ME133 Lecture 5 1/24/23

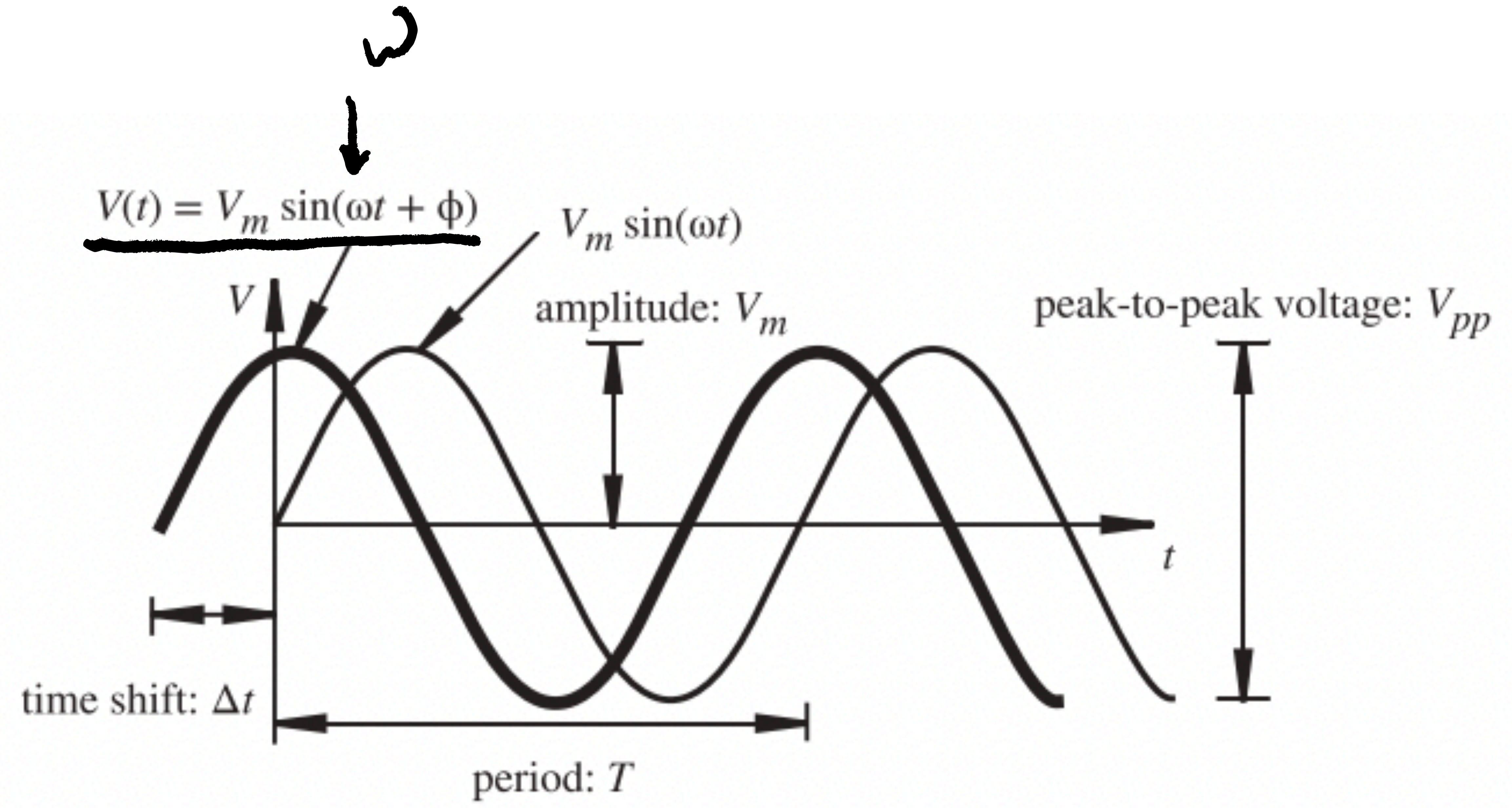
Last time:

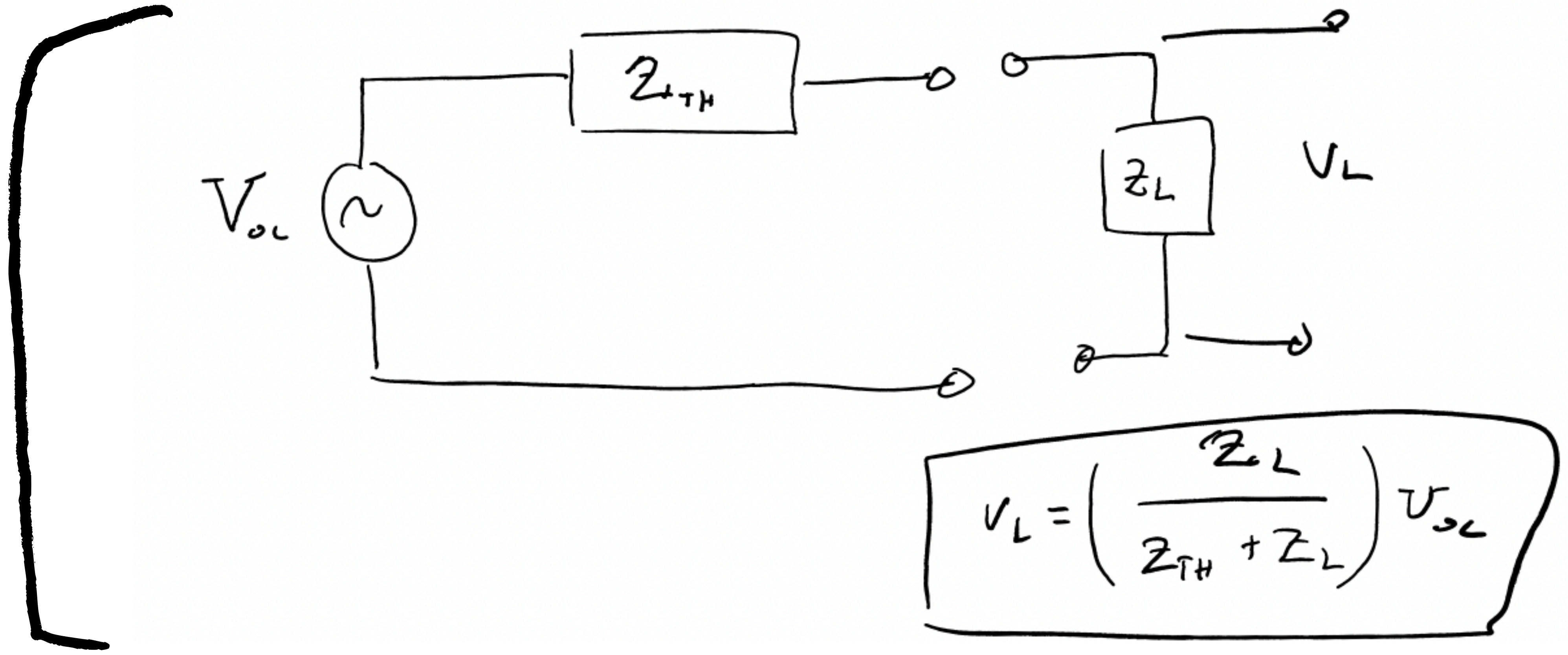
> AC Signals and Circuits

> Impedance

> Transformers

> Intro to semiconductors

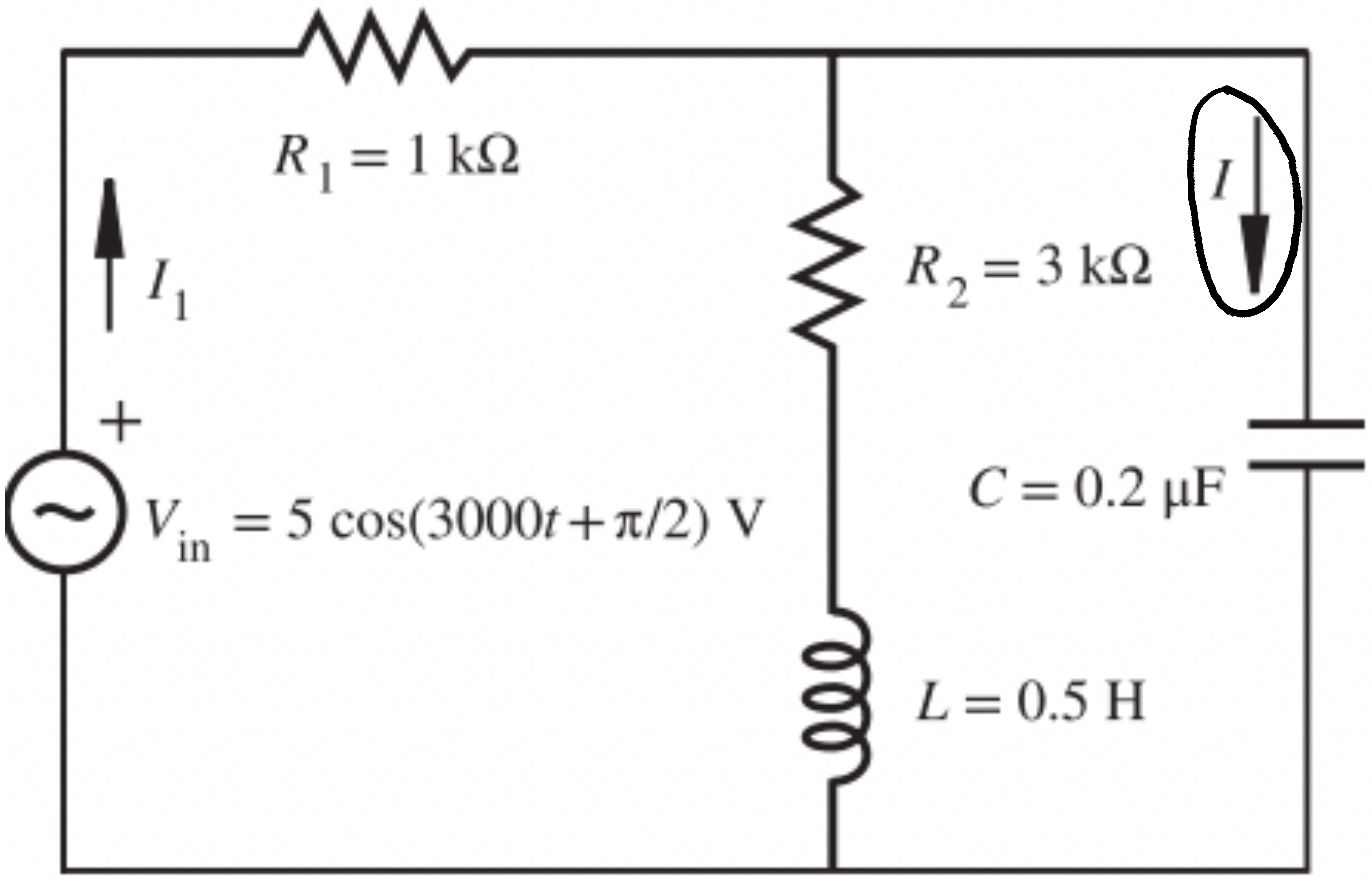




Today:

