Lecture3:
Diode circuits

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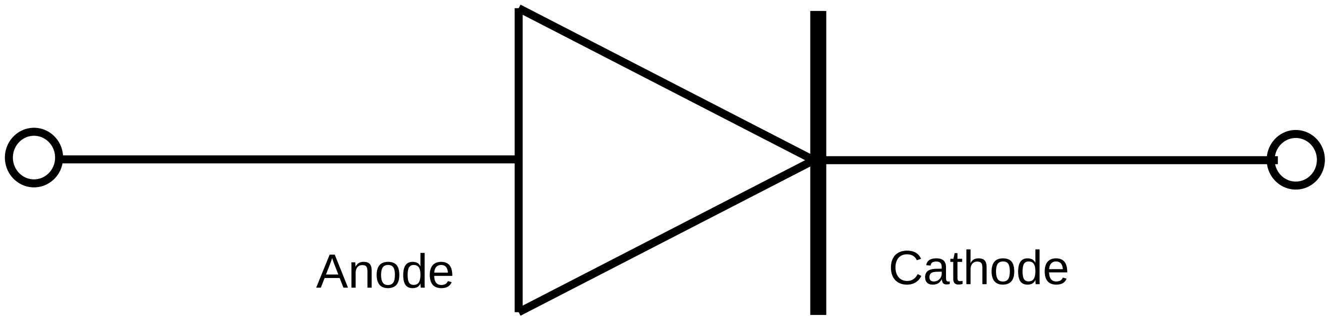
Review

- Diode
  - Its symbol



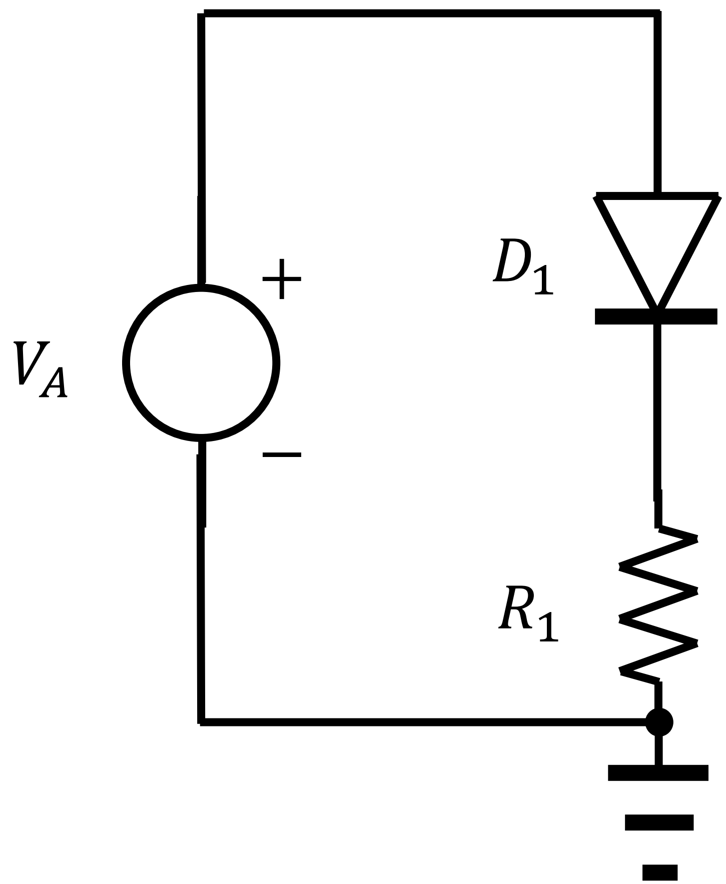
  - Forward/reverse operation
  - How to fabricate it: PN junction
- IV characteristics of a diode

$$I_D = I_S\left(\exp\frac{V_D}{V_T} - 1\right)$$

  - Forward bias: $I_D \approx I_S \exp\frac{V_D}{V_T}$
  - Reverse bias: $I_D \approx -I_S \approx 0$

