ECE/ENGRD 2100

Introduction to Circuits for ECE

Lecture 9

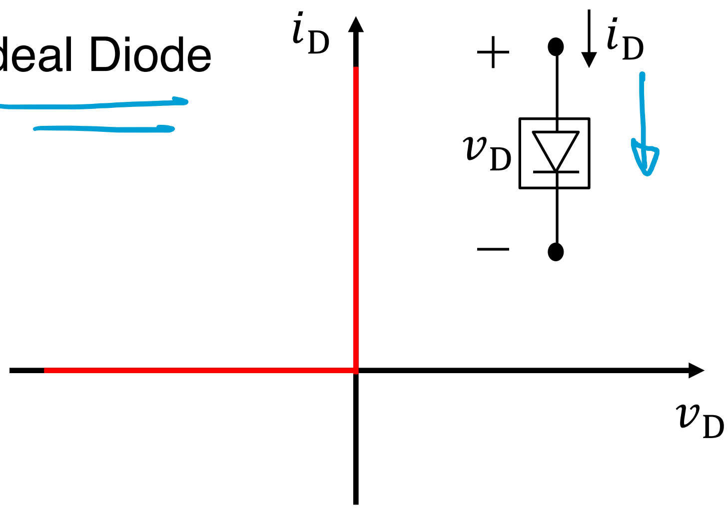
Large-Signal Analysis of Nonlinear Circuits

Announcements

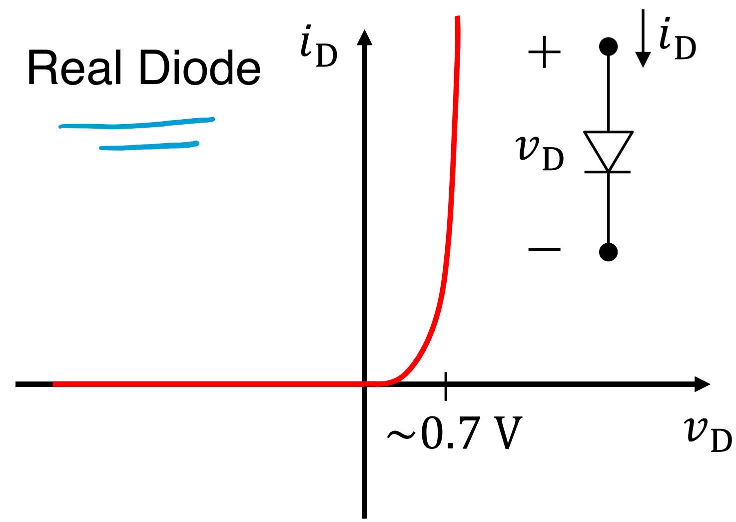
- Upcoming due dates:
  - Prelab 2 due by 12:20 pm on Tuesday February 12, 2019
  - Homework 2 due by 11:59 pm on Friday February 15, 2019
  - Lab report 2 due by 11:59 pm on Friday February 22, 2019
- Lab 2 is this week (starting Tuesday February 12, 2019)
- Prelim 1 on Thursday February 21, 2019 from 7:30 – 9 pm in 203 Phillips