- Diodes

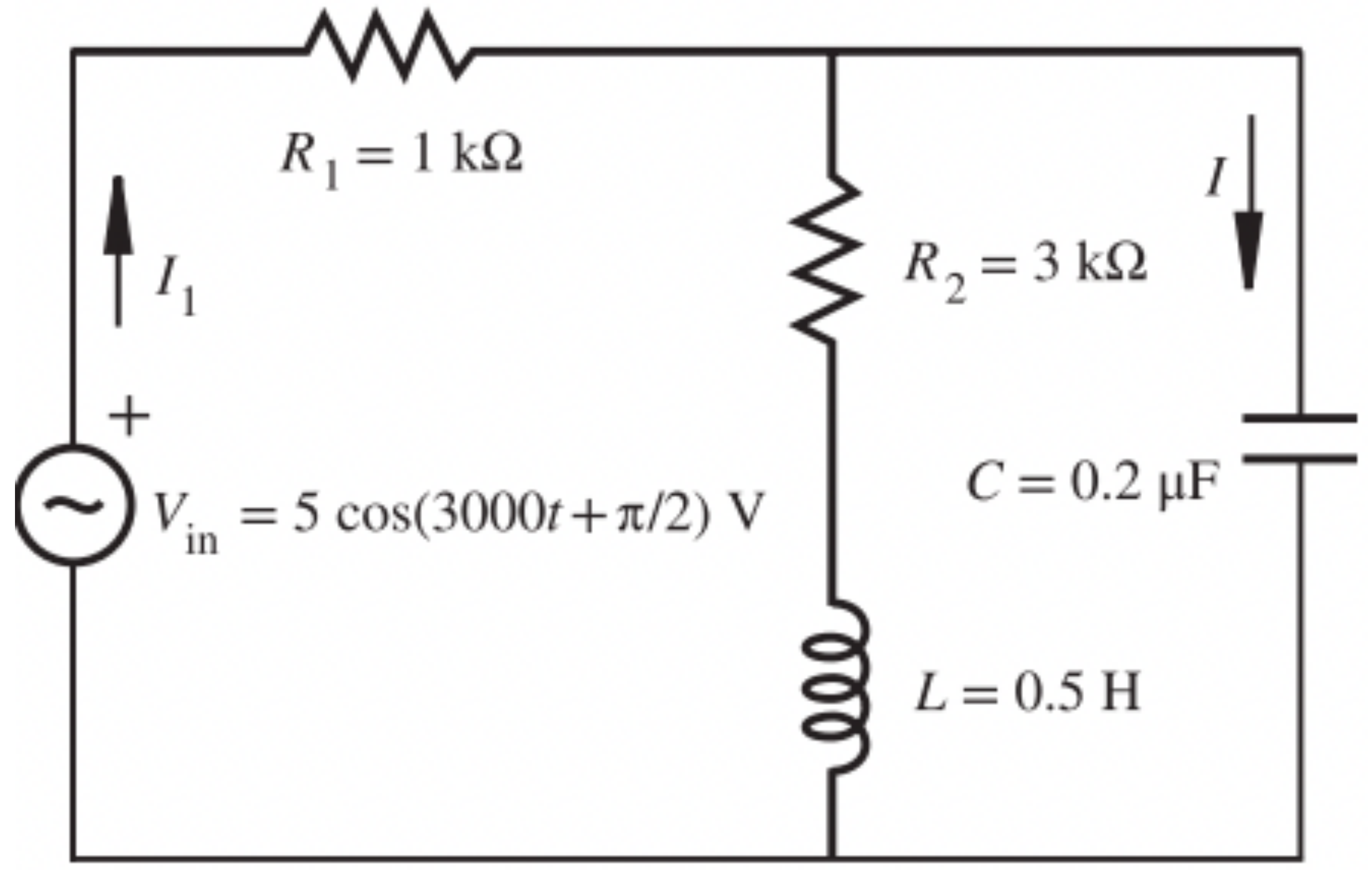
AC circuit Analysis: Ex. 2.7



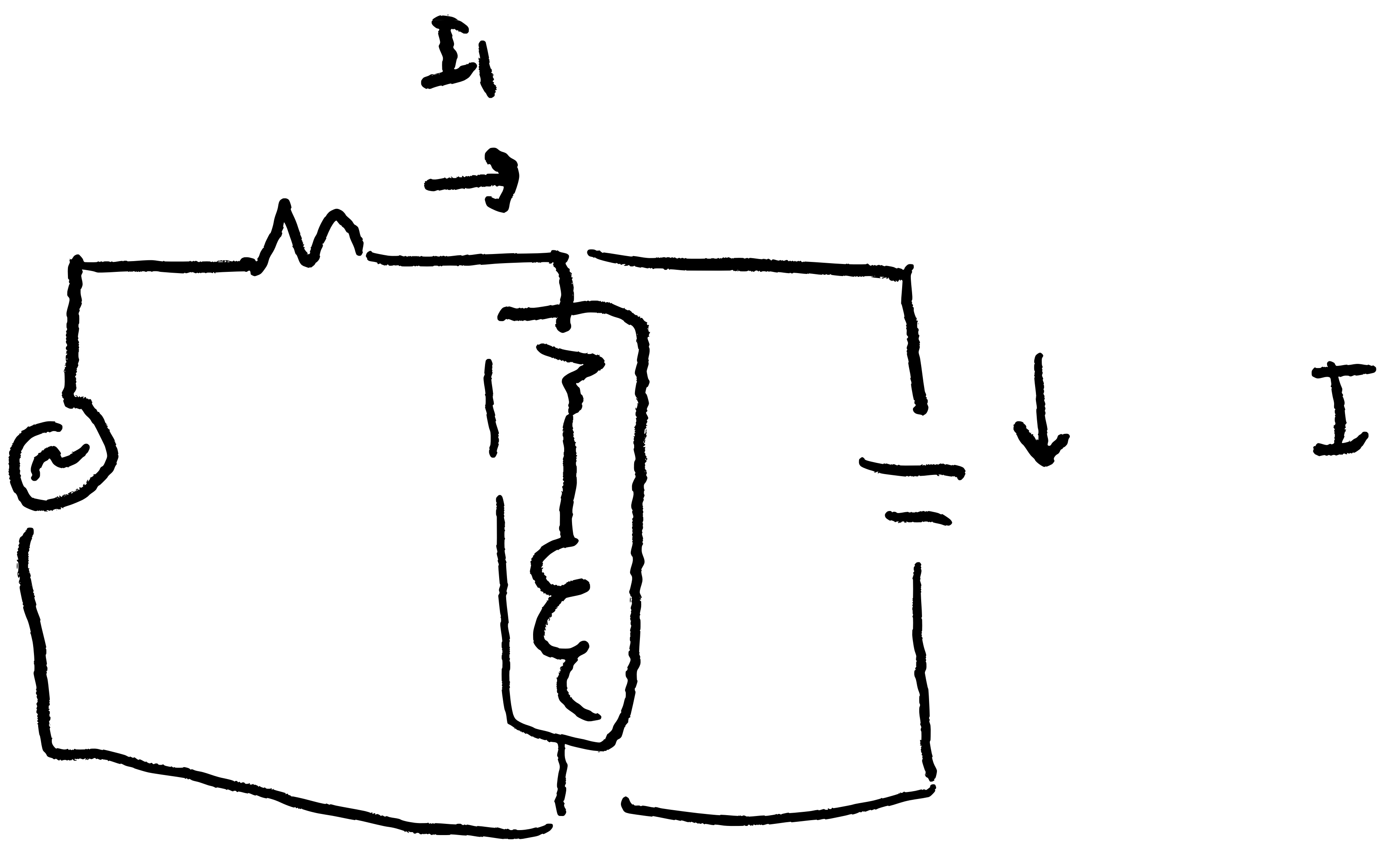
Find steady state current I

Roughly sketch out how to solve.

AC circuit Analysis: Ex. 2.7



Idea: first find the current through the entire circuit (I_1) the just apply current divider.