General solution (1)

- Analyze the following circuit. (A diode-resistor combination)
  - Calculation of node voltages and terminal currents



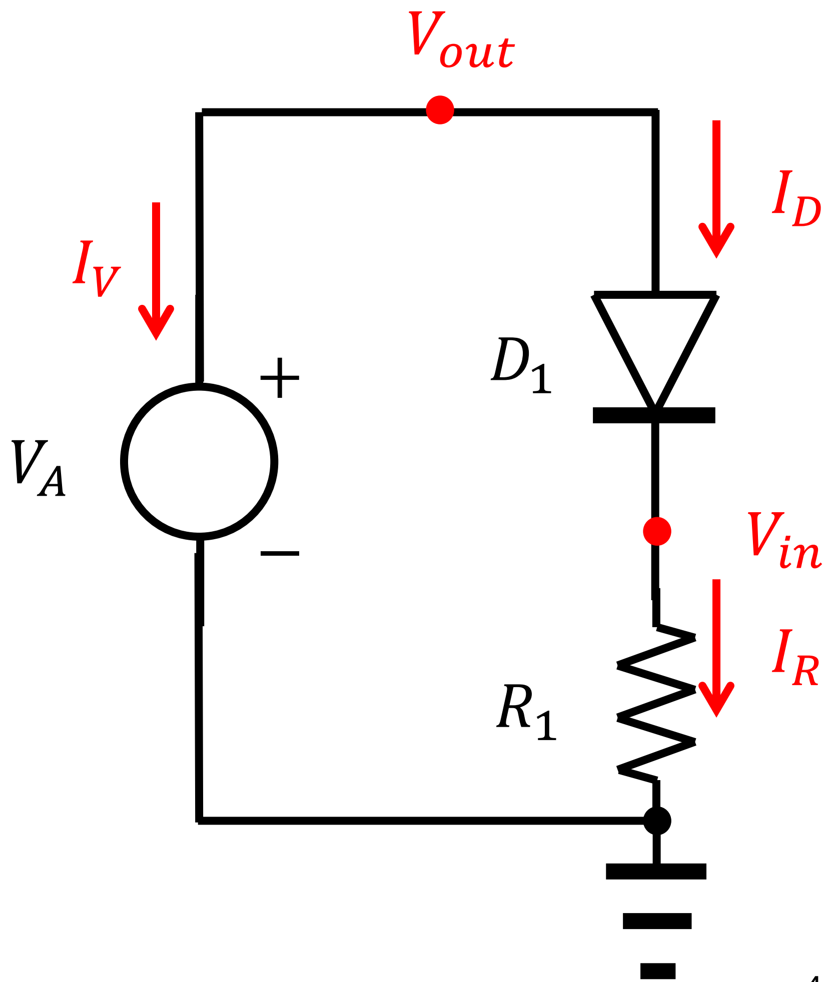
General solution (2)

- Identify the nodes and apply the KCL.
  - Two nodes are found.

$$I_V + I_D = 0$$
$$-I_D + I_R = 0$$

  - Equations for terminal IVs

$$V_{in} = V_A$$
$$I_D = I_S\left(\exp\left(\frac{V_{in} - V_{out}}{V_T}\right) - 1\right)$$
$$I_R = \frac{V_{out}}{R_1}$$



General solution (3)

- Solve the set of equations.
  - After simple manipulation, it is easily found that

$$-I_S\left(\exp\left(\frac{V_A - V_{out}}{V_T}\right) - 1\right) + \frac{V_{out}}{R_1} = 0$$

  - An nonlinear equation for V_{out} is obtained.
  - The solution, V_{out}, can be visualized by drawing the following two curves.