Examples of Two-Terminal Nonlinear Devices

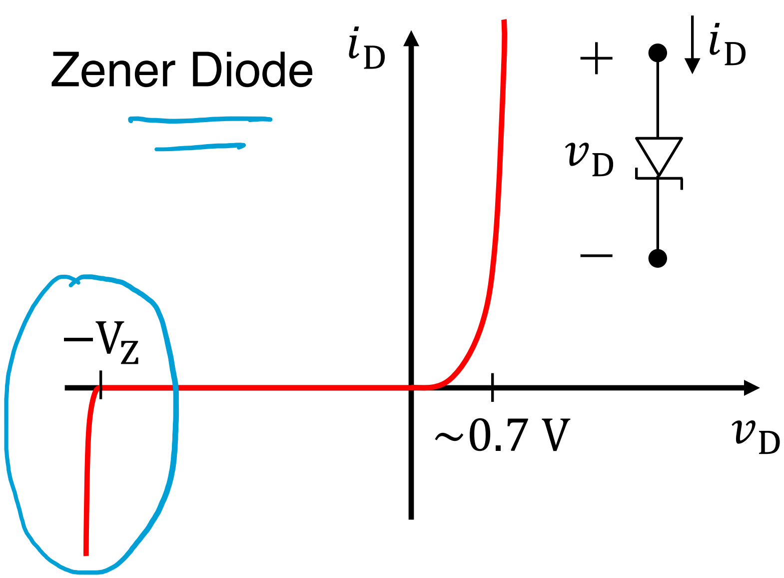
Ideal Diode



Real Diode

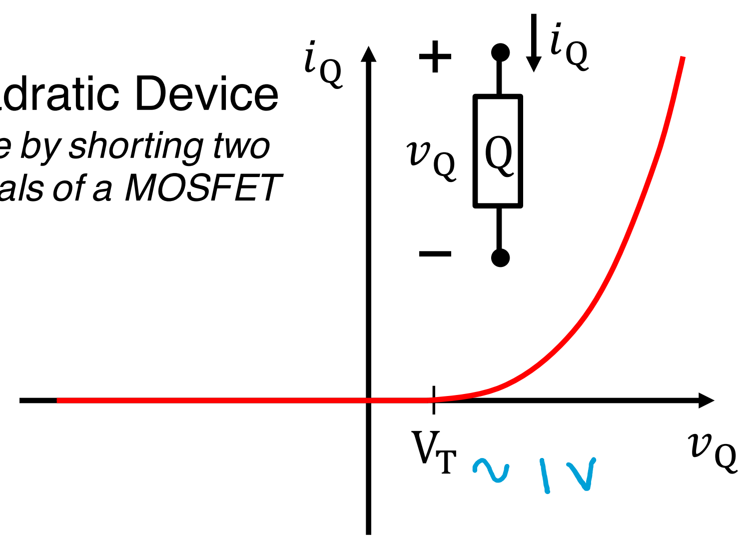


Zener Diode



Quadratic Device

made by shorting two terminals of a MOSFET



Analysis of Circuits with Nonlinear Devices

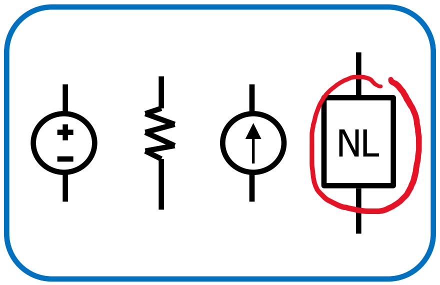
- Following techniques **still work** when circuits have nonlinear components:
  - Brute Force (KVL, KCL and Element Constitutive Relationships)
  - Mesh and Loop Analysis
  - Node Analysis