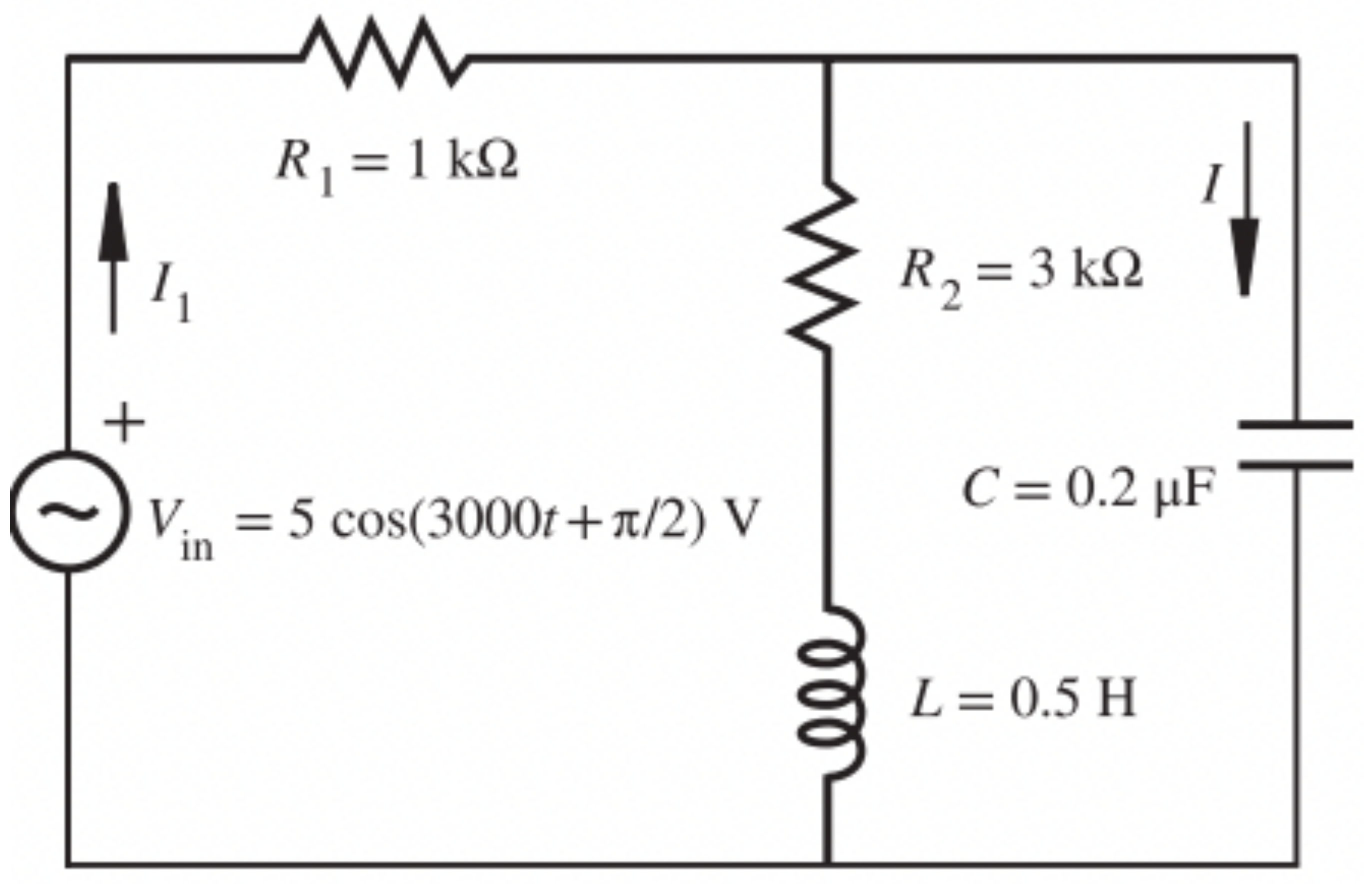
$$Z_{eq} = (R_2 + Z_L) \parallel Z_C$$

$$= \frac{(R_2 + Z_L) Z_C}{(R_2 + Z_L + Z_C)} + R_1$$

$$\therefore I_1 = \frac{V_{in}}{Z_{eq}} \; .....$$

$$\therefore \boxed{I = \frac{R_2 + Z_L}{(R_2 + Z_L) + Z_C} I_1}$$

AC circuit Analysis: Ex. 2.7



$$Z_C = \frac{1}{j\omega C} = -\frac{j}{\omega C}$$

$$Z_L = j\omega L$$

$$Z_R = R$$

Semiconductor Physics: Types of dopants

- donor : enhances electron conductivity

n-type

- acceptor : reduces electron conductivity

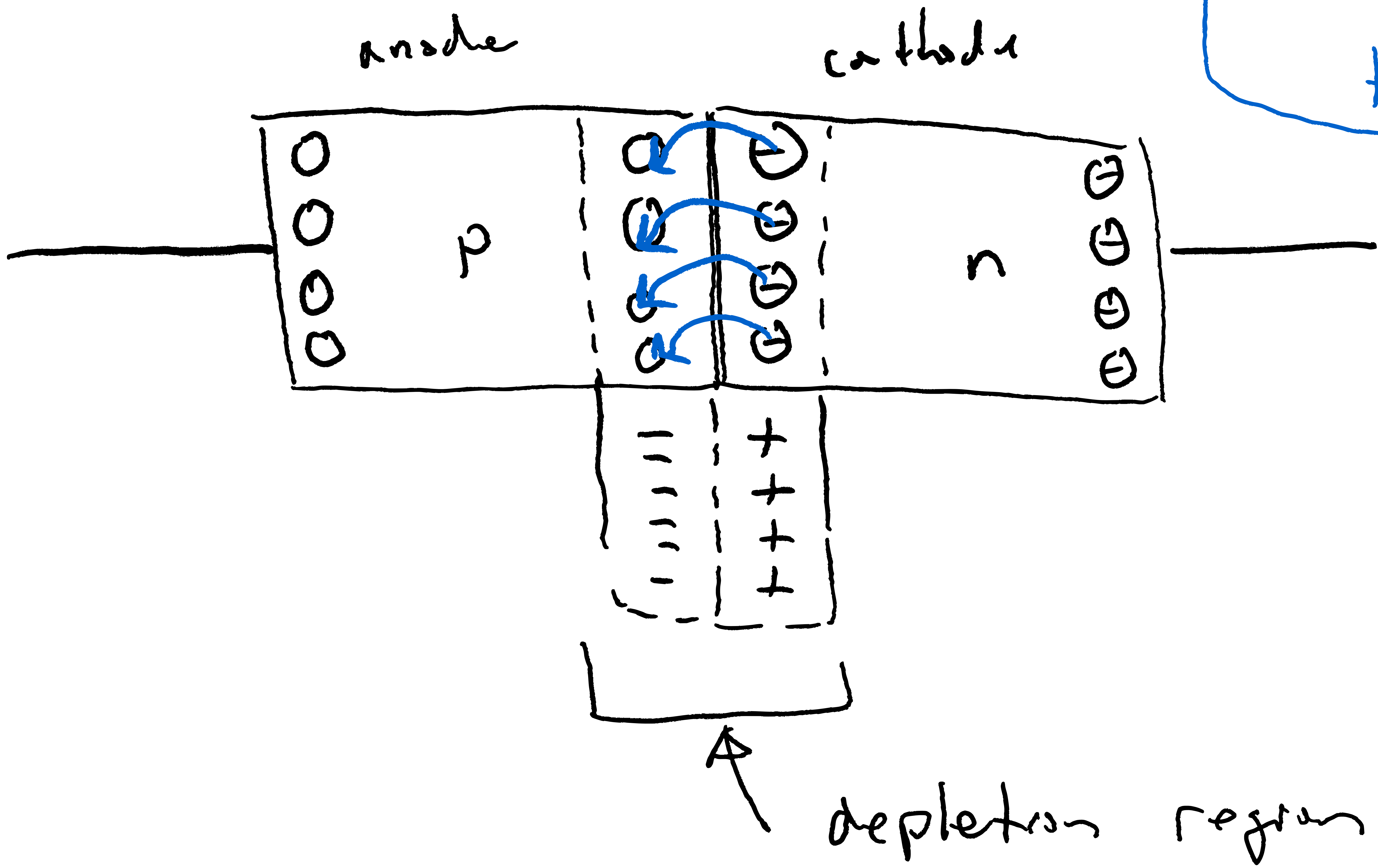
p-type

- n-type : charge carrier e^-
- p-type : charge carrier hole

→ Key idea:

the interaction between n- & p-type areas on the chip.

Junction Diode: pn-junction

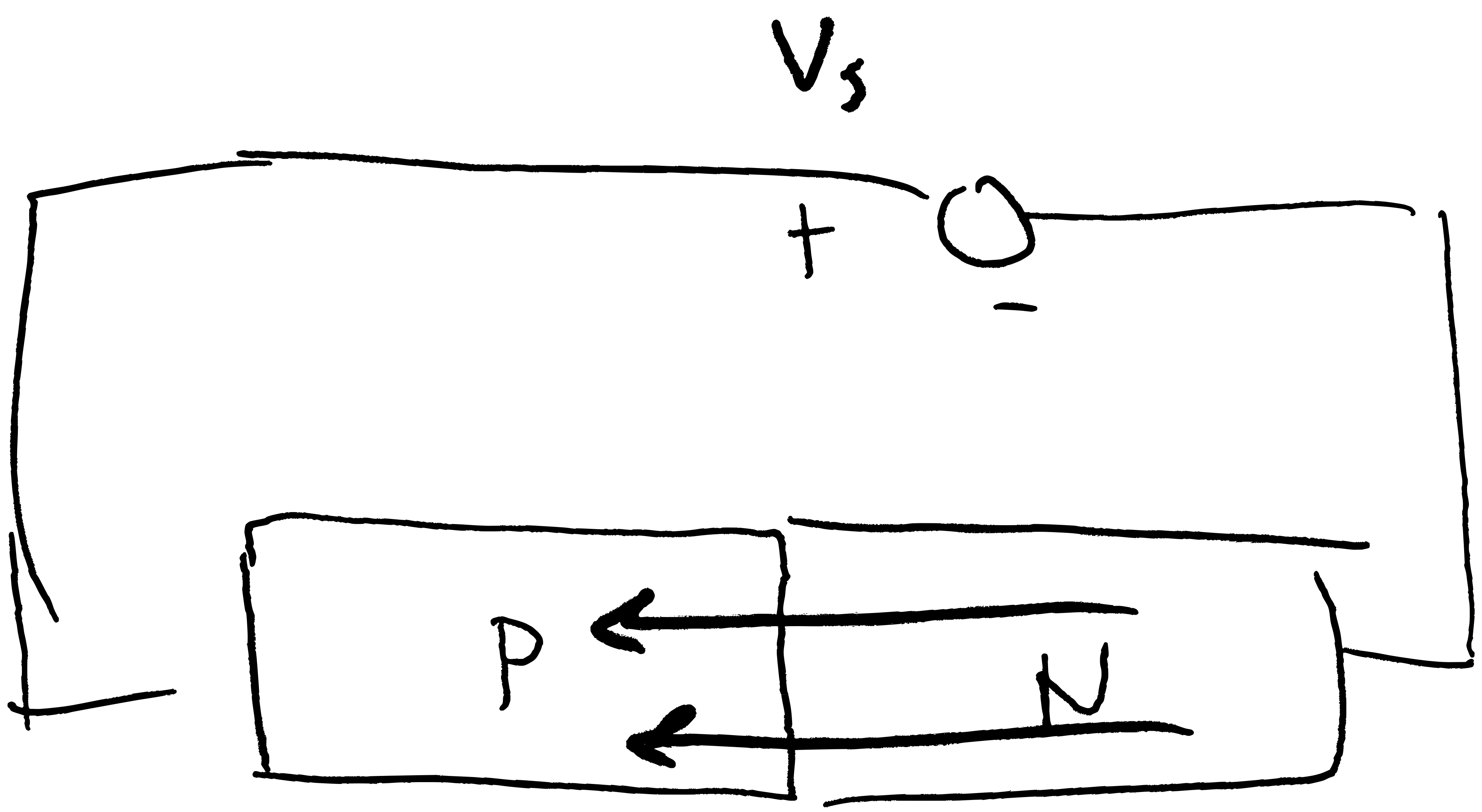


contact potential ~ silicon 0.7 V

* electrons from cathode migrate (diffuse) to occupy the hole on the anode

Junction Diode: pn-junction

what happen with a voltage applied



Forward Bias

$V_s >$ contact Potential

$V_s > 0.7\ V$

- depletion shrinks
- current flows

$$I_D = I_0 \left(e^{\frac{qV_s}{KT}} - 1 \right)$$

I_D: current through the diode

I_0: reverse saturation current

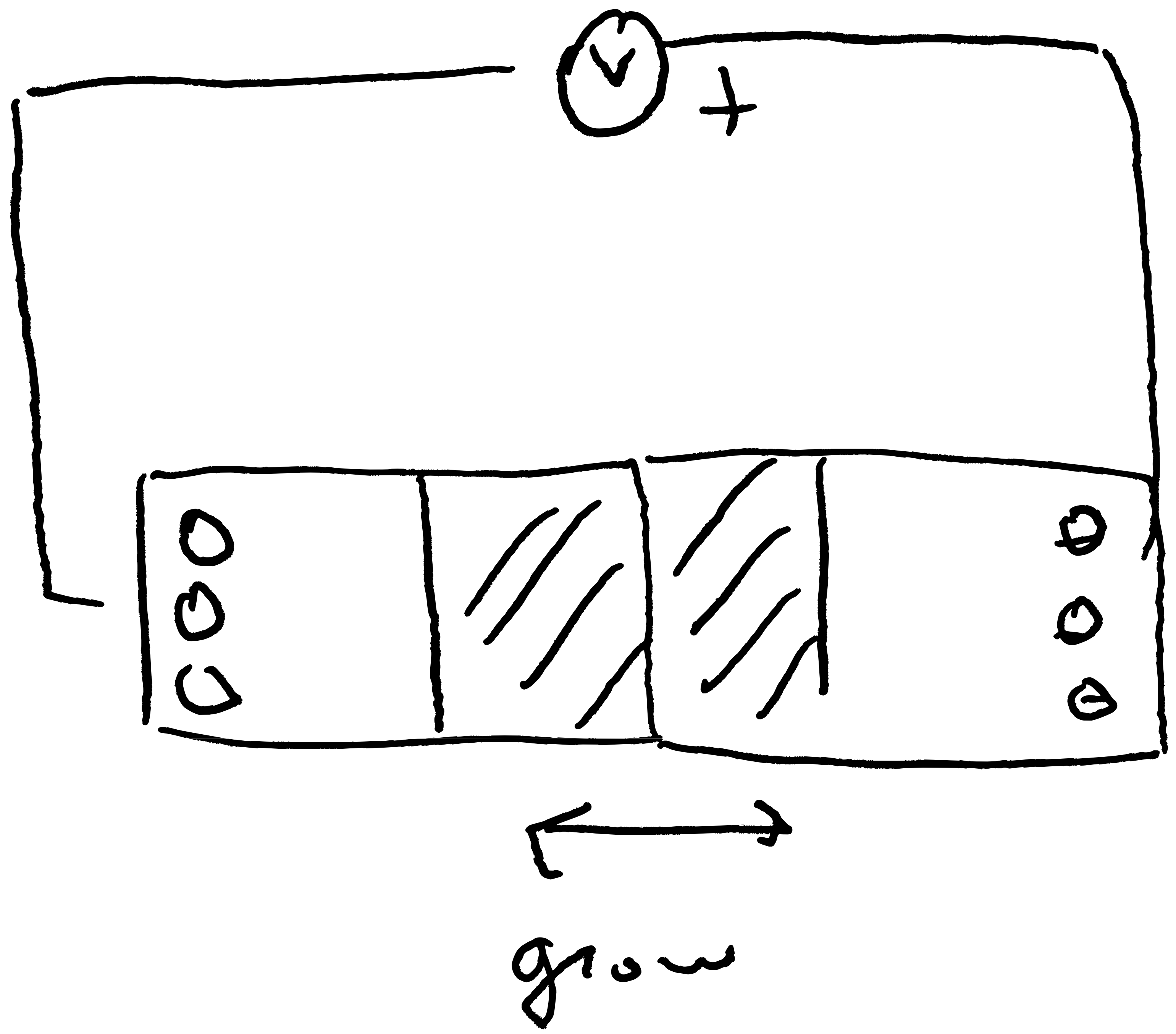
q: electron charge

K: Boltzmann's Constant

V_s: Voltage across diode

Junction Diode: pn-junction

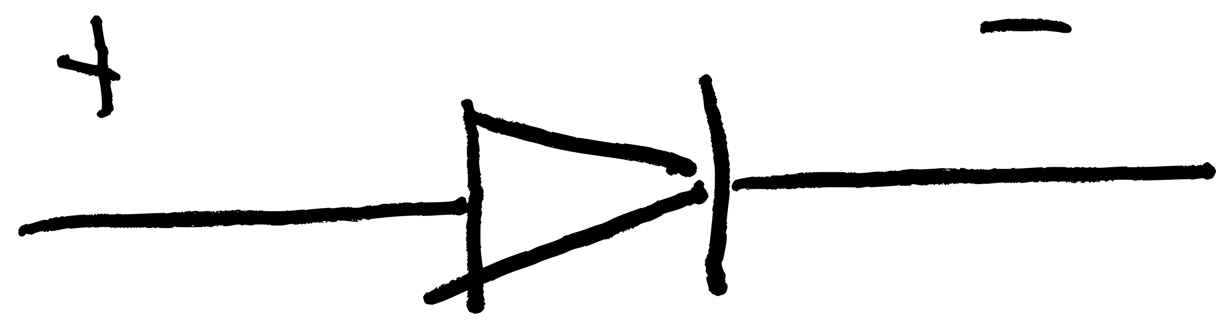
What happens if you flip polarity?

