This is a non-inverting amplifier with a gain of $G = 1 + \frac{408}{194} = 211.3$. With such a large gain, it will saturate when $V_i = \pm 10 V / G = \pm 0.047 V$.

Times when $|V_i| < 0.047 V$, are

$T_1 = \pm \frac{0.1 - 0.047}{0.05} = \pm 1.060$ ms.
$T_2 = \pm \frac{0.1 + 0.047}{0.05} = \pm 2.940$ ms.

**Sketch $V_o$.**

1) From start to $-2.940$ ms, $V_o = -10 V$
2) From $-2.940$ ms to $-1.060$ ms, $V_o = \text{transitions from } -10 V \text{ to } +10 V$
3) From $-1.060$ ms to $0$ ms, $V_o = +10 V$
4) From $0$ ms to $+1.060$ ms, $V_o = -10 V$
5) From $+1.060$ ms to $+2.940$ ms, $V_o = \text{transitions from } -10 V \text{ to } +10 V$
6) From $+2.940$ ms to end, $V_o = +10 V$

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

1) From start to $-2.940$ ms, $V_o = -10 V$
3) From $-1.060$ ms to $0$ ms, $V_o = +10 V$
4) From $0$ ms to $+1.060$ ms, $V_o = -10 V$
6) From $+2.940$ ms to end, $V_o = +10 V$

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

Yes
**Question: B**

- Sketch $V_0$.
- At what times does $V_0$ reach $\pm 10\, \text{V}$?
- Does this circuit suffer from multiple transitions?

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

Thresholds at $\pm \frac{1.36\, \text{k}\Omega}{546+1.36\, \text{k}\Omega} \times 10\, \text{V} = \pm 0.025\, \text{V}$.

Conditions:
1) If $V_i < V_+ \implies V_o = +10\, \text{V}$ and $V_+ = +0.025\, \text{V}$.
2) If $V_i > V_+ \implies V_o = -10\, \text{V}$ and $V_+ = -0.025\, \text{V}$.

- Sketch $V_o$.
  1) Initially, $V_o = +10$ and $V_+ = +0.025\, \text{V}$
  2) when $V_i$ crosses $+0.025\, \text{V}$, then $V_o = -10$ and $V_+ = -0.025\, \text{V}$
  3) when $V_i$ crosses $-0.025\, \text{V}$, then $V_o = +10$ and $V_+ = +0.025\, \text{V}$
  4) when $V_i$ crosses $+0.025\, \text{V}$, then $V_o = -10$ and $V_+ = -0.025\, \text{V}$

- At what times does $V_0$ reach $\pm 10\, \text{V}$?
  Transitions at $\pm \frac{0.1-0.025}{5\, \text{V}/100\, \text{ms}} = \pm 1.50\, \text{ms}$.
  1) Beginning until $-1.50\, \text{ms} \implies V_o = +10\, \text{V}$.
  2) $-1.50\, \text{ms}$ until $0\, \text{ms} \implies V_o = -10\, \text{V}$.
  3) $0\, \text{ms}$ until $+2.50\, \text{ms} \implies V_o = +10\, \text{V}$.
  4) $+2.50\, \text{ms}$ until end $\implies V_o = -10\, \text{V}$.

- 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?

(Note: 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 $G = -\frac{517\, \text{k}\Omega}{16.6\, \text{k}\Omega} = -31.14$.

With such a large gain, it will saturate when $V_i = \pm 10$ V / $G = \pm 0.321$ V.

The time constant is $\tau = 517\, \text{k}\Omega \times 582\, \text{nF} = 300.9$ ms.

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

  Transitions at $\pm \frac{0.1 + 0.321}{5\, \text{V}/100\, \text{ms}} = \pm 8.4$ ms.

  Thus: 1) Begining until $-8.4$ ms $\implies V_o = +10$ V.

  2) $+8.4$ 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)

  Begining until $-8.4$ ms $\implies V_o = +10$ V. Then, from $+8.4$ ms until $-8.4$ 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 $+8.4$ 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 $RC = 300.9$ 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.