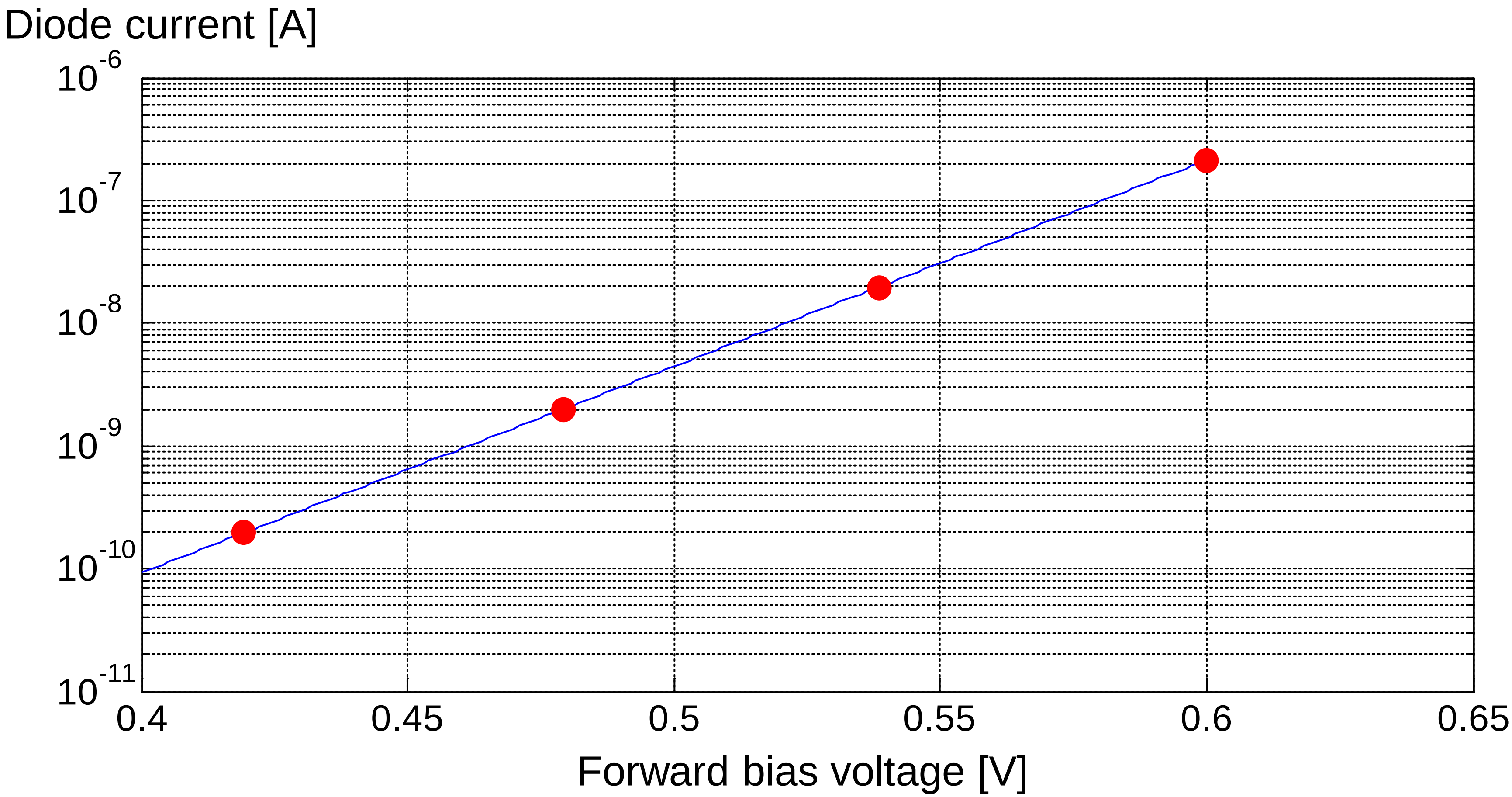
$$y = I_S\left(\exp\left(\frac{V_A - x}{V_T}\right) - 1\right)$$

$$y = \frac{x}{R_1}$$

  - The x coordinate of the intersecting point is V_{out}.
  - Of course, a general solver for the nonlinear equation is desirable.
  - **S**imulation **P**rogram with **I**ntegrated **C**ircuit **E**mphasis