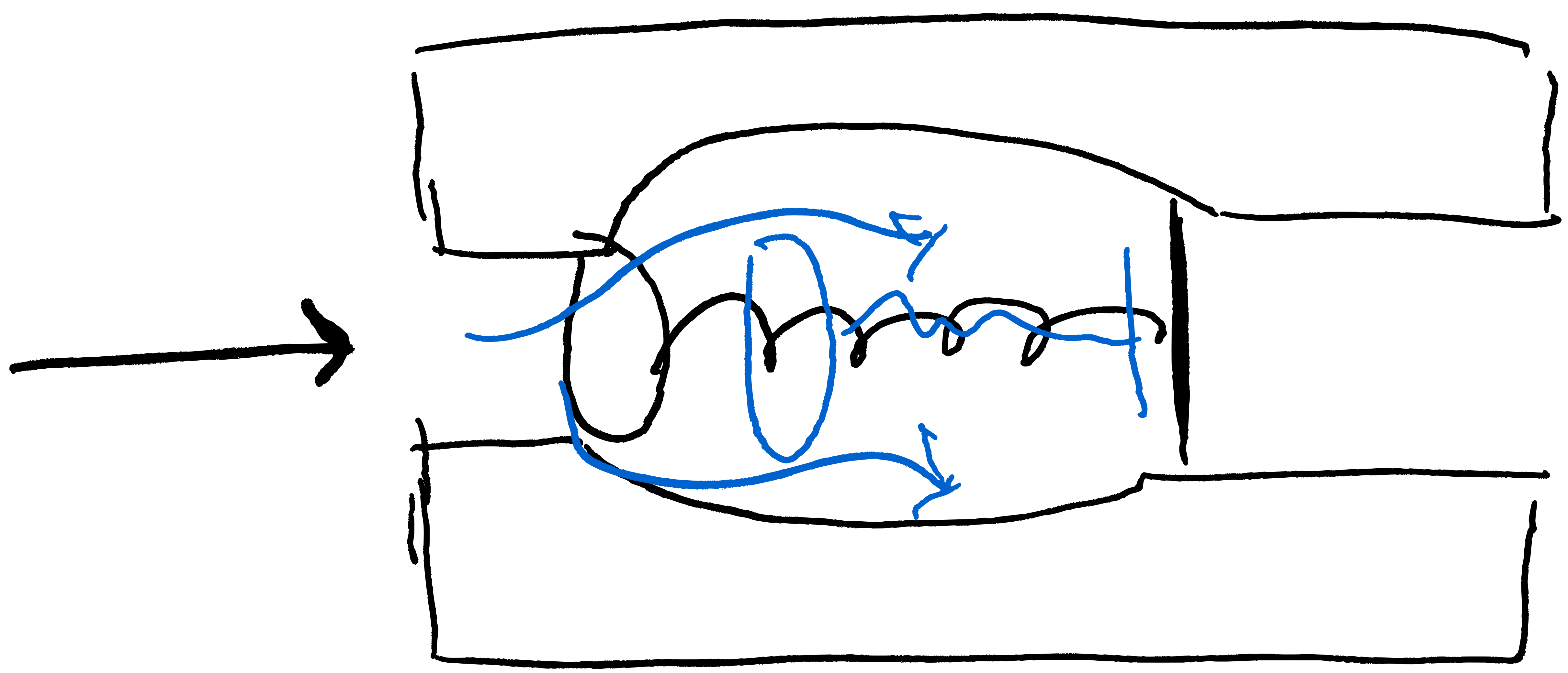


* Reverse saturation current flow, but on the order 10e-9

∴ Diode: lets current flow in only one direction.

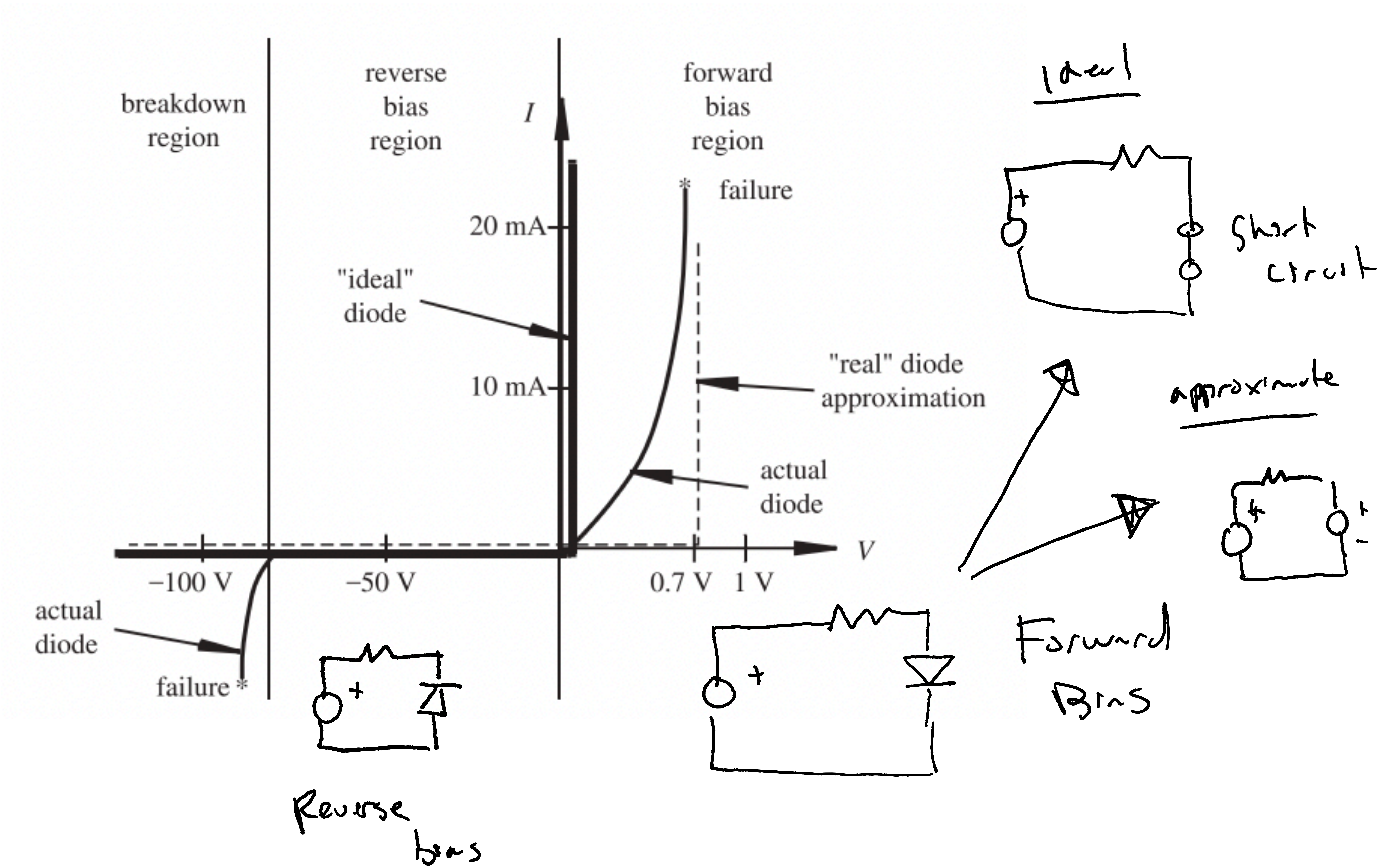
Diode water analogy





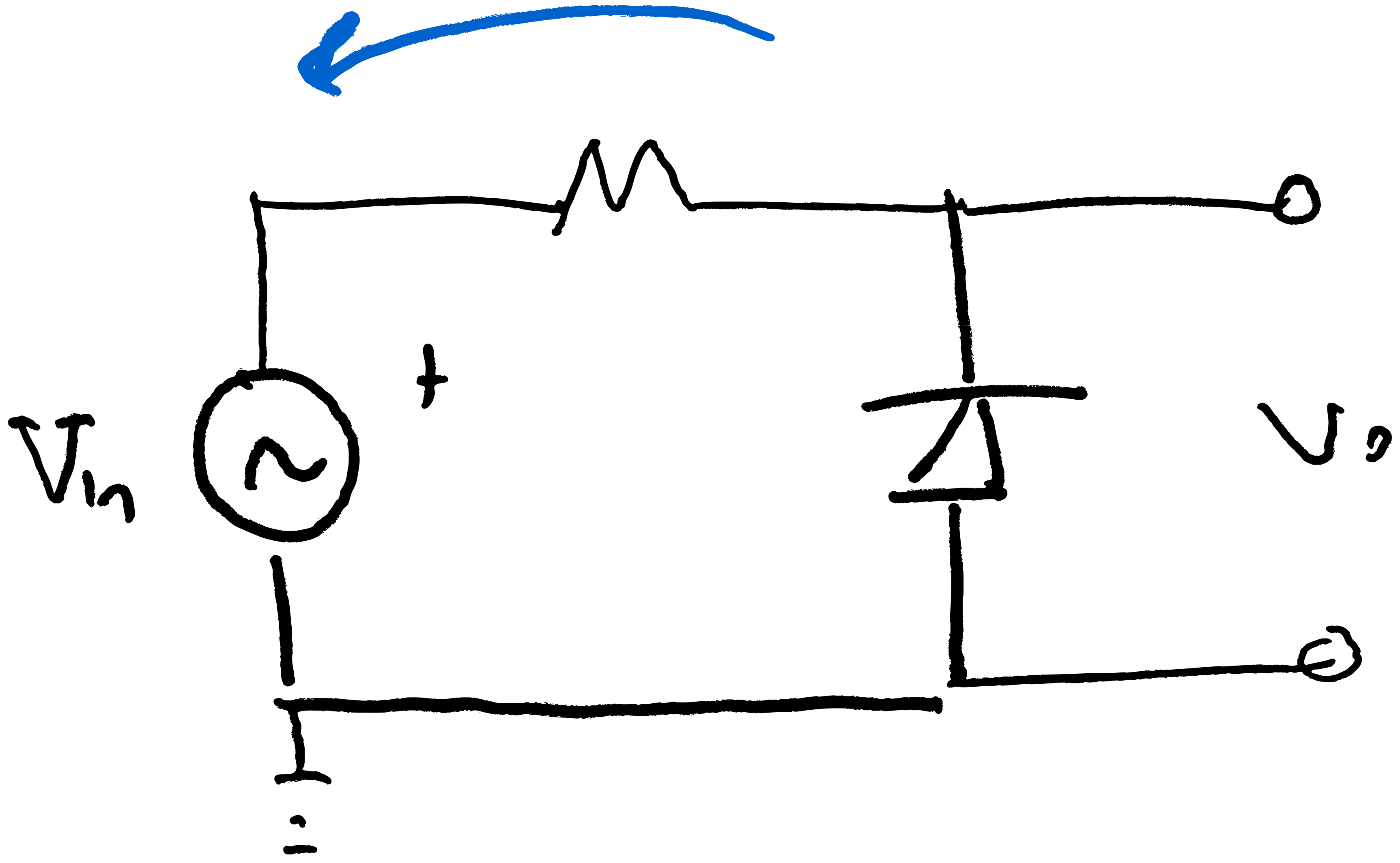
- on/off → this action of pn-junction is the fundamental basis for all digital devices.

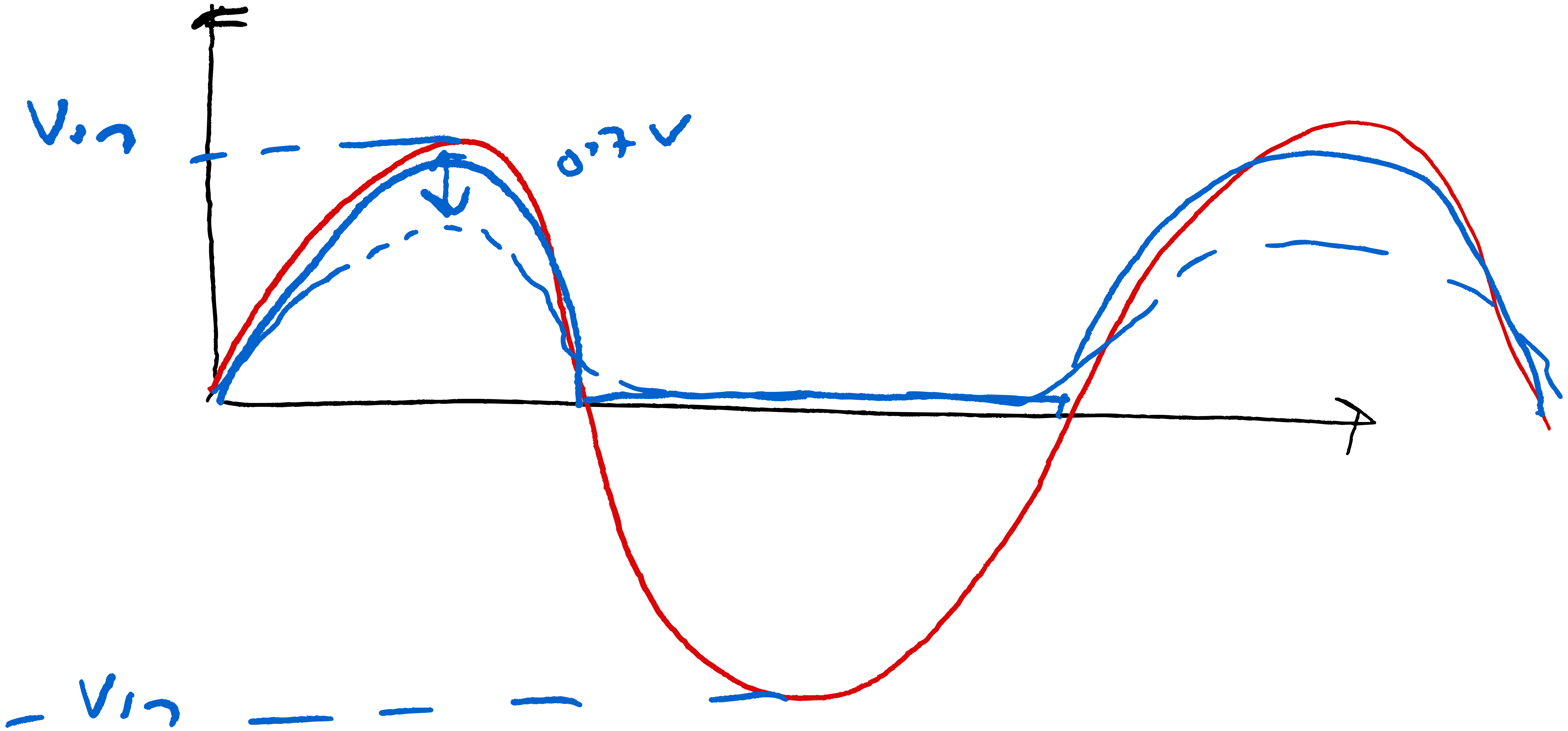
Ideal, actual, and approximate diode curves



