Q1

The concentration of the majority electrons is

$$n_n = N_D = 10^{17}/cm^3$$

The concentration of the minority holes is

$$p_n = \frac{n_i^2}{N_D} = \frac{(1.5\times10)^2}{10^{17}}$$

$$= 2.25\times10^3/cm^3$$

Q2

(a)

Draw the equivalent circuit.

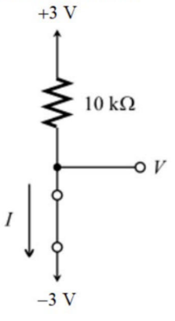


Figure 2

Note that the node V is directly connected to -3 V source in the circuit of Figure 2. Therefore, the output voltage, V is,

$$V = -3\text{ V}$$

Use Ohm's law to find the current in the circuit.

$$\begin{aligned} I &= \frac{3\text{ V} - (-3\text{ V})}{10\text{ k}\Omega} \\ &= \frac{6\text{ V}}{10\times10^3\ \Omega} \\ &= 0.6\times10^{-3}\text{ A} \\ &= 0.6\text{ mA} \end{aligned}$$

Thus, the voltage, V is $\boxed{-3\text{ V}}$ and the current, I is $\boxed{0.6\text{ mA}}$.

(b)

Draw the equivalent circuit.

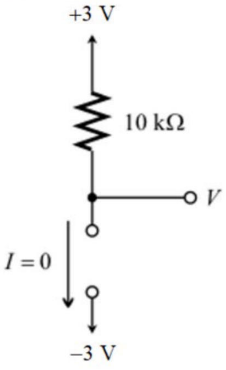


Figure 3

Note that there is no path for the current in the circuit of Figure 3. Therefore, the current, I through the diode is,

$I = 0\text{ A}$

Use Ohm's law to find the output voltage.

$$I = \frac{3\text{ V} - V}{10\text{ k}\Omega}$$

$$\frac{3\text{ V} - V}{10\times10^3\ \Omega} = 0$$

$$3\text{ V} - V = 0$$

$$V = 3\text{ V}$$

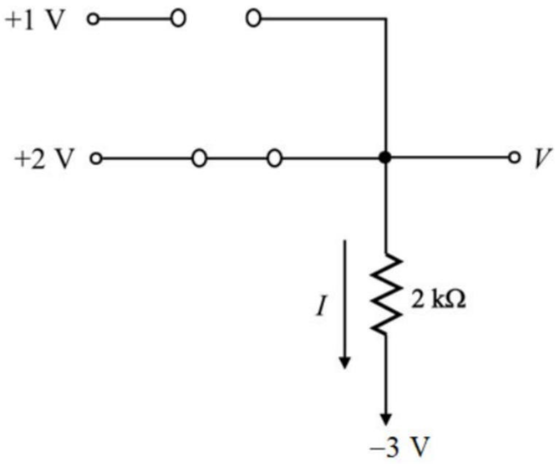
Thus, the voltage, V and the current, I in the circuit are $\boxed{3\text{ V}}$ and $\boxed{0\text{ A}}$ respectively.

(c)

In case of multiple diodes in the circuit, the diode which has highest potential difference between the anode and cathode conducts (short circuit) and other diodes acts as open circuit.

The diode D_1 is cut-off, and the diode D_2 is in the conducting mode in the circuit.

Draw the modified circuit diagram.



The voltage, V at the output terminal of Figure 1 is obtained as the voltage at the receiving end of the diode, D_2.

$$V = 2\text{ V}$$

Therefore, the value of voltage V is $\boxed{2\text{ V}}$.

Calculate the value of the current that flows through the resistance.

$$I = \frac{V-(-3)}{2\text{ k}\Omega} = \frac{V+3}{2\times10^3}$$

Substitute 2 V for V.

$$I = \frac{2+3}{2\times10^3} = \frac{5}{2\times10^3} = 2.5\text{ mA}$$

Therefore, the value of current I is $\boxed{2.5\text{ mA}}$.

Q3

(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.

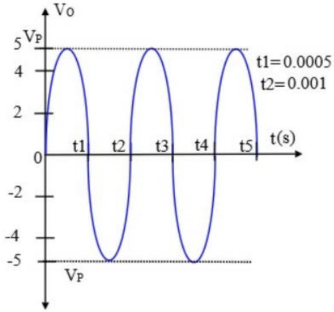


Figure 5

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 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 $1\,\mathrm{k\Omega}$ resistor.

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

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

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 $1\,\mathrm{k\Omega}$ resistor.

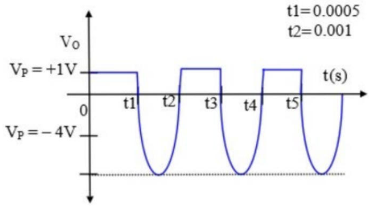
Current flowing $1\,\mathrm{k\Omega}$ resistor is $1\,\mathrm{mA}$.

