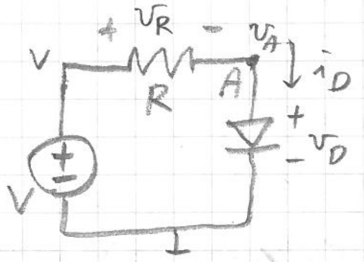
Motivation for graphical analyses:

Consider the following example



KCL at node A:

$$\frac{v_A - V}{R} + I_s\left(e^{v_D/V_{THE}} - 1\right) = 0$$

$$\Rightarrow \frac{v_D - V}{R} + I_s\left(e^{v_D/V_{THE}} - 1\right) = 0$$

Solving for v_D is like solving for

x for $ax + be^x + c = 0$ for some constants a, b, and c.

→ May be solved by trail-and-error

→ little insight, however.

What if we want to know the impact of increasing/decreasing V to the value of v_D? And, how would v_D change with the change of R? These are critical questions to ask when designing a electronic circuit. Now, <u>graphical analyses</u> can be very helpful in this aspect!

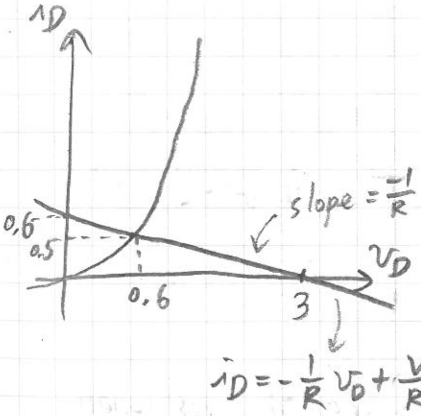
For concreteness, suppose $\begin{cases} V = 3\,\mathrm{V} \\ R = 500\,\Omega \end{cases}$ in the example.

$V_{THE} = 0.025\,\mathrm{V}$ in room temperature

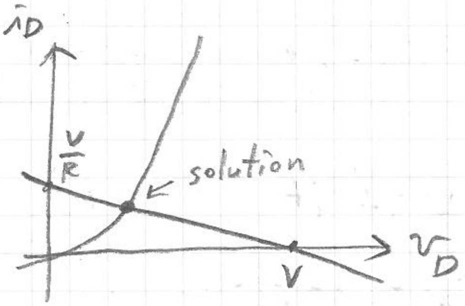
We can rearrange the KCL equation to give two equations for i_D:

$$\begin{cases} i_D = I_s\left(e^{v_D/v_{THE}} - 1\right) = 10^{-12}\left(e^{v_D/0.025} - 1\right) \\ i_D = \dfrac{V - v_D}{R} = -\dfrac{1}{R} v_D + 0.006 \qquad (\text{unit}: A) \end{cases}$$

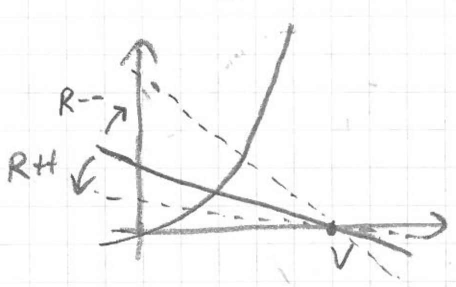
then graphically speaking, the solution of i_D and v_D lies at the intersection point of the two curves on a v_D-i_D plot:



$\Rightarrow$



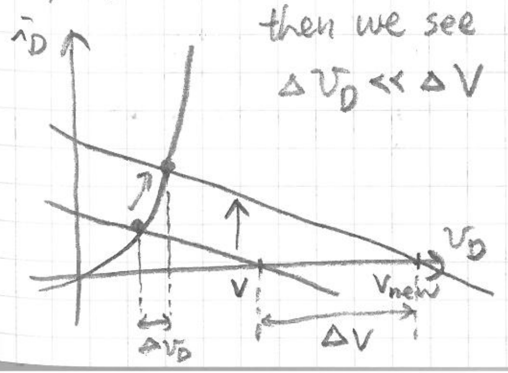
if R changes



which give much insight in how the circuit behaves!

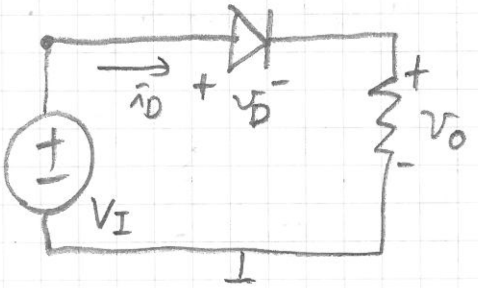
if V increases

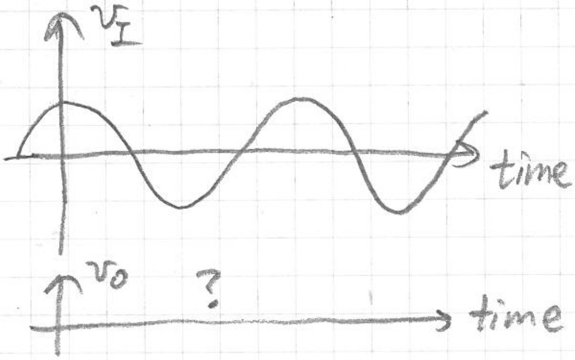
then we see $\Delta v_D \ll \Delta V$



P38 Another example (half-wave voltage rectifier)

In the following circuit,
given a time-varying voltage source v_I,
what will be the output voltage v_O across
a resistor?