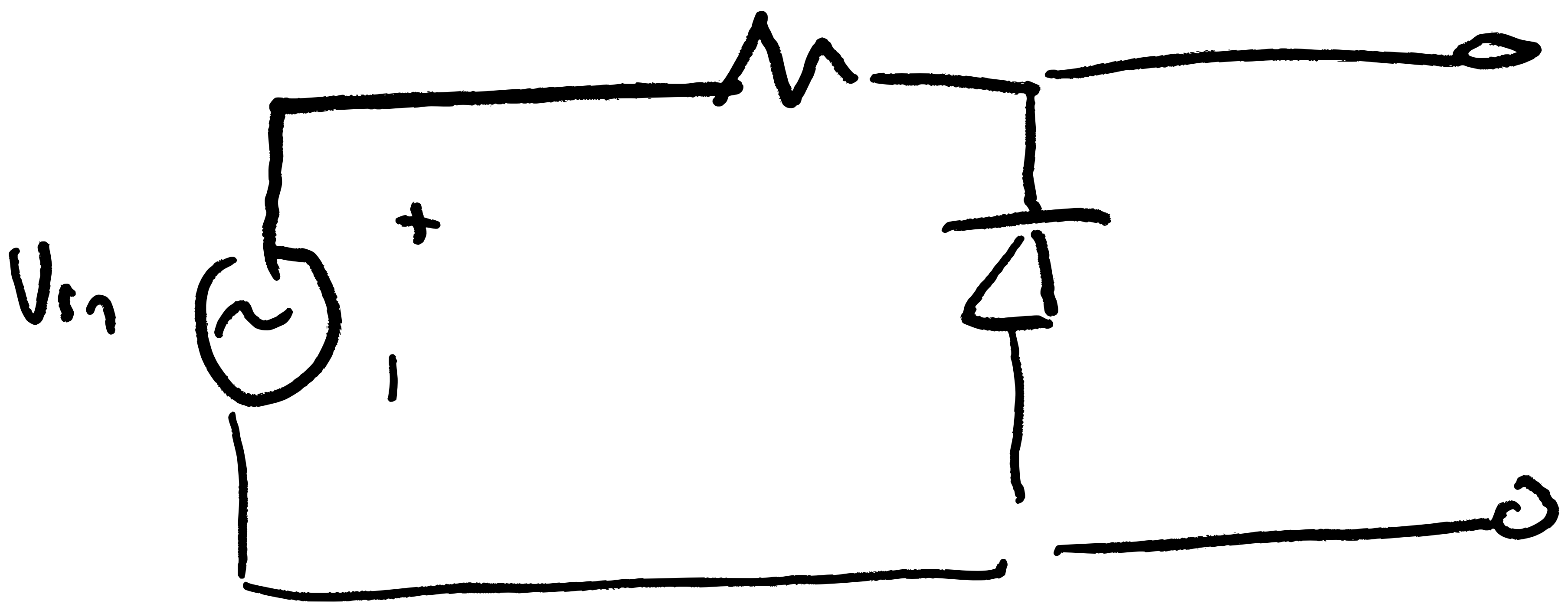
Why are diodes useful?