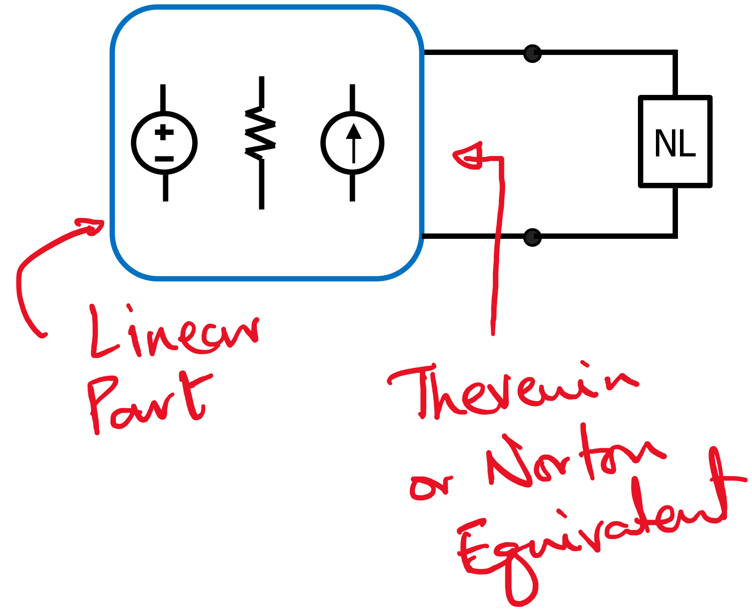
non-linear for non-linear device

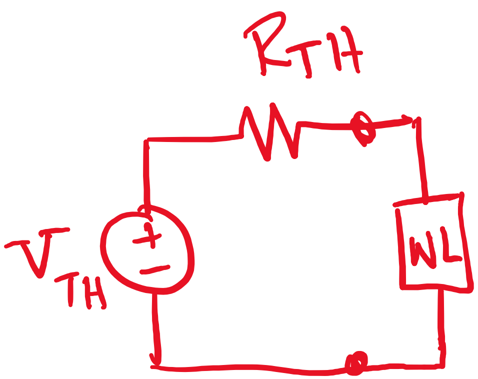
Go to method

- Superposition **does not** work when circuits have nonlinear components

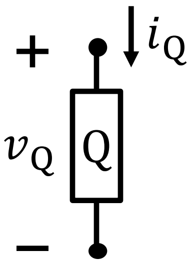
Analysis of Circuits with One Nonlinear Device

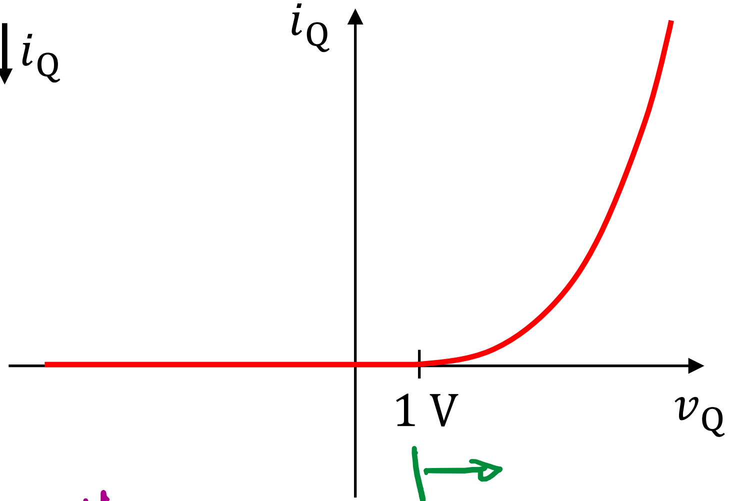




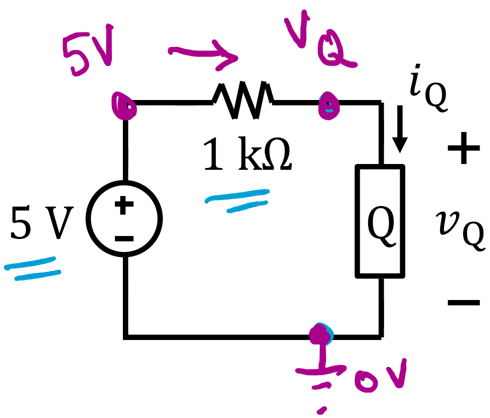


Nonlinear Device Circuit – Example 1





$$i_Q = \begin{cases} 0 & \text{if } v_Q < 1\text{ V} \\ 0.5(v_Q - 1)^2\text{ mA} & \text{if } v_Q \geq 1\text{ V} \end{cases}$$



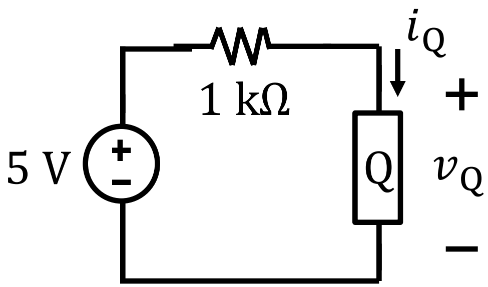
$$\frac{5 - v_Q}{1\text{k}\Omega} = i_Q$$

Try Assuming $v_Q < 1\text{V} \Rightarrow i_Q = 0$

$$\frac{5 - v_Q}{1\text{k}\Omega} = 0 \Rightarrow v_Q = 5\text{ V} \quad \times$$

Not consistent with assumption

Nonlinear Device Circuit – Example 1 (Cont.)



$$i_Q = \begin{cases} 0 & \text{if } v_Q < 1\text{ V} \\ 0.5(v_Q - 1)^2 \text{ mA} & \text{if } v_Q \geq 1\text{ V} \end{cases}$$

Try $v_Q \geq 1V \Rightarrow i_Q = 0.5(v_Q - 1)^2$ mA

$\frac{5 - v_Q}{1k\Omega} = i_Q = 0.5(v_Q - 1)^2$ mA $\Rightarrow 5 - v_Q = 0.5(v_Q - 1)^2$