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

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

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

The output waveform is shown in Figure 11.



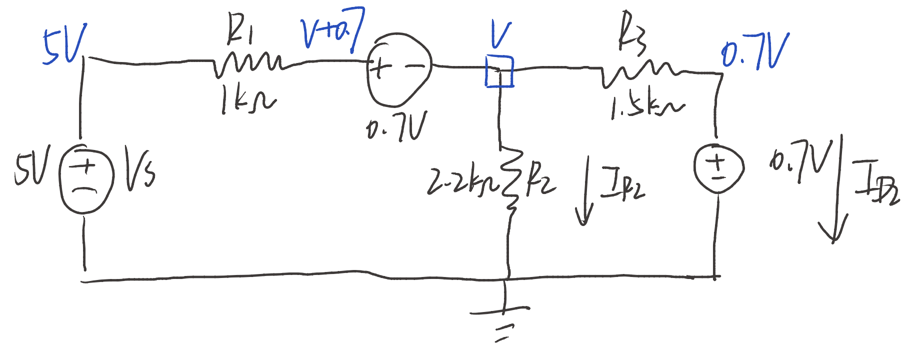
Figure

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

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

Q4

Assume D_1 and D_2 are all on



By KCL: $\dfrac{V+0.7-5}{1k} + \dfrac{V-0}{2.2k} + \dfrac{V-0.7}{1.5k} = 0$

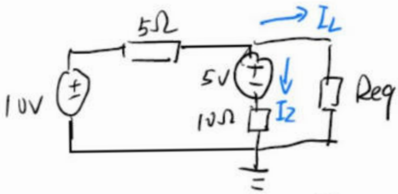
$\Rightarrow V = 2.25\,V$

$$I_{R2} = \frac{V}{2.2k} = 1.02mA$$

$$I_{D2} = \frac{V-0.7}{1.5k} = 1.03mA$$

Q5

(1) Assume the diode works in breakdown region



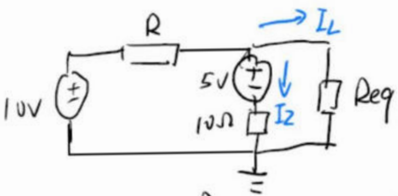
$R_{eq} = (20 \| 20) = 10\Omega$

$$\begin{cases} 10I_L = 5 + 10I_Z \\ 10 - 5(I_L + I_Z) = 10I_L \end{cases} \Rightarrow \begin{cases} I_L = \frac{5}{8}A \\ I_Z = \frac{1}{8}A \end{cases}$$

Since $I_Z > 0$ Assumption is correct.

$$\boxed{I_L = \frac{5}{8}A}$$

(2) For reverse breakdown to happen: $I_Z > 0$



$$\begin{cases} 10I_L = 5 + 10I_Z \\ 10 - R(I_L + I_Z) = 10I_L \end{cases}$$

$$5 - \frac{R}{2} = (10 + 2R)I_Z$$

For $I_Z > 0$. $5 - \frac{R}{2} \geq 0$ $R \leq 10$.

Then the $\boxed{R_{min} = 0 \quad R_{max} = 10.}$

Q6

(a) $C = \frac{V_p - V_{on}}{V_r} \cdot \frac{T}{2R}$

$V_r < 0.1V \Rightarrow \frac{V_p - V_{on}}{C} \cdot \frac{T}{R} < 0.1$

$\Rightarrow C > \frac{V_p - V_{on}}{0.1} \cdot \frac{T}{R}$

$= \frac{5-0.9}{0.1} \cdot \frac{\frac{1}{100}}{100}$

$= 4.1mF$

$V_{dc} = V_p - V_{on} = 5-0.9 = 4.1V$

$I_{dc} = \frac{V_{DC}}{R} = \frac{4.1}{100} = 4.1 \times 10^{-2} A$

$\theta_c = \sqrt{\frac{2V_r}{V_p}} = \sqrt{\frac{2 \times 0.1}{5}} = 0.2 rad$

$\Delta T = \frac{\theta_c}{w} = \frac{0.2}{2\pi \times 100} = 3.18 \times 10^{-4} s$

$I_{peak} = \frac{2I_{dc}}{\Delta T} = \frac{2 \times 4.1 \times 10^{-2}}{3.18 \times 10^{-4}} = 2.576A$

$I_{surge} = WCV_s = 2\pi \times 100 \times 4.1 \times 10^{-3} \times 5$

$= 12.88A$

$PIV = 2V_p - V_{on} = 2 \times 5 - 0.9 = 9.1V$

(b)