i$ is applied to the circuit, and the output voltage $V_o$ is observed.

### Question B

- Sketch $V_o$.
- At what times does $V_o$ reach ±10 V?
- Does this circuit suffer from multiple transitions?

**Notes:**
- Voltage axis not to scale.
- The slope of the voltage may be approximated as 5 V/100 ms.
- Op amps are ideal.

#### Conditions:

1) If $V_i < V_+$ then $V_o = +10 V$ and $V_+ = +0.028 V$.
2) If $V_i > V_+$ then $V_o = -10 V$ and $V_+ = -0.028 V$.

#### Sketch $V_o$.

1) Initially, $V_o = +10$ and $V_+ = +0.028 V$
2) When $V_i$ crosses $+0.028 V$, then $V_o = -10$ and $V_+ = -0.028 V$
3) When $V_i$ crosses $-0.028 V$, then $V_o = +10$ and $V_+ = +0.028 V$
4) When $V_i$ crosses $+0.028 V$, then $V_o = -10$ and $V_+ = -0.028 V$

#### At what times does $V_o$ reach ±10 V?

Transitions at $\pm 0.1 - 0.028 \times 10 V = \pm 1.44 V$.

1) Beginning until $-1.44 ms \implies V_o = +10 V$.
2) $-1.44 ms$ until $0 ms \implies V_o = -10 V$.
3) $0 ms$ until $+2.56 ms \implies V_o = +10 V$.
4) $+2.56 ms$ until end $\implies V_o = -10 V$.

#### Does this circuit suffer from multiple transitions?

Yes
• Sketch $V_o$ (this is difficult because of the exponential – indicate the main features of the curve)

• At what times does $V_o$ reach $\pm 10$ V?

• Does this circuit suffer from multiple transitions?

(Notes: voltage axis not to scale. The slope of the voltage may be approximated as 5 V/100 ms. Op amps are ideal)

This is a low pass filter with a gain of $G = -\frac{546 \, k\Omega}{10.9 \, k\Omega} = -50.09$.
With such a large gain, it will saturate when $V_i = \pm 10$ V/$G = \pm 0.200$ V.
The time constant is $\tau = 546 \, k\Omega \times 360 \, nF = 196.6$ ms.

• At what times does $V_o$ reach $\pm 10$ V?
  Transitions at $\pm \frac{0.1 + 0.200}{5 \, V/100 \, ms} = \pm 6.0$ ms.
  Thus: 1) Beginning until $-6.0 \, ms \implies V_o = +10$ V.
  2) $+6.0 \, ms$ until end $\implies V_o = -10$ V.

• Sketch $V_o$ (this is difficult because of the exponential – indicate the main features of the curve)
  Beginning until $-6.0 \, ms \implies V_o = +10$ V. Then, from $+6.0 \, ms$ until $-6.0 \, ms$ the will go from $+10$ to $-10$ V, following the flipped the blue line (with gain) but with a slight delay. However, it will only deviate slightly at the zigzag. The time constant $\tau$ is longer than the gap in the zigzag. Finally, from $+6.0 \, ms$ until end $\implies V_o = -10$ V.

• Does this circuit suffer from multiple transitions?
  No

Explanation: In the above case, the response is linear throughout the +/-0.1V transition of the input signal. The addition of the capacitor turns the circuit into a “lossy integrator”. Its step response would be an exponential with time constant $RC = 196.6$ ms. We don’t have exactly a step at the input; however, if the input transitions are short compared to the time constant we can approximate the output as an exponential (perhaps with a “bump” $V_i$ briefly changes sign). assuming the input transitions are short compared to $RC$, then $V_o$ will NOT suffer from multiple transitions.