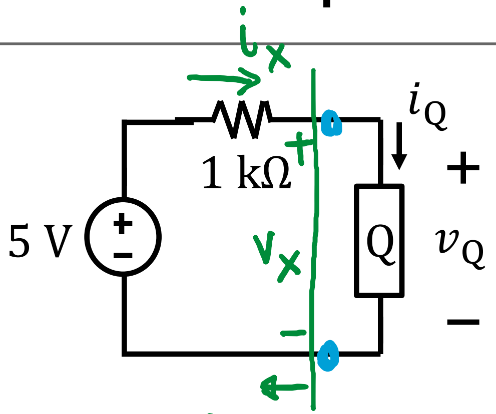
$10 - 2v_Q = v_Q^2 - 2v_Q + 1 \Rightarrow v_Q^2 = 9 \Rightarrow \underline{v_Q = \pm 3}$

–ve value is non-physical

$\Rightarrow \quad v_Q = +3V$

$i_Q = 0.5(3-1)^2 = \underline{2 \text{ mA}}$

Example 1: Graphical Analysis using Load Line



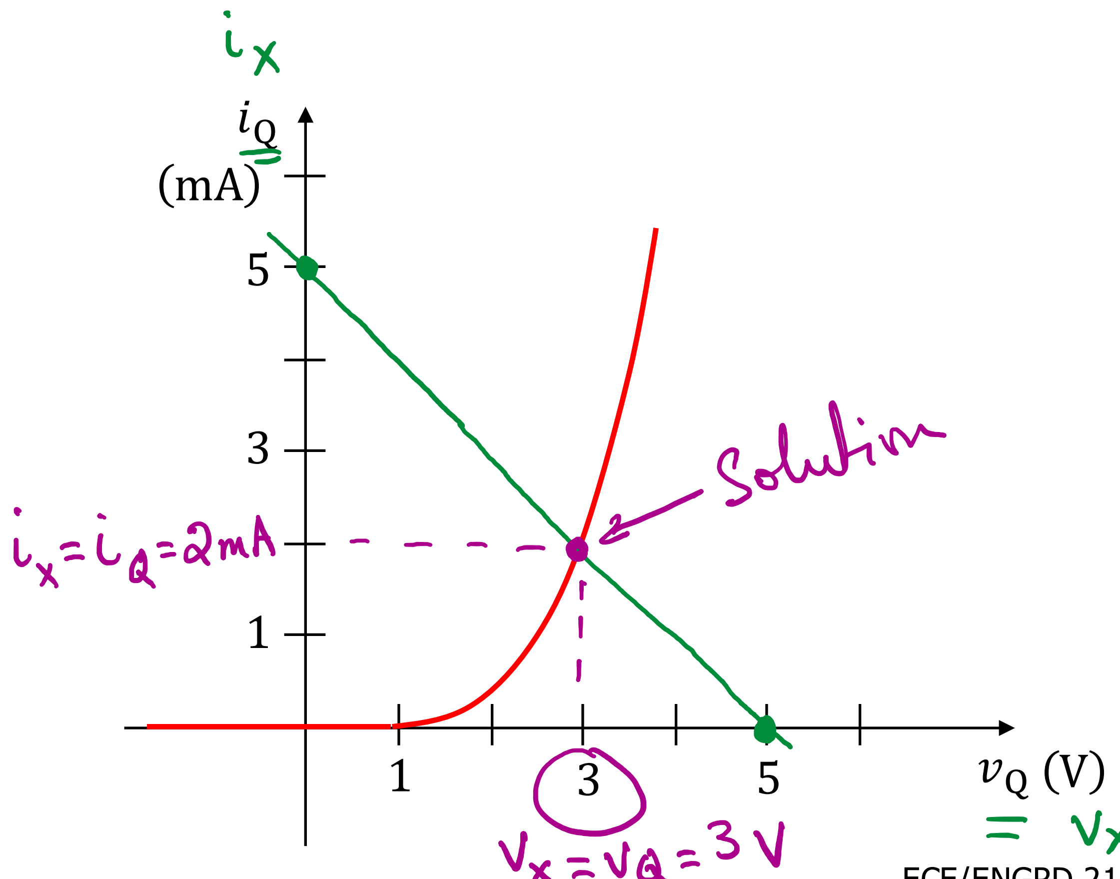
$$i_Q = \begin{cases} 0 & \text{if } v_Q < 1\text{ V} \\ 0.5(v_Q - 1)^2 \text{ mA} & \text{if } v_Q \geq 1\text{ V} \end{cases}$$

