Introduction to Nonlinear Resistive Circuits

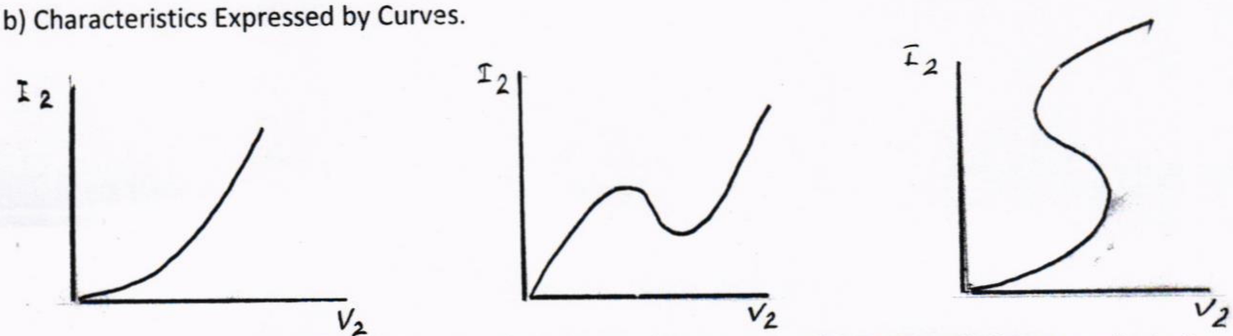
A resistive circuit is nonlinear if it contains at least one resistive nonlinear element. A resistive nonlinear element is one with a voltage-current characteristics which cannot be described by Ohm's law The relationship between V and I cannot be described by Ohm's law (V = IR) but is described by a characteristic equation, characteristic curve or even a table.

The examples below show the characteristics of some real or hypothetical nonlinear resistors.

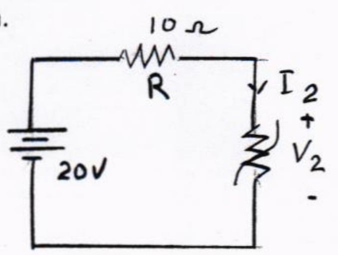
a) Characteristics in Equation Form

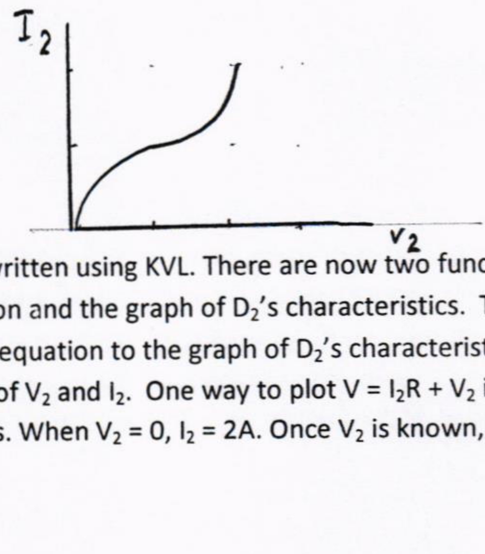
$I = K_1V^2$, $I = K_2V^{3/2}$, $I = I_o(e^{V/nV_T} - 1)$, where K_1, K_2, I_o, n and V_T are constants.

b) Characteristics Expressed by Curves.

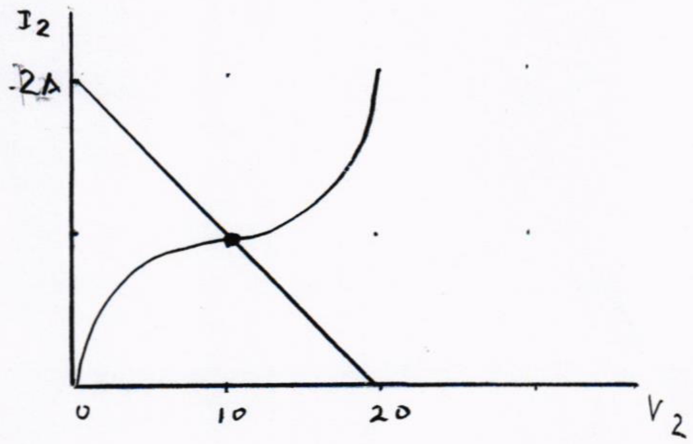


A common problem is to find voltages and currents in some parts of the network. For example, in the following network, it may be desired to find V_1, V_2 and the current I. The characteristic curve of D_2 is shown.