- circuit protection
- half-wave rectifier





How to analyze

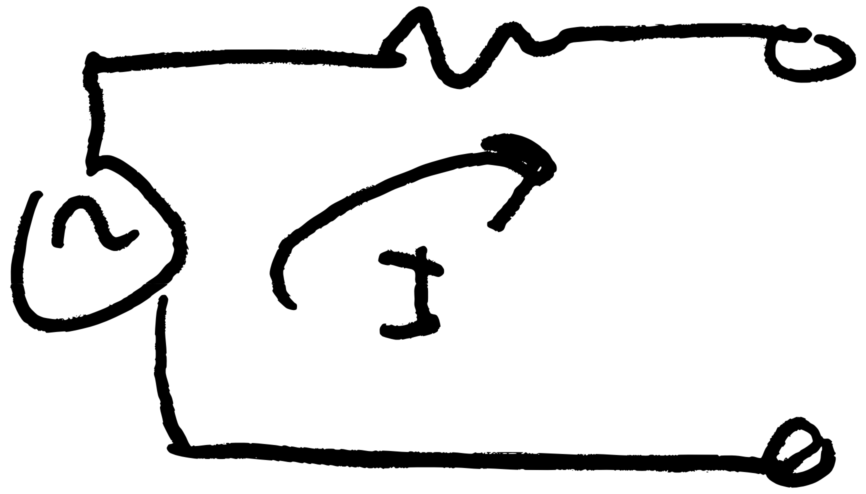


- split into two circuits
  1. Vin > 0
  2. Vin < 0

(1) Vin > 0

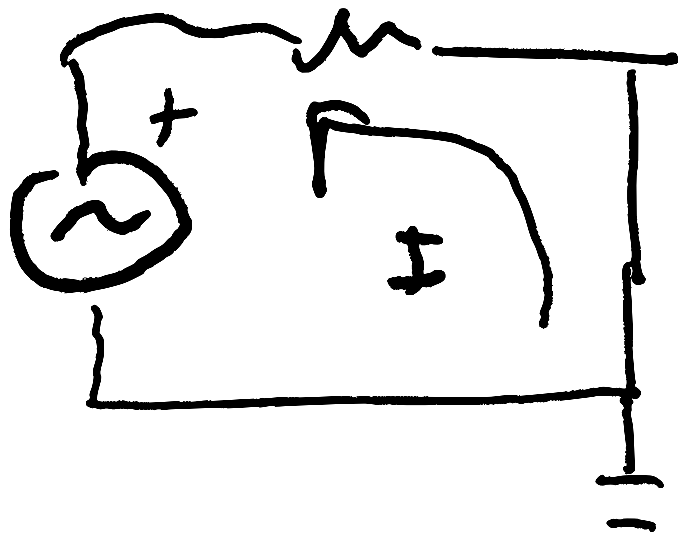
diode → reverse bias

→ open circuit

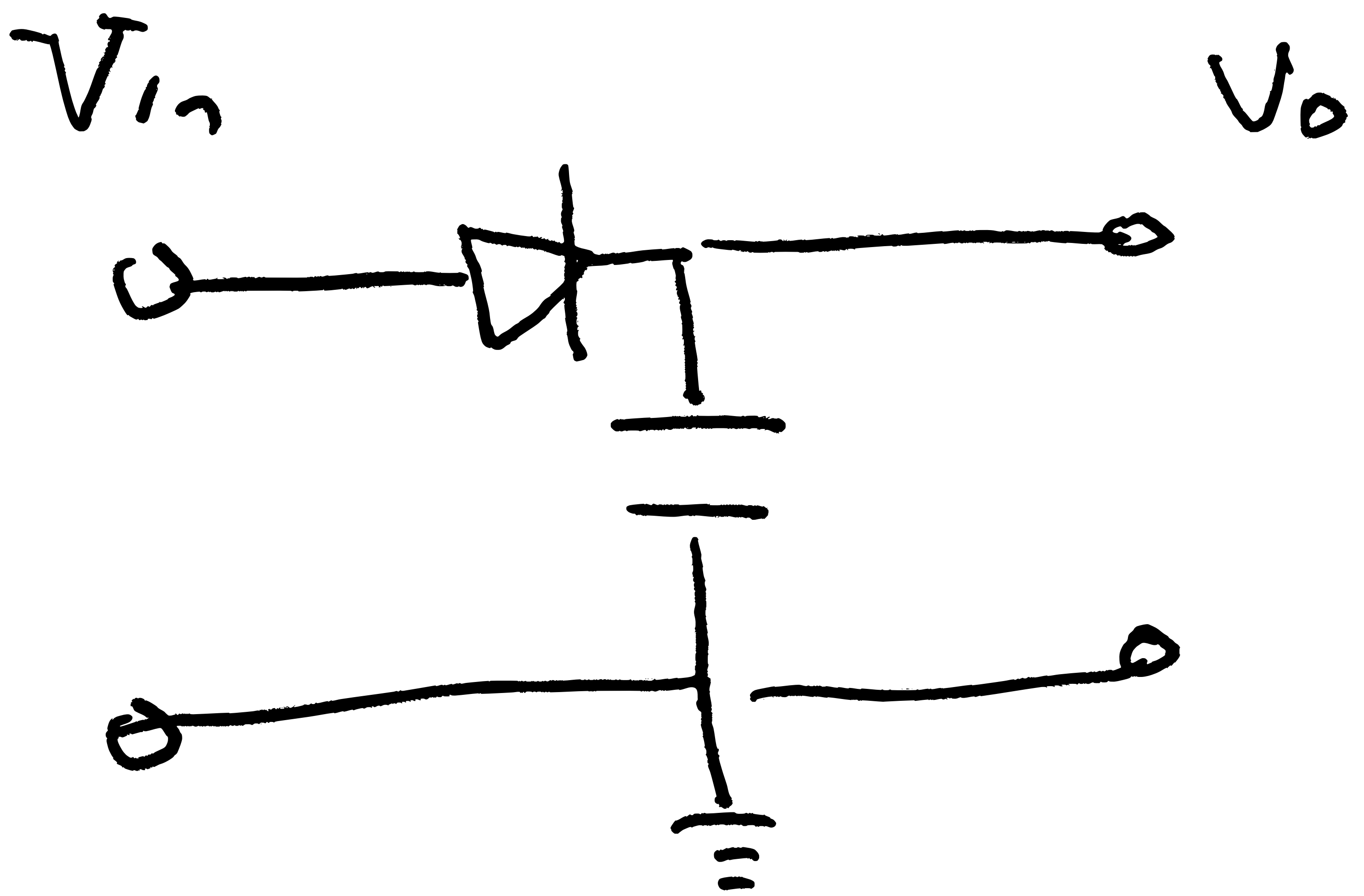


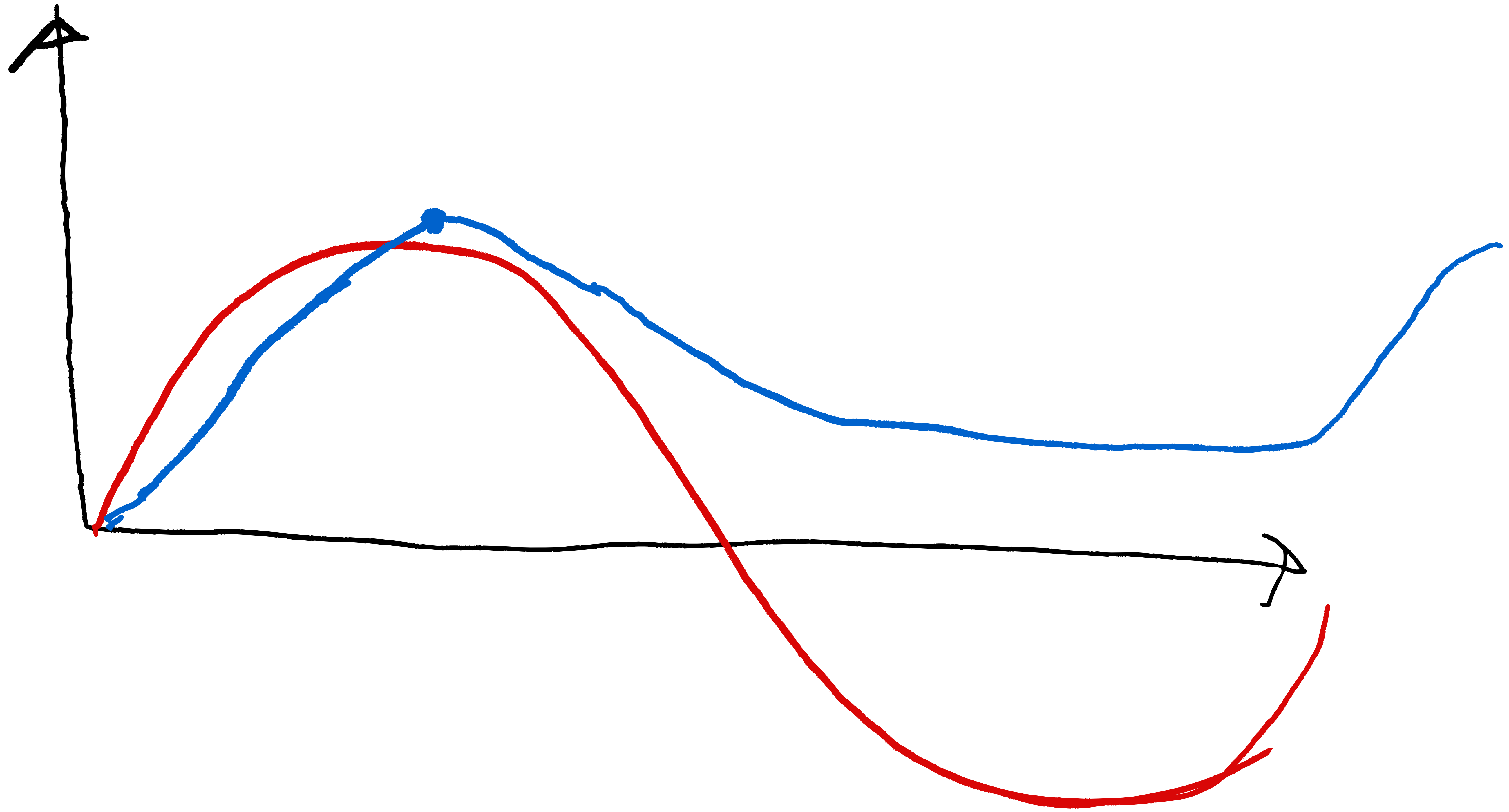
(2) Vin < 0 diode → forward bias

→ short



Peak detector

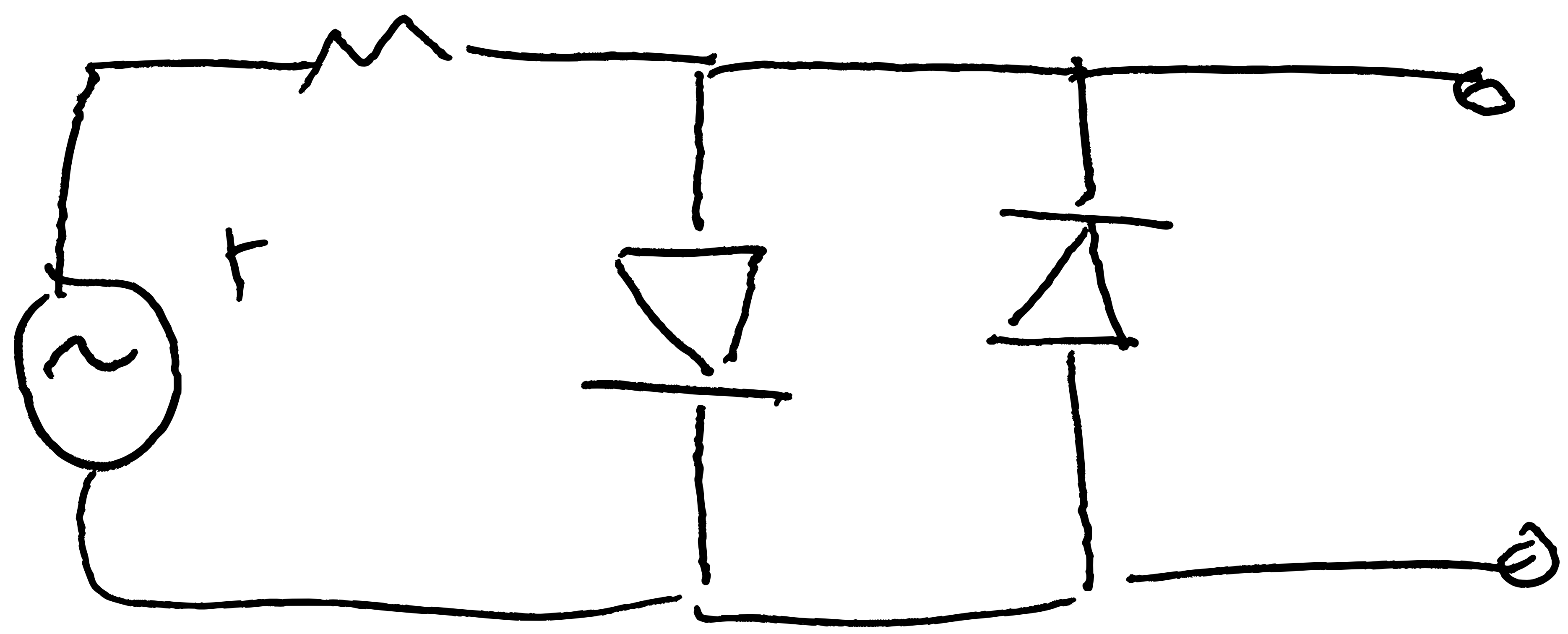


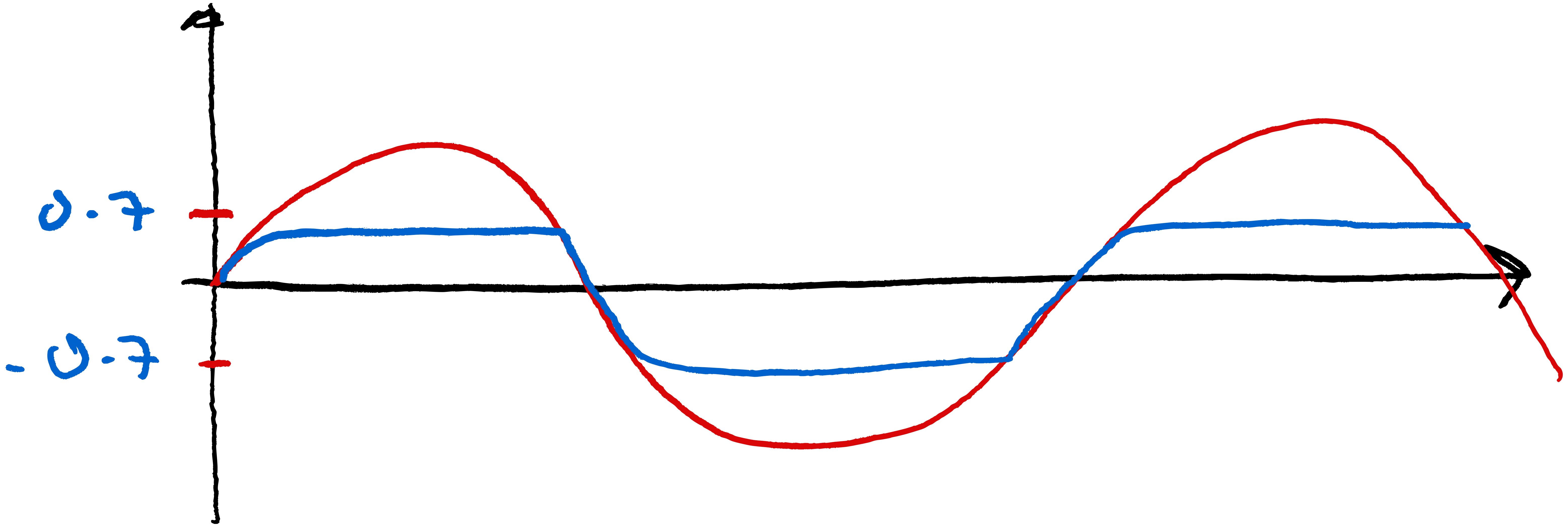


- $V_{in} > 0$ forward bias
  → short circuit
  capacitor will charge

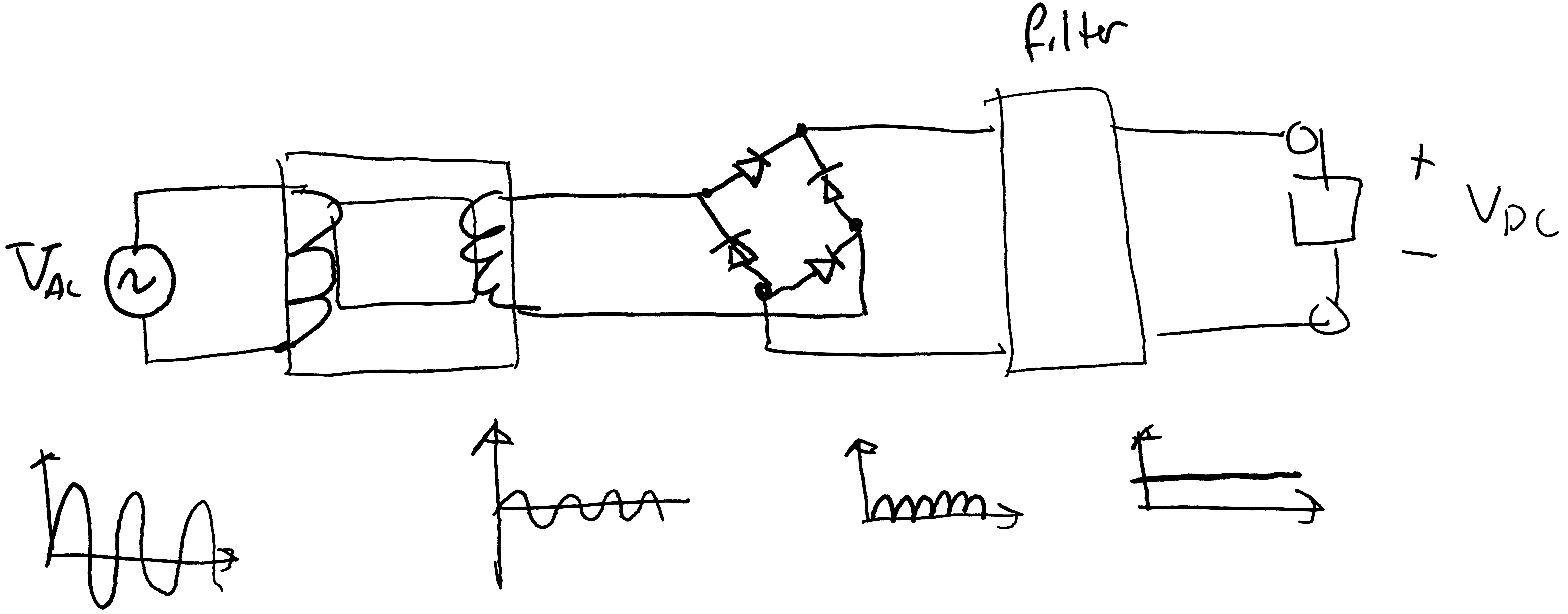
- $V_{in} < 0$ reverse bias
  → capacitor retains
  voltage