$i_x = i_Q$

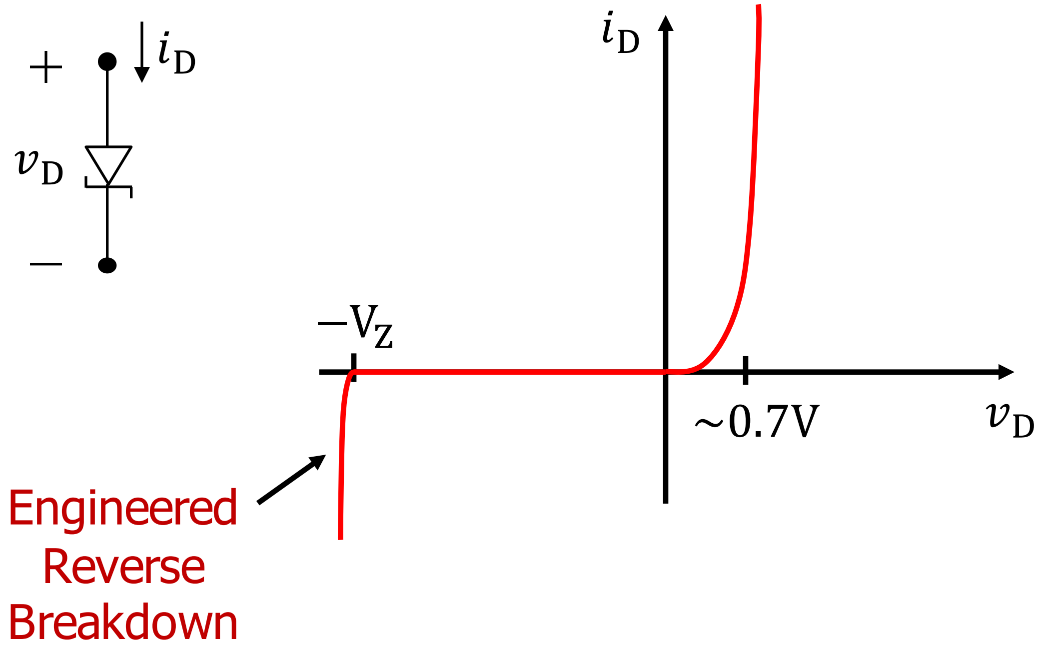
$V_x = V_Q$

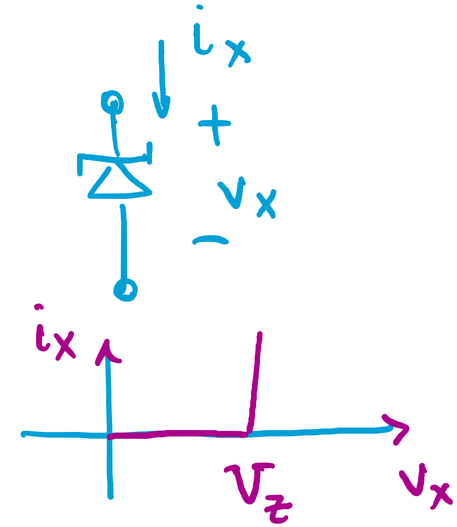
V_x vs. i_x

$v_x = 5V - 1k\Omega(i_x)$



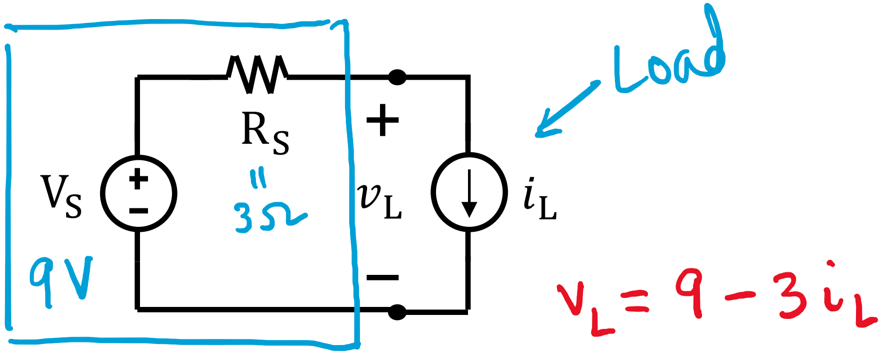
Zener Diode





- Behaves mostly like a normal diode
- Reverse breakdown occurs typically with a sharper knee at designed voltage