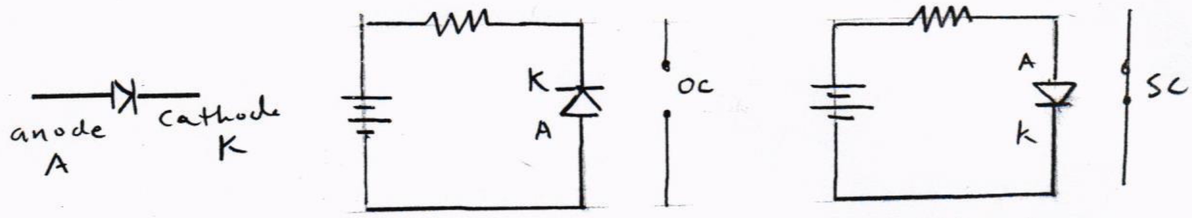


$I = I_2$. The equation 20 volts = $I_2R + V_2$ can be written using KVL. There are now two functions (or relations) relating V_2 to I_2, the previous equation and the graph of D_2's characteristics. The solution can be found by , superimposing the graph of the equation to the graph of D_2's characteristics. The intersection of the two curves gives the value of V_2 and I_2. One way to plot $V = I_2R + V_2$ is to use the intercepts, noting that when I = 0, V_2 = 20 volts. When V_2 = 0, I_2 = 2A. Once V_2 is known, V_1 can be obtained by KVL.

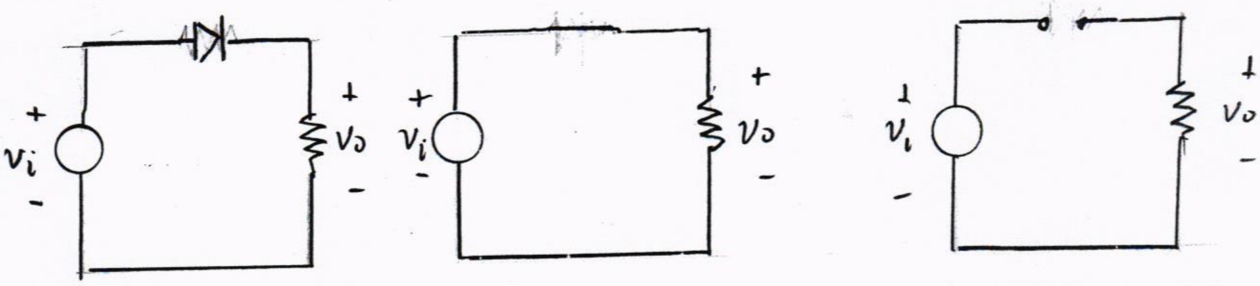


In some circuits, the solution is straight forward. In some the solution may require trial and error or graphical techniques.

A common network is the rectifier circuit with an ideal diode. The ideal diode behaves in such a way such that, if the diode sees a Thevenin voltage wherein its cathode is positive with respect to its anode, it will behave as an open circuit. Otherwise, it will behave as a short circuit. If the diode behaves as a short circuit, it is said to be ON. If it behaves as an open circuit, it is said to be OFF.



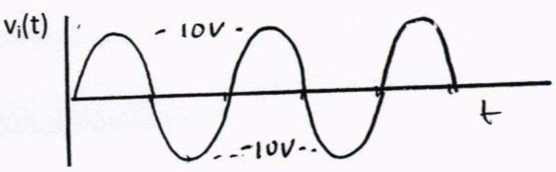
Consider the following circuit with a time-varying input voltage, $v_i(t)$, the plot of which, is shown. When $v_i(t)$ is positive, the Thevenin voltage as seen by the diode from its anode to its cathode is positive. The diode will behave as a short circuit and the output $v_o(t)$ can be seen to be equal to $v_i(t)$. When $v_i(t)$ is negative, the Thevenin voltage as seen by the diode from its anode to its cathode is negative and $v_o(t)$ can be seen to be 0 volts. The voltage $v_o(t)$ is shown below.