Clipper Circuit





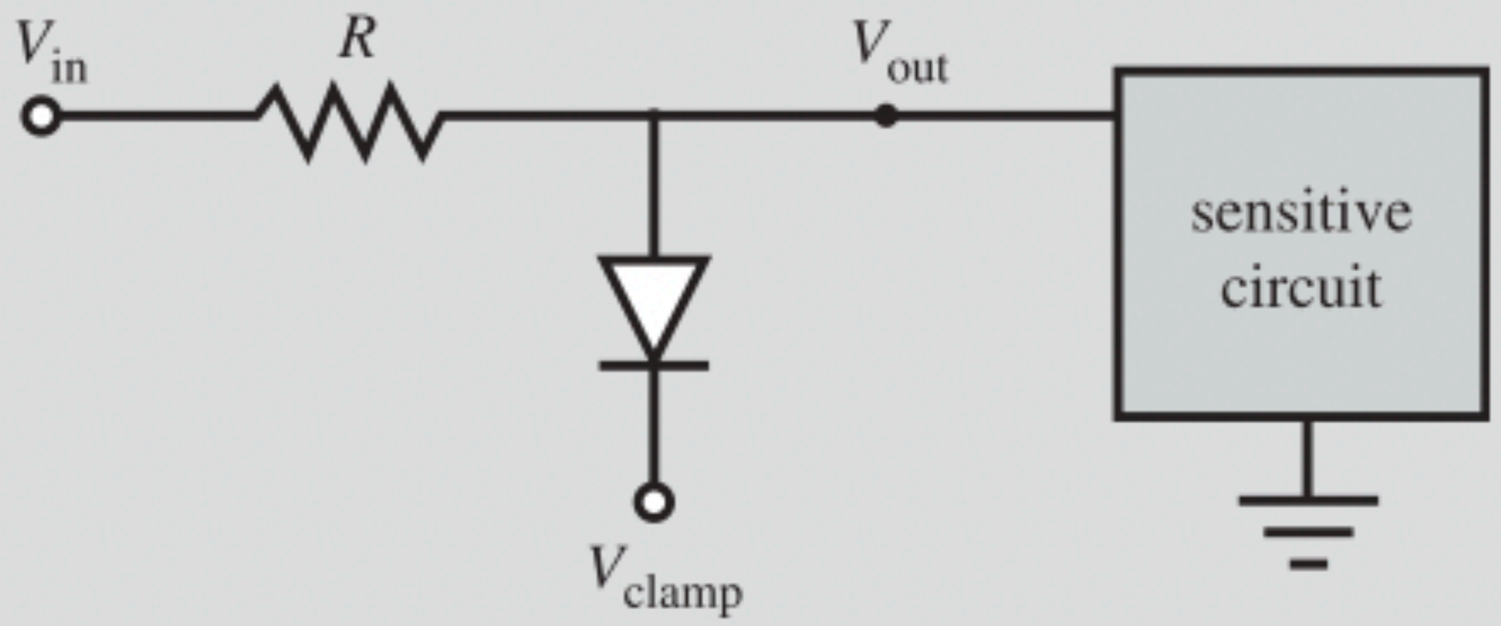
AC-to-DC converter with full- bridge rectifier



■ CLASS DISCUSSION ITEM 3.2

Diode Clamp

The circuit below is called a **diode clamp** because it limits ("clamps") the voltage going to a sensitive circuit. If the circuit has very high input impedance, discuss how the voltage applied to the circuit (V_{out}) varies when the input voltage (V_{in}) changes, based on the clamp voltage (V_{clamp}). Consider both "real" and "ideal" models of the diode.



LED: Light emitting diode

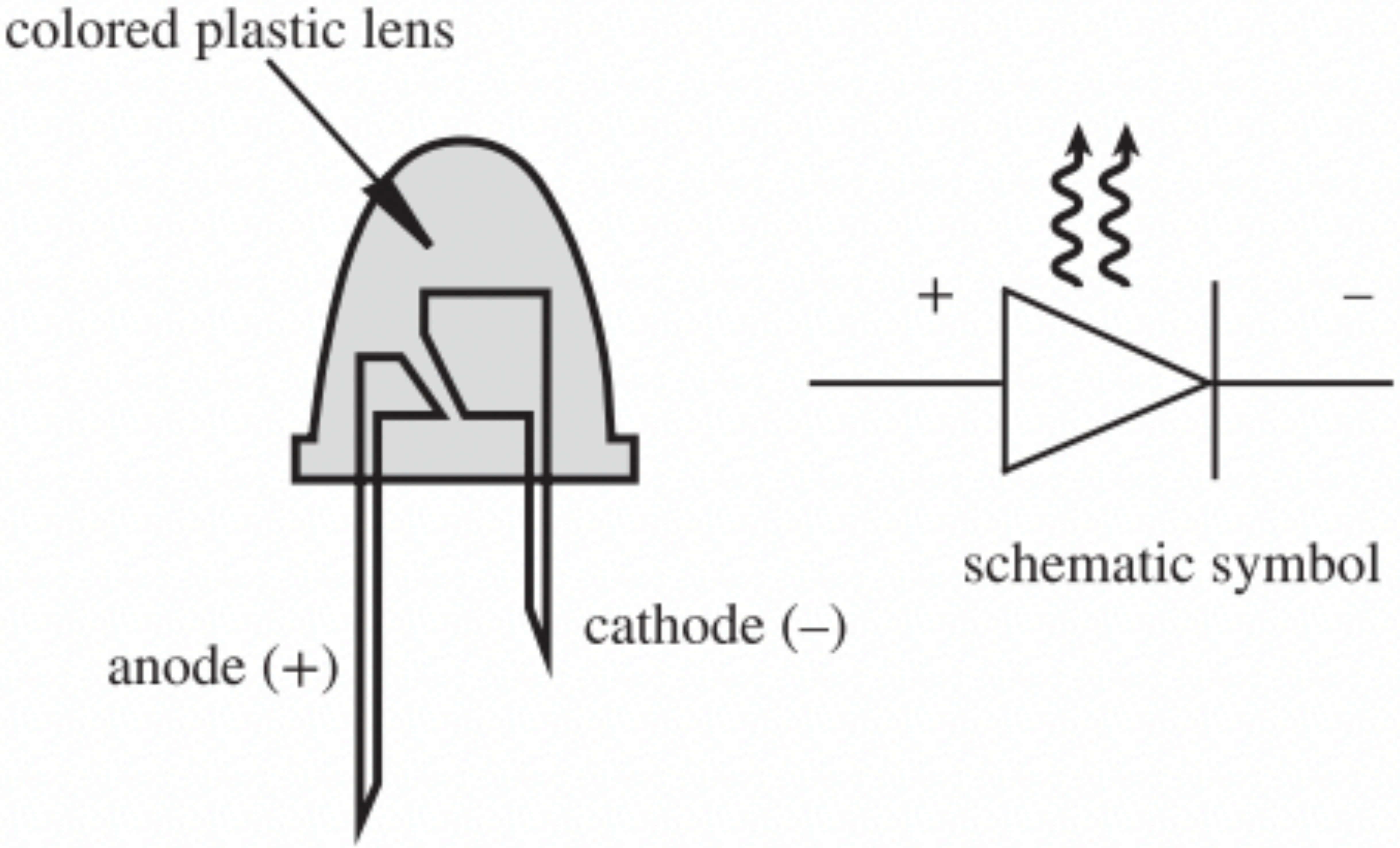
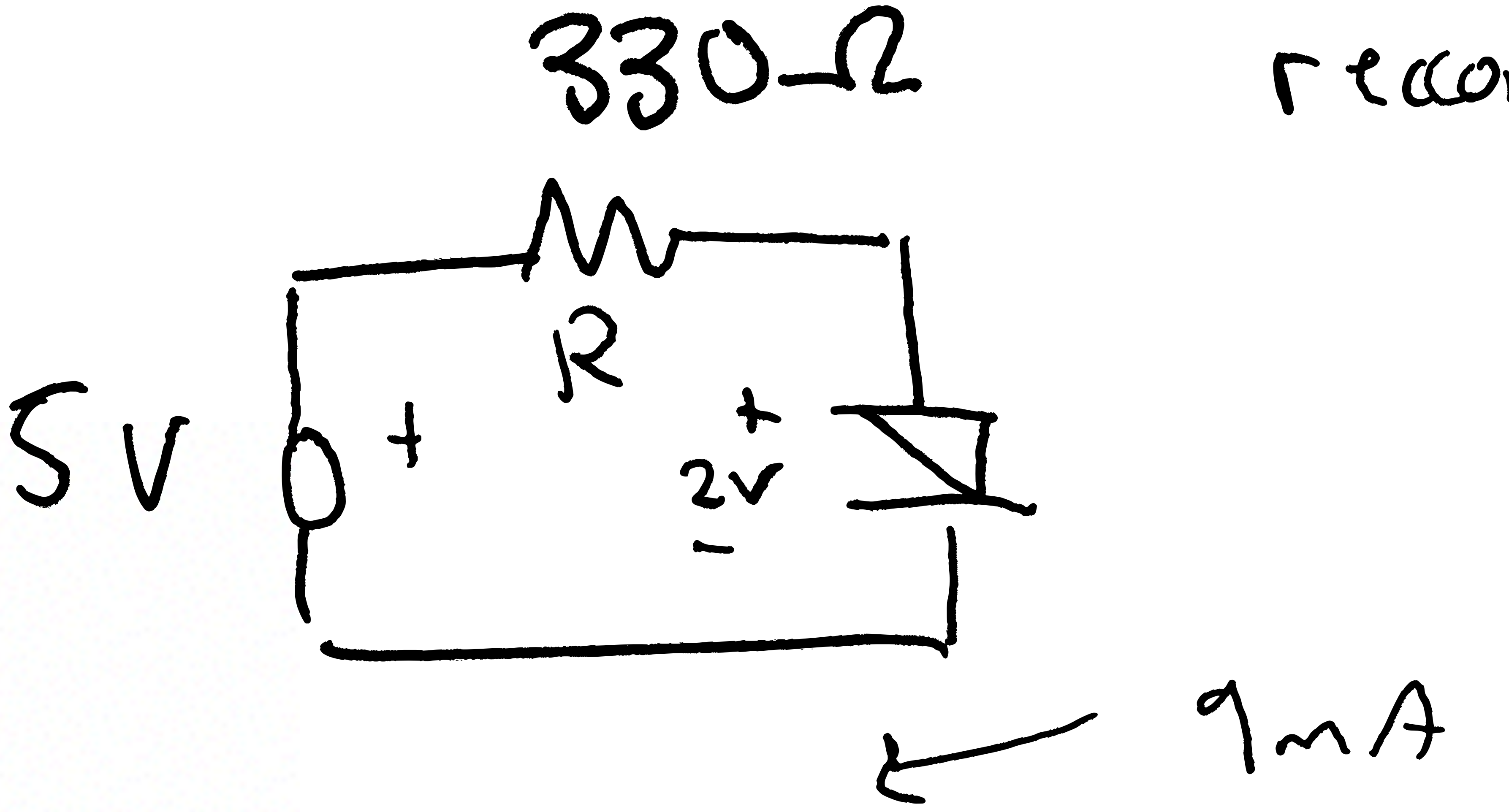


Figure 3.11 Light-emitting diode.