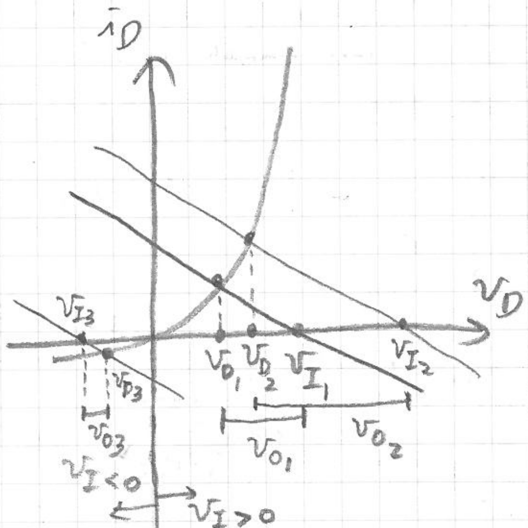


from KVL, $v_I - v_D - v_O = 0$

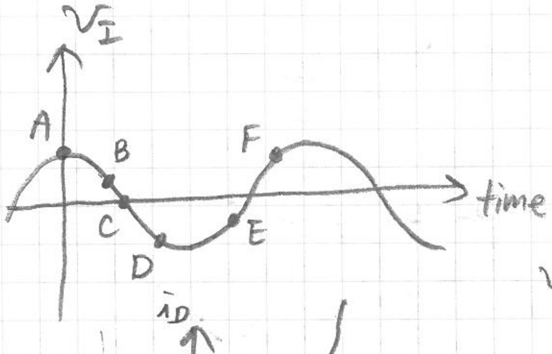
$\Rightarrow \underline{v_O = v_I - v_D}$

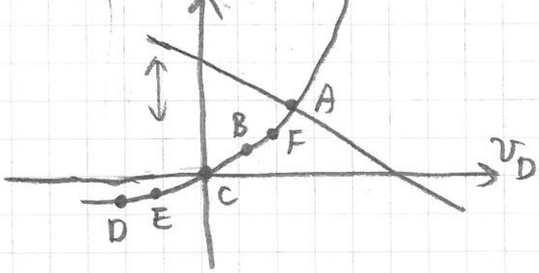
from KCL, element law, and
the i-v characteristic of the diode:

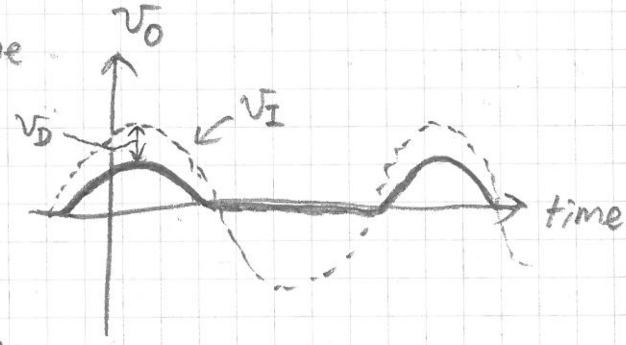
$$\begin{cases} i_D = I_S\left(e^{v_D/V_{THE}} - 1\right) \\ i_D = \dfrac{v_I - v_D}{R} \end{cases}$$