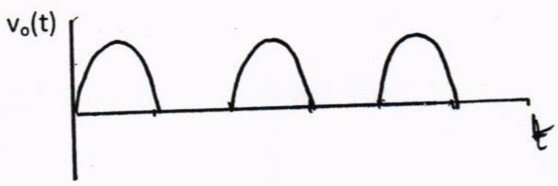


Circuit

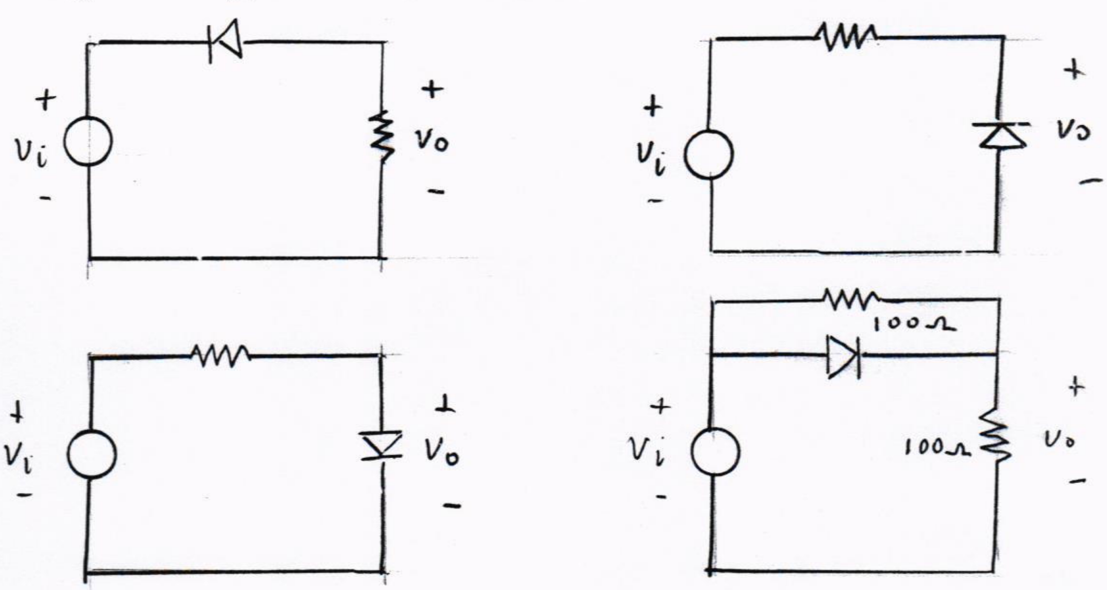
Equivalent Circuit When $v_i(t) > 0$.

Equivalent Circuit When $v_i(t) < 0$.

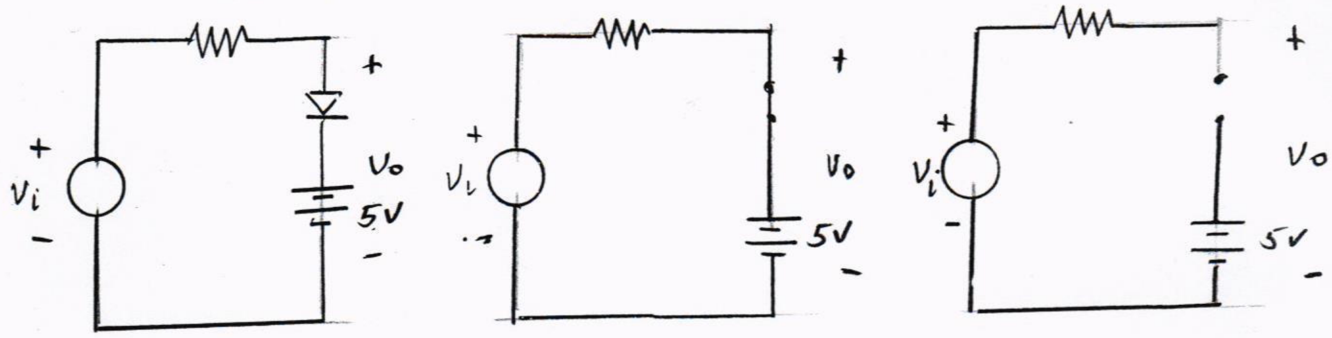




Using the same $v_i(t)$ find the output voltage $v_o(t)$ of the following circuits.

