Question 1

(a)

Case (i):

For the positive half cycle:

The diode D_1 is in forward bias condition and the diode acts as a short circuited.

The diode D_2 is in reverse bias condition and the diode acts as an open circuited.

Therefore the overall circuit is conducting. Ideally the diode voltage is treated 0 V.

For positive half cycle, the output voltage is equal to input voltage.

Case (ii):

For the negative half cycle:

The diode D_1 is in reverse bias condition and the diode acts as an open circuited.

The diode D_2 is in forward bias condition and the diode acts as a short circuited.

Therefore the overall circuit is conducting. Ideally the diode voltage is treated 0 V.

For negative half cycle, the output voltage is equal to input voltage.

The output waveform is shown in Figure 5.

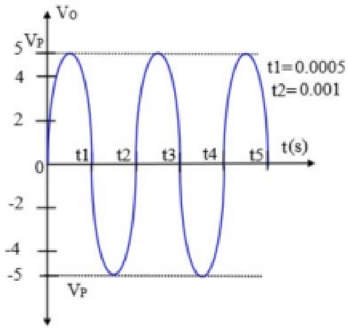


Figure 5

Therefore, the positive peak value is $\boxed{+5\ \text{V}}$.

Therefore, the negative peak value is $\boxed{-5\ \text{V}}$.

(b)

Case (i):

For the positive half cycle $v_i > 0$, the diode D_1 is in reverse bias condition and the diode acts as a open circuit.

The total input voltage is flows as output voltage.

Therefore, the output voltage is equal to input voltage.

Case (ii):

For the negative half cycle $v_i < 0$, the diode D_1 is in forward bias condition and the diode acts as a short circuit.

The circuit acts a voltage divider circuit.

Find the total output voltage.

$$v_o = \frac{1\,\text{k}\Omega}{1\,\text{k}\Omega + 1\,\text{k}\Omega} v_i$$
$$= \frac{1\,\text{k}\Omega}{2\,\text{k}\Omega}(5\text{ V})$$
$$= 0.5(5)$$
$$v_o = 2.5\text{ V}$$

Therefore, the output voltage is -2.5 V.

The output waveform is shown in Figure 9.

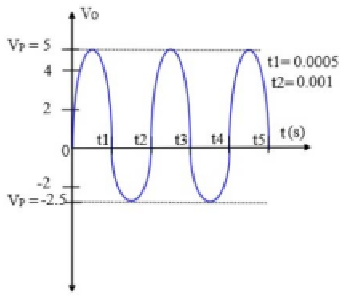


Figure 9

Therefore, the positive peak value is $\boxed{+5\text{ V}}$.

Therefore, the negative peak value is $\boxed{-2.5\text{ V}}$.

(c)

Case (i):

For the positive half cycle $v_i > 0$:

The diode D_1 is in reverse bias condition and the diode D_2 is in forward bias condition.

Hence, the diode D_1 acts as a open circuited to ground and D_2 acts as short circuit.

Find the voltage across the $1\,\text{k}\Omega$ resistor.

Current flowing $1\,\text{k}\Omega$ resistor is $1\,\text{mA}$.

Voltage across $1\,\text{k}\Omega$ resistor is $V_o = (1\,\text{k}\Omega)(1\,\text{mA}) = 1\,\text{V}$.

Case (ii):

For the negative half cycle $v_i < 0$:

The diode D_1 is in forward bias condition and the diode D_2 is in reverse bias condition.

Hence, the diode D_1 acts as a short circuited to ground and D_2 acts as open circuit.

Find the voltage across the $1\,\text{k}\Omega$ resistor.

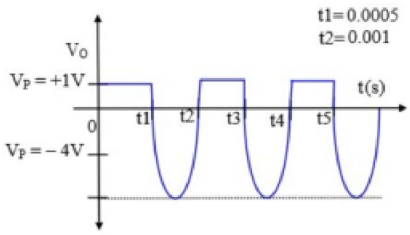
Current flowing $1\,\text{k}\Omega$ resistor is $1\,\text{mA}$.

Voltage across $1\,\text{k}\Omega$ resistor is $V_o = V_i + 1\,\text{V}$.

$V_o = -5 + 1\,\text{V}$
$V_o = -4\,\text{V}$

Voltage across $1\,\text{k}\Omega$ resistor is $V_o = -4\,\text{V}$.

The output waveform is shown in Figure 11.



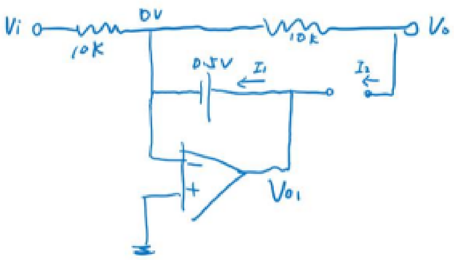
Figure

Therefore, the positive peak value is $\boxed{+1\,\text{V}}$.