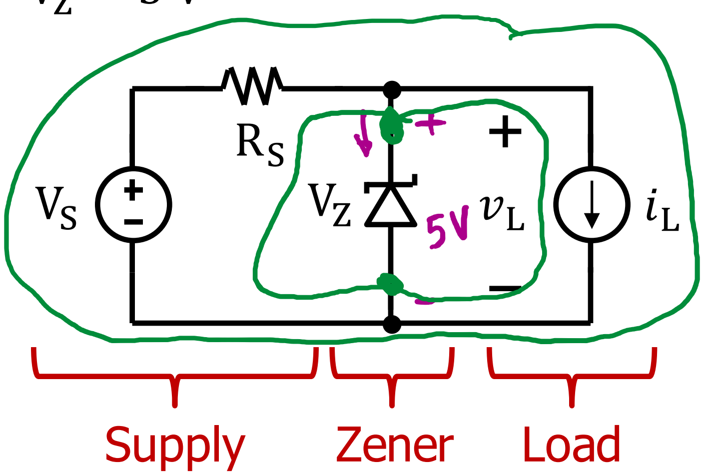
Regulated Power Supply using Zener Diode

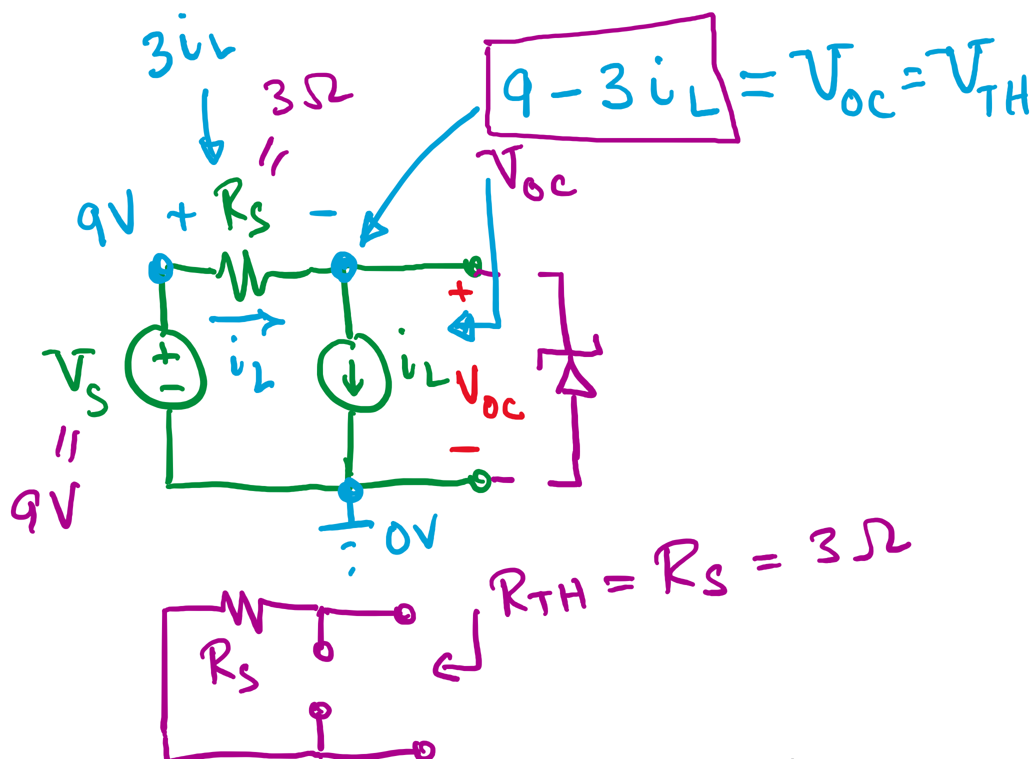


$V_S = 9$ V

$R_S = 3\ \Omega$

$V_Z = 5$ V

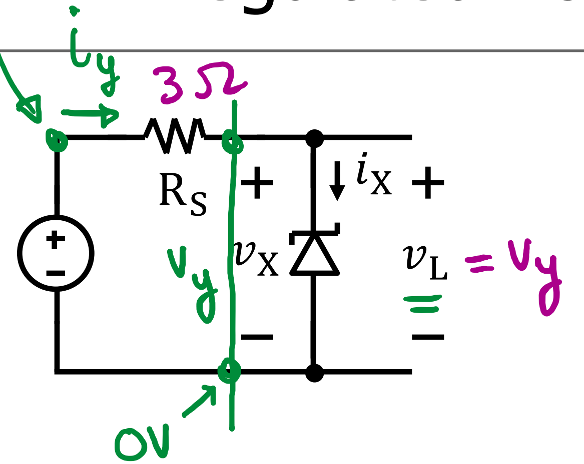




Regulated Power Supply (Cont.)

$9 - 3i_L$

$V_S - R_S i_L$