We see $v_{O_3} \approx 0$ when $v_D < 0$

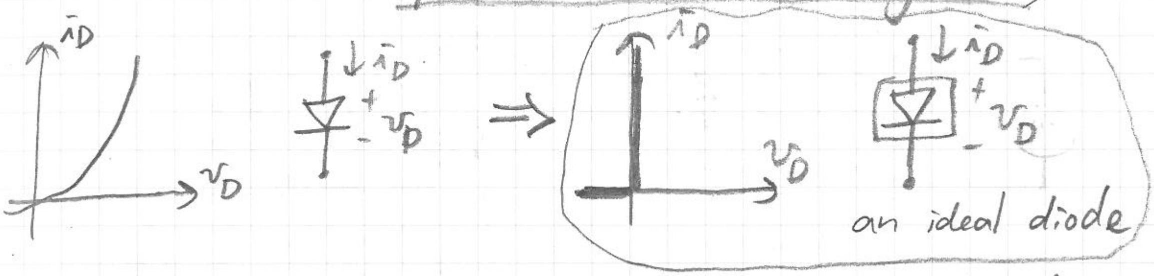






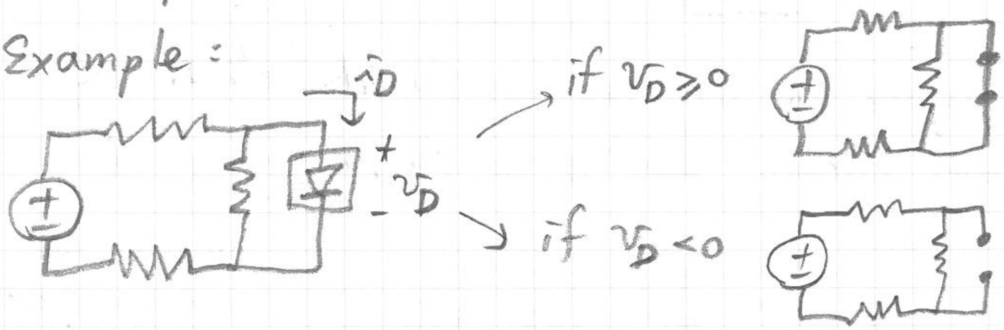
Besides the graphical analysis, in some occasion we may simplify our analysis of a nonlinear circuit by considering an approximated version of the i-v characteristic of a given nonlinear element.

This is called the piecewise linear analysis.



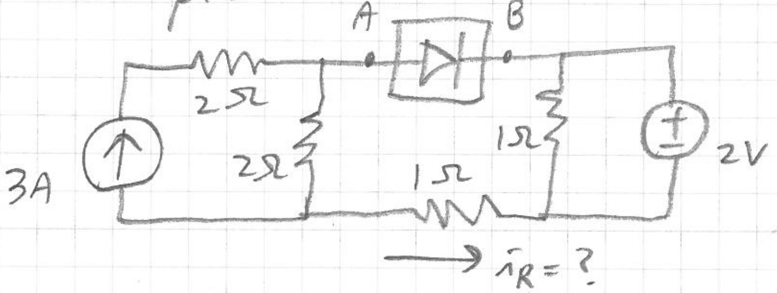
For an ideal diode, depending on the actual voltage (or the actual current direction), we may replace the diode by either a short circuit or an open circuit.

Example:

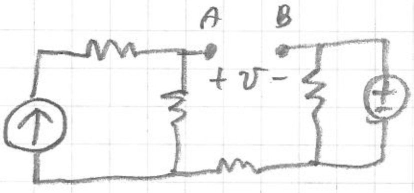


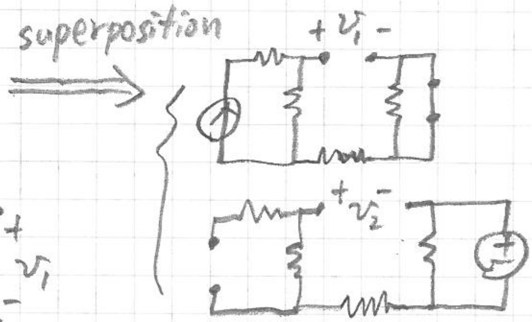
(Note: in class I conditioned on the direction of the current flowing through the diode, but perhaps it makes more sense to condition (i_D) on v_D. Either way, we follow the associated variable convention (see page 8 of this note).)

P40 Example:

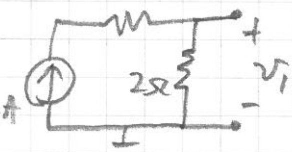


We first find the voltage across A and B.



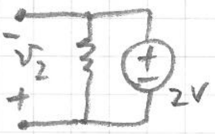


for v_1:



$v_1 = 3A \times 2\Omega = 6\,V$

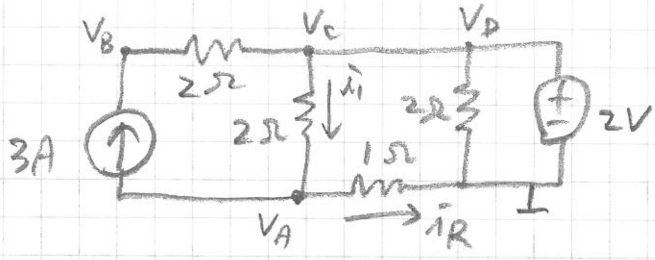
for v_2:



$v_2 = -2V$

$\rightarrow v = v_1 + v_2$
$= 6 - 2 = 4\,v$

→ therefore we may replace the ideal diode by a short circuit, leading to the following equivalence:



in class we used superposition; here, let's try using the node method!

$V_C = V_D = 2$

$i_1 = 3 + i_R$

$\Rightarrow \dfrac{2 - V_A}{2} = 3 + \dfrac{V_A - 0}{1}$

$\rightarrow 2 - V_A = 6 + 2V_A$

$\Rightarrow V_A = \dfrac{-4}{3}$

$\Rightarrow i_R = \dfrac{V_A - 0}{1} = \dfrac{-4}{3}\,A$ ※