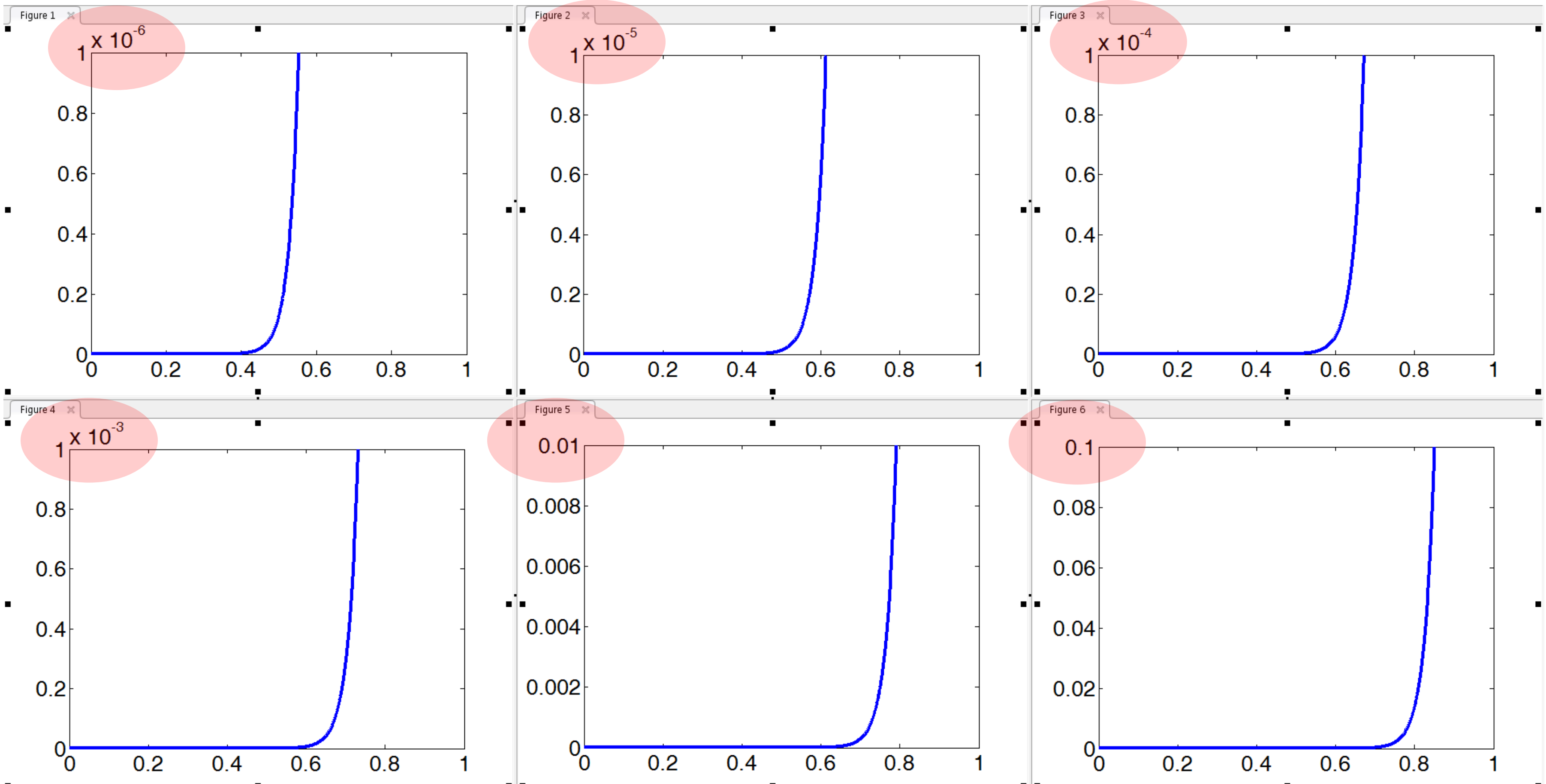
Important observation

- In order to obtain 10x large current,
  - We must apply only 60 mV additionally. (300K)