Therefore, the negative peak value is $\boxed{-4\,\text{V}}$.

Question 2

① D1 on , D2 off



swing ok

$V_{01} = 0.5 > 0 \Rightarrow V_i < 0$

$I_1 > 0,\quad I_2 = 0$

$\frac{V_i - 0}{10k} + \frac{V_0 - 0}{10k} + I_1 = 0$

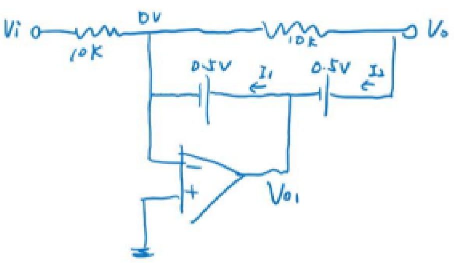
$\frac{0 - V_0}{10k} - I_2 = 0 \Rightarrow V_0 = 0$

$\left.\begin{matrix} V_0 = 0 \\ V_{01} = 0.5 \end{matrix}\right\} \Rightarrow$ D2 off ✓

Therefore, when $V_i < 0 \Rightarrow V_0 = 0$

② D1 on , D2 on

$I_1 > 0,\ I_2 > 0$



swing ok

$V_{01} = 0.5 > 0 \Rightarrow V_i < 0$

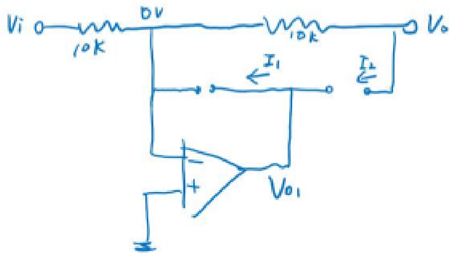
$V_0 = V_{01} + 0.5 = 1$

$\frac{V_i - 0}{10K} + \frac{V_0 - 0}{10K} + I_1 = 0$

$\frac{V_0 - 0}{10K} + I_2 = 0$

impossible. since $\left\{\begin{matrix} V_0 = 1 > 0 \\ I_2 > 0 \end{matrix}\right.$

③ D_1 off, D_2 off



$I_1 = I_2 = 0$

$V_{o1} < 0.5$

$\frac{V_i - 0}{10k} + \frac{V_o - 0}{10k} = 0$

$\Rightarrow V_o = -V_i$

$\frac{0 - V_o}{10k} - I_2 = 0$

$\Rightarrow V_o = 0$

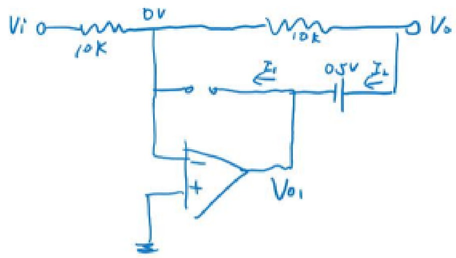
$\therefore V_i = 0 \quad \Rightarrow V_{o1} = 0$ swing ok