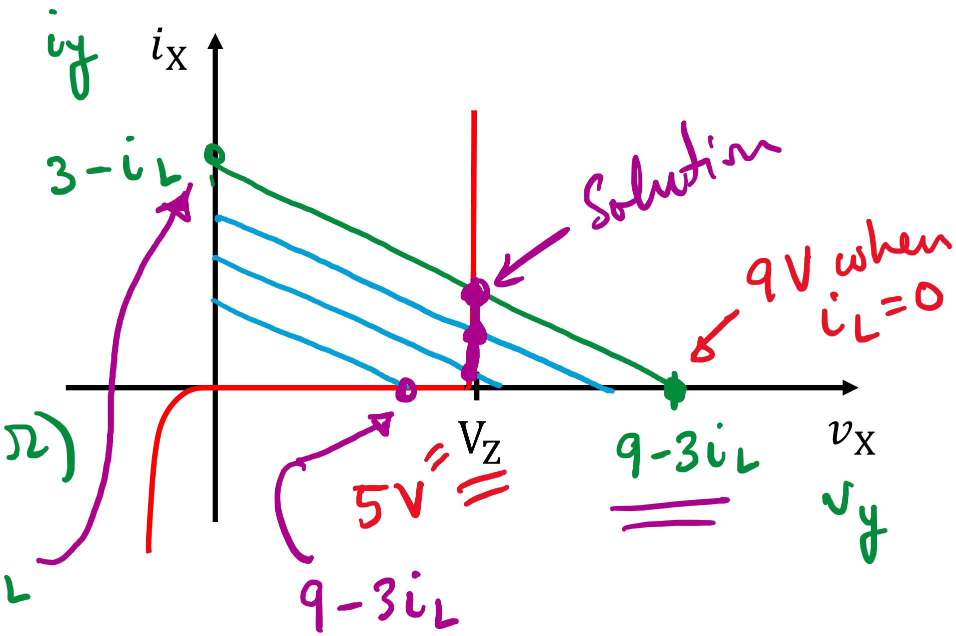
$V_S = 9$ V

$R_S = 3\ \Omega$

$V_Z = 5$ V

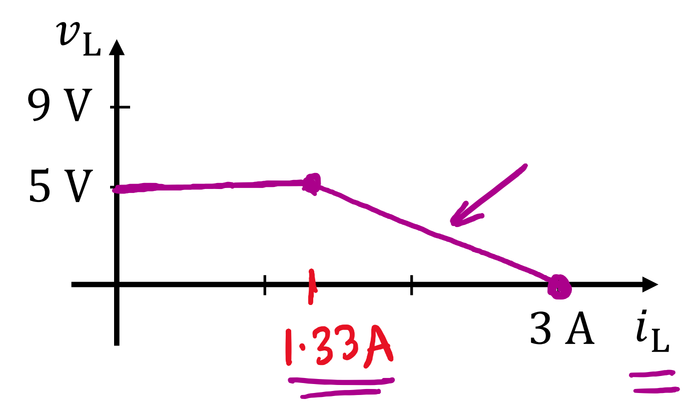
$v_y = (9 - 3i_L) - i_y(3\Omega)$

$v_y = 0 \Rightarrow i_y = 3 - i_L$



$9 - 3i_L = 5$

$\Rightarrow 3i_L = 4 \Rightarrow i_L = 1.33A$



Piecewise Linear (Approximate) Analysis