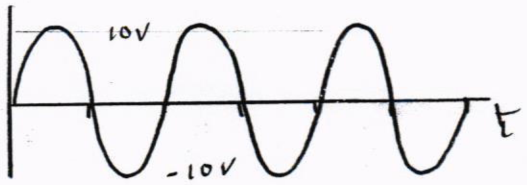


In the following circuit, it can be seen that the diode is ON when $v_i(t) > 5V$. It is OFF when $v_i(t)$ is less than 5V. When the diode is ON, it can be seen below that $v_o(t) = 5V$ and when the diode is OFF, it can be seen that $v_o(t) = v_i(t)$.

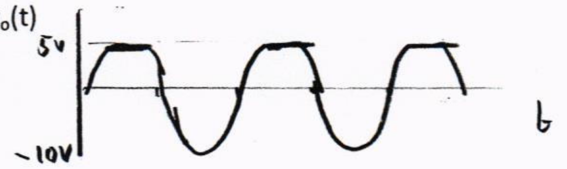


Circuit | Equivalent Circuit When $v_i(t) > 5V$. | Equivalent Circuit When $v_i(t) < 5V$.

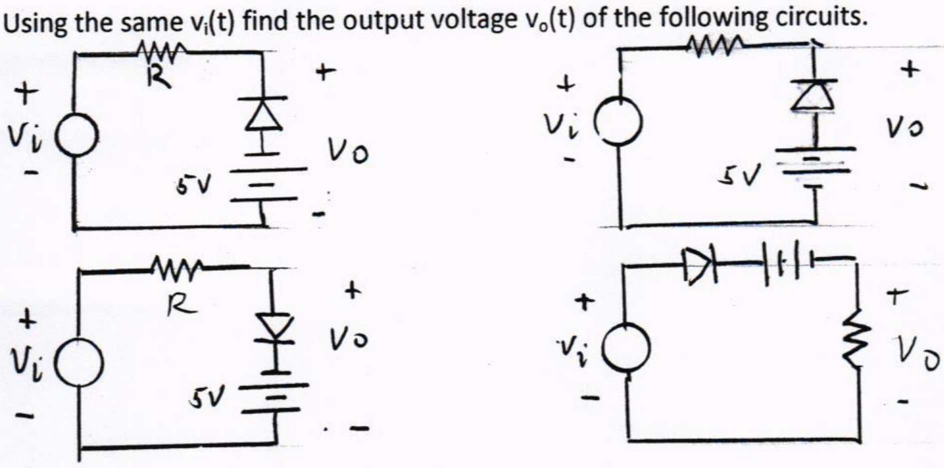
$v_i(t)$



$v_o(t)$



Using the same $v_i(t)$ find the output voltage $v_o(t)$ of the following circuits.



Find an expression for the Thevenin voltage as seen by the diode in terms of $v_i(t)$. The Thevenin voltage v_{th} is the open circuit voltage from the anode A to the cathode K.

It could be better if the two following sentences are added to the guide.

If v_{th} = ____________________ > 0, then diode is ON.
If v_{th} = ____________________ < 0, then diode is OFF

The following guide can be used to analyze single diode circuits.

If $v_i(t)$ (<>)________________(A) then the diode is ON.
If $v_i(t)$ (<>)________________(B) then the diode is OFF.
If the diode is ON, the it can be replaced by a short circuit.
If the diode is OFF, then it can be replaced by an open circuit.
If the diode is replaced by the short circuit, $v_o(t)$ = ________________(C).
If the diode is replaced by an open circuit, then $v_o(t)$ = ________________(D).
Therefore: If v_i (t) ______________(A) then $v_o(t)$ = ________________(C).
If $v_i(t)$ ______________(B) then $v_o(t)$ = ________________(D).