IV curves

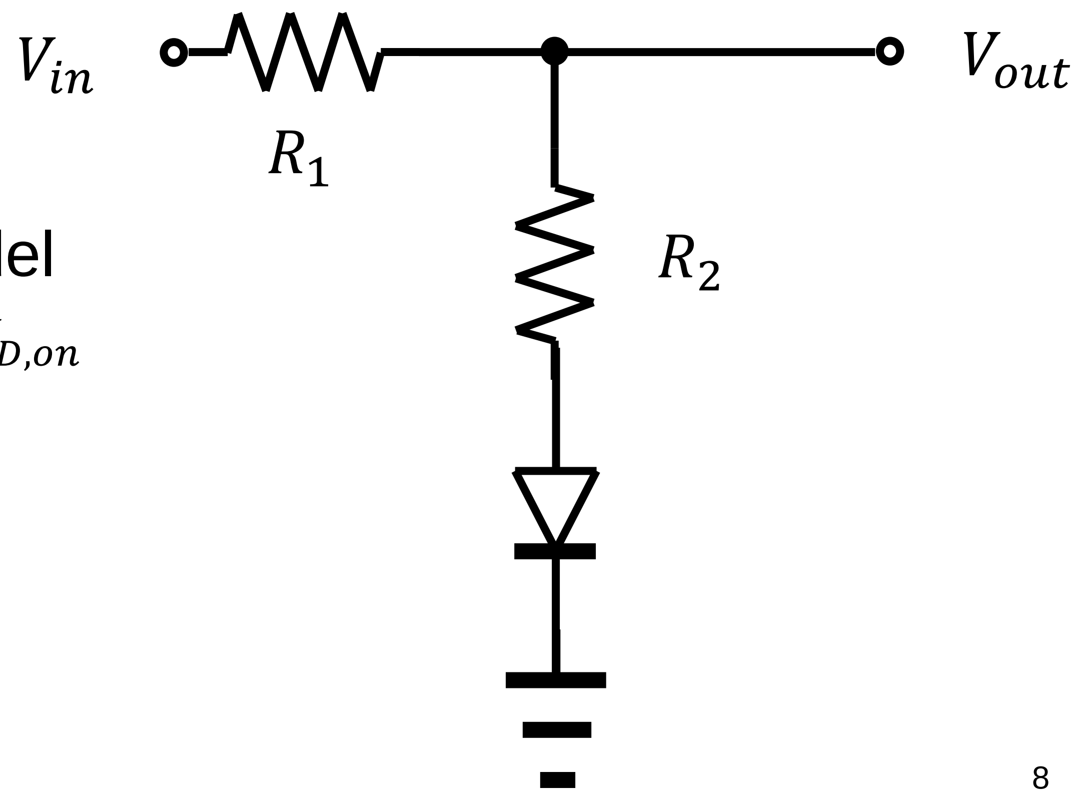
- A diode with $I_S = 5 \times 10^{-16}\mathrm{A}$ (Only different y scales)
  - How do they look like?



