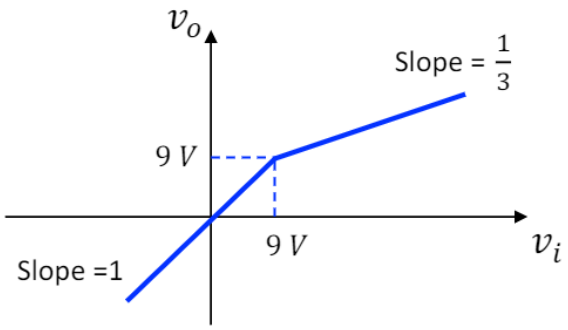
a) Design a diode waveform shaping circuit that would have the below transfer characteristics.
   - You can use PN junction diodes and Zener diodes with $V_{D0} = 0.7\ V$, $V_Z = 4\ V$, DC voltage sources, and resistors in your design.
   - **You must use a Zener diode in your design.**
   - In your circuit schematic, show v_i with the symbol of a voltage source. Clearly label the terminals that are used to measure the output.

b) Write the possible cases of the operation of the diode(s) in your designed circuit, and for each case, include the calculation of finding v_o and the range of v_i.
   Show your work.

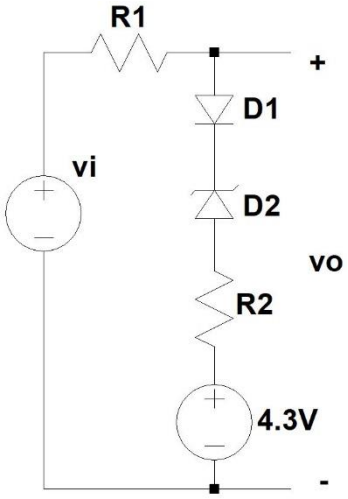
c) Sketch the output, $v_o(t)$, for $0 \le t \le 2ms$, if the input is a 5V DC signal, $v_i(t) = 5\ V$.



Solution:

(a) Here,

$$v_o = \begin{cases} v_i; & v_i < 9 \\ \frac{v_i}{3} + 9 \times \frac{2}{3}; & v_i \ge 9 \end{cases}$$



(b) D2 can never be ON as i_{D2} must be less than or equal to 0 depending on the state of D1. Therefore, there are two possible cases of operation.

D1 ON, D2 Zener

$$v_o = 4.3 + V_{Do} + V_Z + \left(v_i - (4.3 + V_{Do} + V_Z)\right)\frac{R2}{R1 + R2}$$

$$\Rightarrow v_o = v_i\frac{R2}{R1 + R2} + 9\frac{R1}{R1 + R2} = \frac{v_i}{3} + 9 \times \frac{2}{3}$$

From the equation, $R1 = 2R2$. Taking R1=2kΩ and R2=1kΩ

To operate in this condition, we need to make sure that $i_{D1} \geq 0$. Then,

$$i_{D1} \geq 0$$
$$\Rightarrow \frac{v_i - 9}{1k + 2k} \geq 0 \Rightarrow v_i \geq 9$$

D1 OFF, D2 OFF

$$i_{D1} = i_{D2} = 0$$

Then,

$$v_o = v_i$$

To operate in this condition, we need to make sure that $v_{D1} < V_{Do}$ and $-V_Z < v_{D2} < V_{Do}$. Thus,

$$v_o = v_i = v_{D1} - v_{D2} + 4.3$$
$$\Rightarrow v_i < V_{Do} + V_Z + 4.3$$
$$\Rightarrow v_i < 9$$

(c)