Therefore, when $V_i = 0 \Rightarrow V_o = 0$

④ D_1 off, D_2 on

$I_1 = 0$, $I_2 > 0$

$V_{o1} < 0.5V$, $V_o = V_{o1} + 0.5$



$\frac{V_i - 0}{10k} + \frac{V_o - 0}{10k} = 0$

$\Rightarrow V_o = -V_i$

$\frac{0 - V_o}{10k} - I_2 = 0$

$\Rightarrow V_o = -10k \cdot I_2 < 0$

$\Rightarrow V_i > 0 \Rightarrow V_{o1} < 0$

$\because \pm 3V$ swing

$\therefore -3 \leq V_{o1} < 0$

$V_{o1} = V_o - 0.5 = -V_i - 0.5$

$\therefore -3 \leq -V_i - 0.5 < 0$

$-0.5 < V_i \leq 2.5$

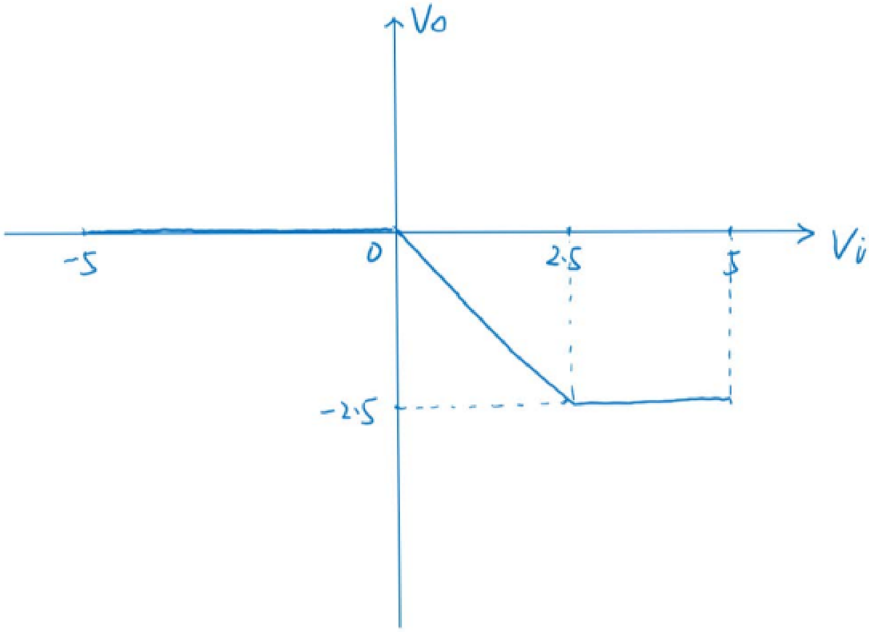
$\Rightarrow 0 < V_i \leq 2.5$

Therefore, when $0 < V_i \leq 2.5$

$\Rightarrow V_o = -V_i$

When $2.5 < V_i \leq 5$, the opamp output saturates $\Rightarrow V_{o1} = -3V$

$\Rightarrow V_o = -2.5V$



Vo
Vi
-5
0
2.5
5
-2.5

Question 3

(a) Assume that $\Delta T \ll T$

$V_r \cong (V_s - V_{on})\left(\frac{T}{RC}\right) = (5-0.8)\left(\frac{\frac{2\pi}{2\pi 100}}{100C}\right) < 0.1$

$\frac{4.2}{10000C} < 0.1$

$C > 4.2\times10^{-3} F$

$V_{dc} = V_s - V_{on} = 5V - 0.8V = 4.2V$

$I_{dc} = \frac{V_{dc}}{R} = \frac{4.2V}{100\Omega} = 4.2\times10^{-2} A$

$\theta_c = \sqrt{\frac{2V_r}{V_s}} < \sqrt{\frac{2\times0.1}{5}} = 0.2 rad$

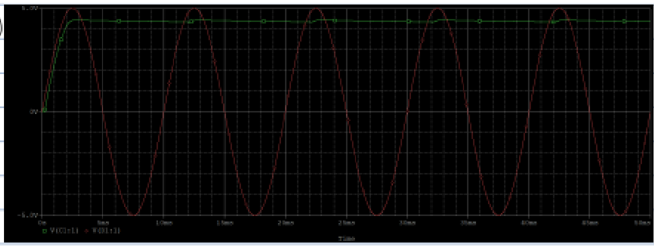
$\Delta T = \frac{\theta_c}{\omega} < \frac{0.2}{2\pi 100} = 3.18\times10^{-4} s \ll T$, assumption is right

$I_{peak} \simeq \frac{2I_{dc}T}{\Delta T} > \frac{2\times4.2\times10^{-2}\times\frac{1}{100}}{3.18\times10^{-4}} = 2.64 A$

$I_{surge} = \omega C V_s > 2\pi 100 \times 4.2\times10^{-3} \times 5 = 13.19 A$

$PIV = 2V_s - V_{on} = 10V - 0.8V = 9.2V$

(b)



From the graph, we can know that

$V_{dc} \approx 4.4V$

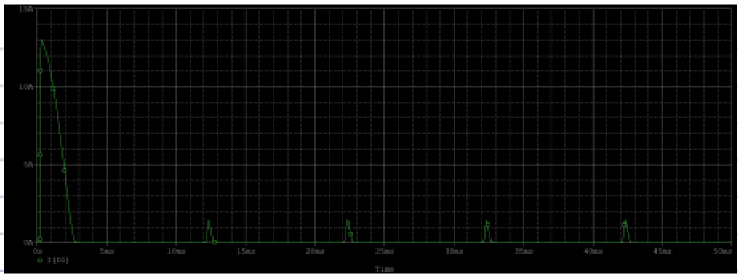
$I_{dc} = \frac{V_{dc}}{R} = 4.4\times10^{-2} A$

$V_r \approx 0.1V$

$PIV \approx 9.4V$

Compared with calculated ones, they are very close

(c)



From the graph, we can know that

$I_{peak} \approx 1.44A$

$I_{surge} \approx 13.01A$

Compared with calculated ones. Ipeak is very different but Isurge is very close