PN junction as a diode

- Exponential model

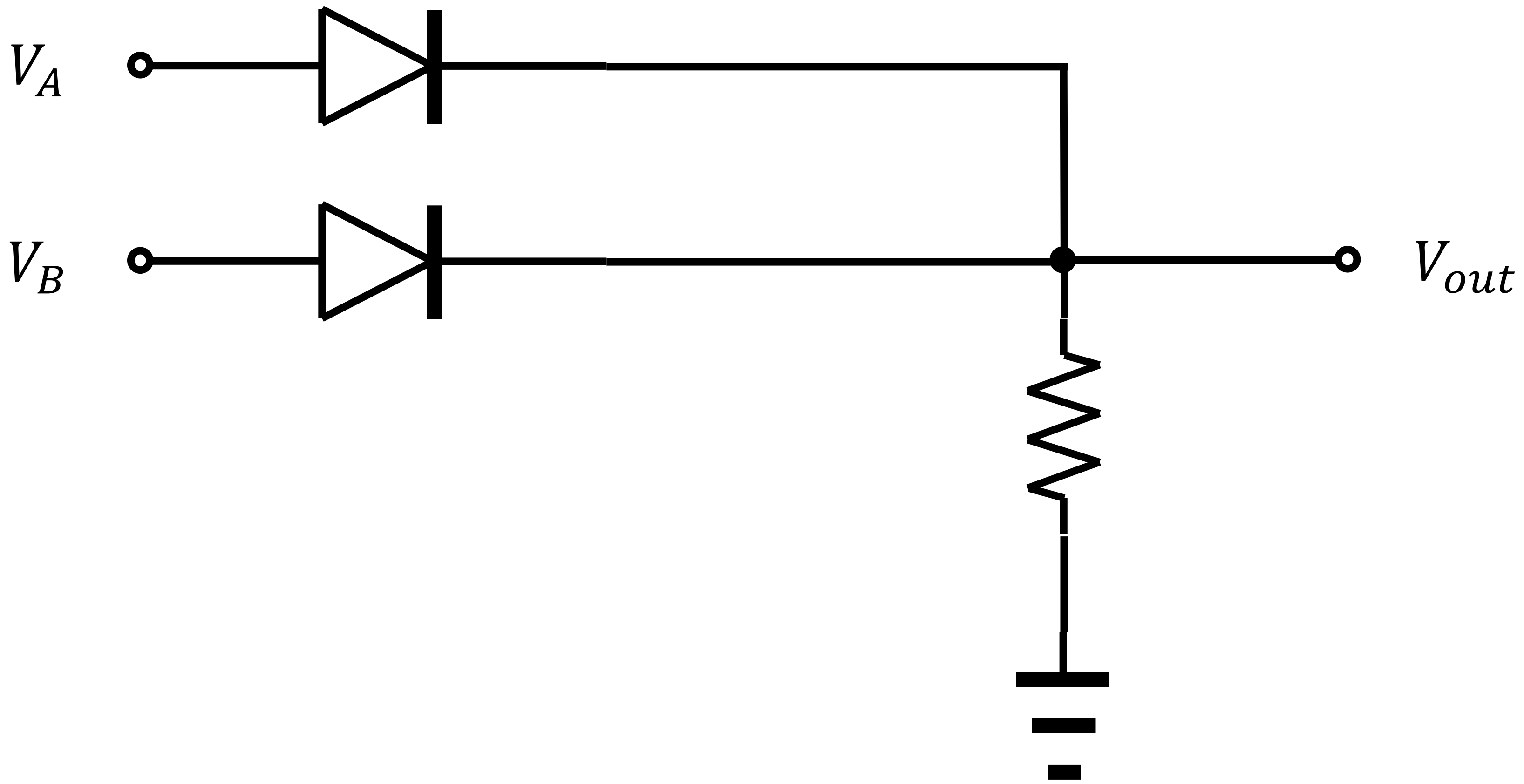
$$I_D = I_s\left(\exp\frac{V_D}{V_T} - 1\right)$$



- Constant-voltage model
  - An “offset” voltage of $V_{D,on}$

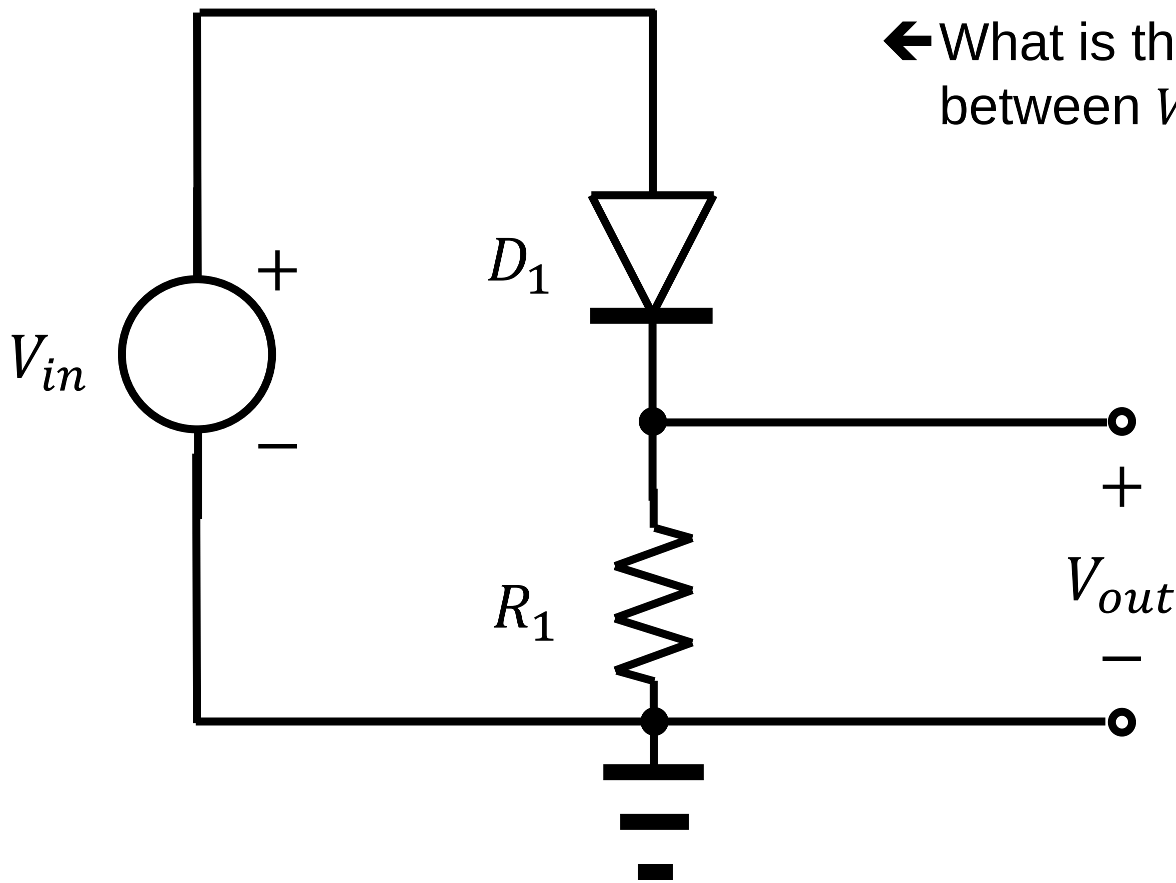
Example 3.6 (Razavi)

- An OR gate



Rectifier

- Revisiting our first example



← What is the relation between V_{in} and V_{out}?

Homework#2 (1)

- Due: 09:00, March 19
- Update your program.
  - Read the input file.
  - Print out the names of voltage sources, current sources, resistors, capacitors, and inductors.
  - Print out the name of each node.
  - For each node, print out a list of the connected elements and their terminal names.
  - An example of the input file is uploaded in our GitHub repository.

Homework#2 (2)

- Calculate the current in the circuit.
  - Obtain the numerical value for the following parameters.

$V_A = 2\ \mathrm{V}$

$I_S = 5 \times 10^{-16}\ \mathrm{A}$

$V_T = \frac{k_B T}{q}$

$R_1 = 1k\Omega$

  - Show the calculation method.