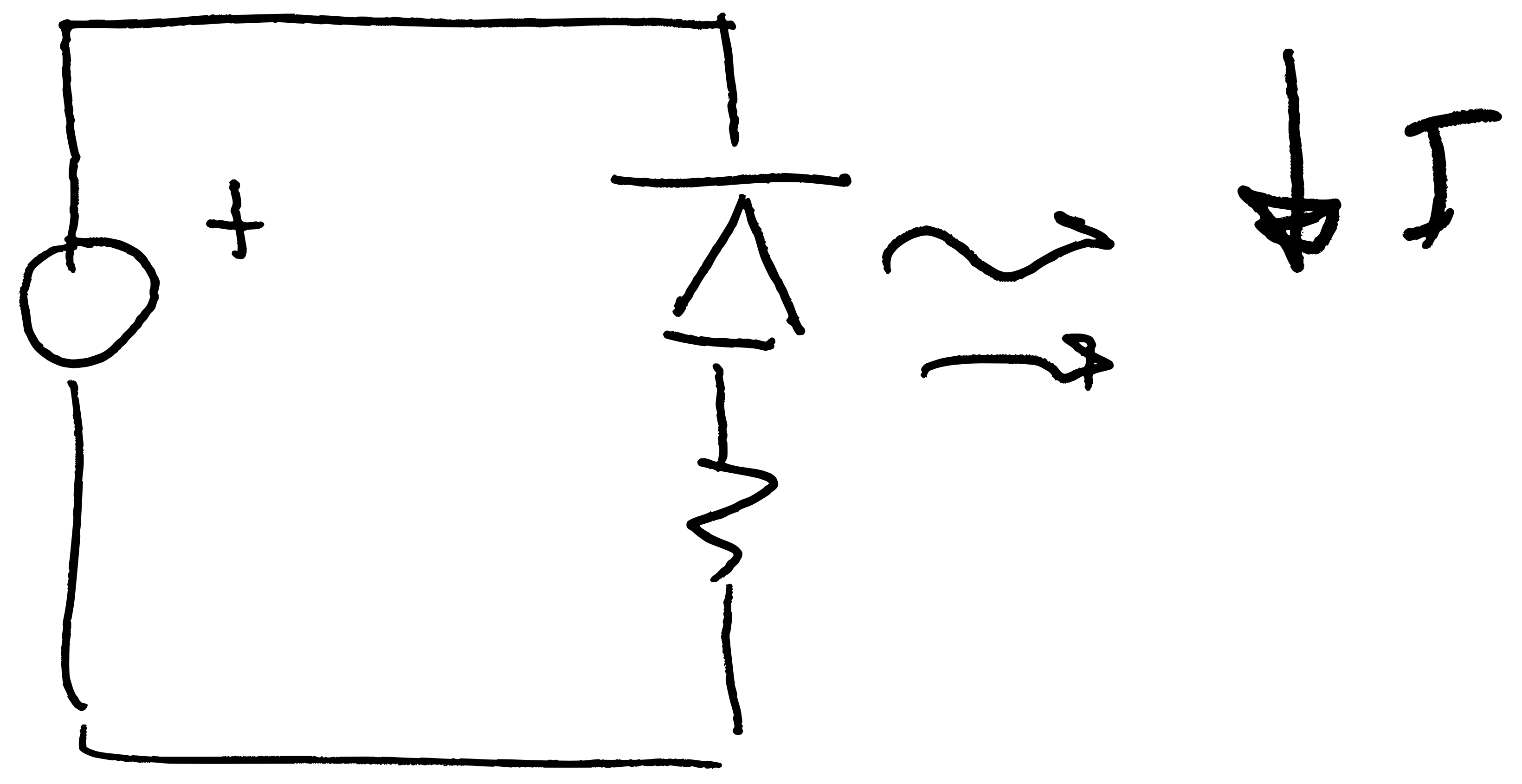
reccomendations



R: current-limiting resistor, prevents excess forward current

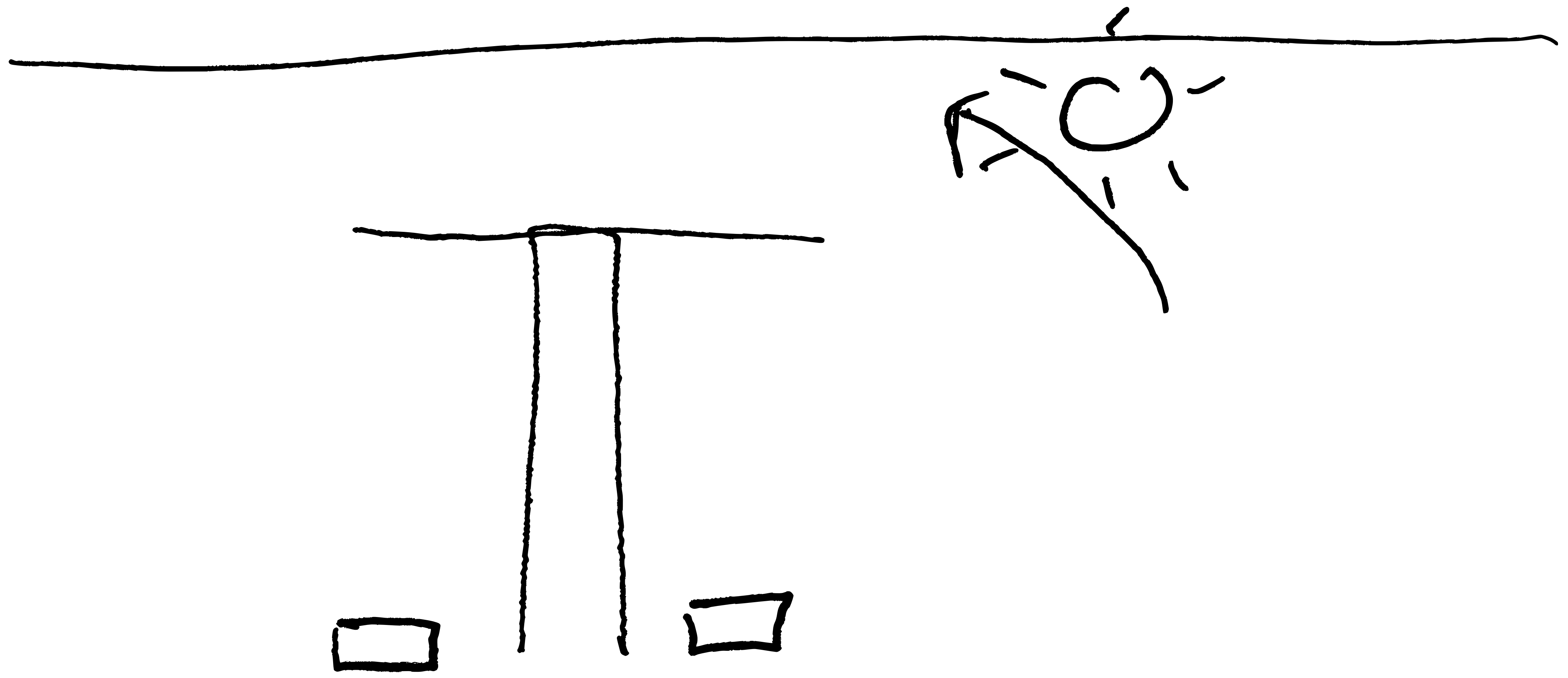
Photo Diode

- recall: semiconductors have properties that are sensitive to environmental stimuli

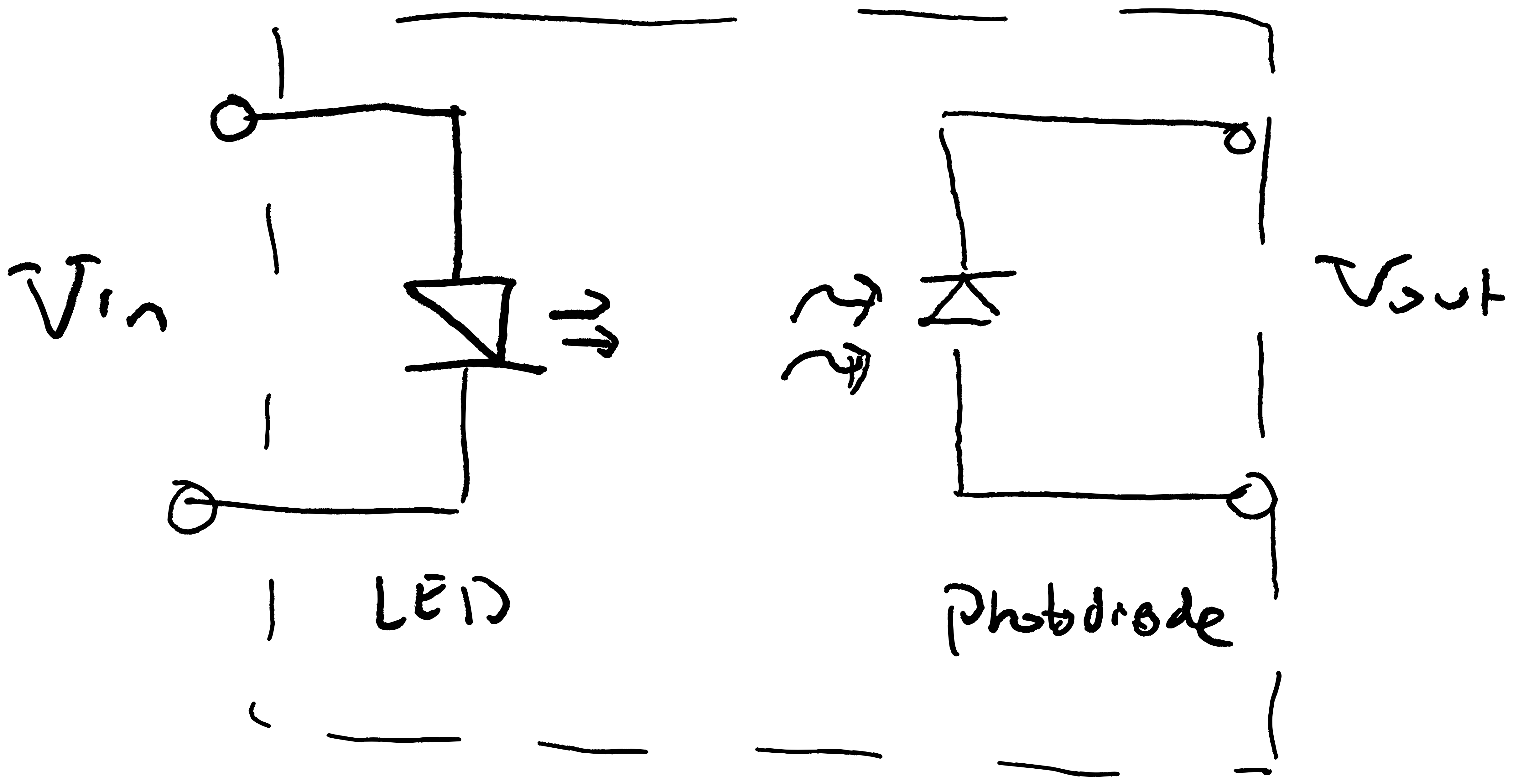


- photodiode detect photons

  (quantum effect)



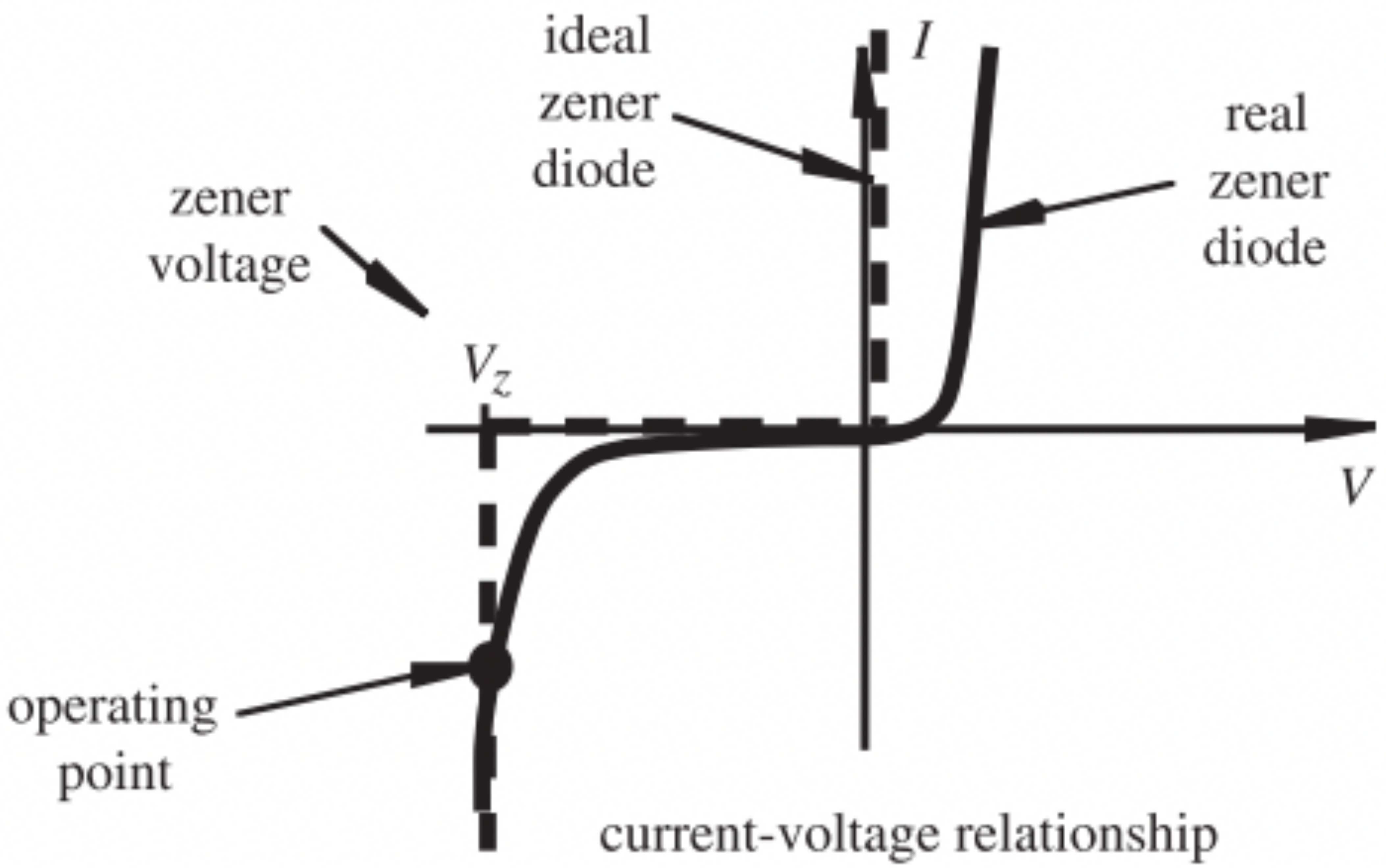
Optocoupler



- isolation device
- allows signal transmission between two isolated circuits

Why? low-voltage controller → high voltage circuit.

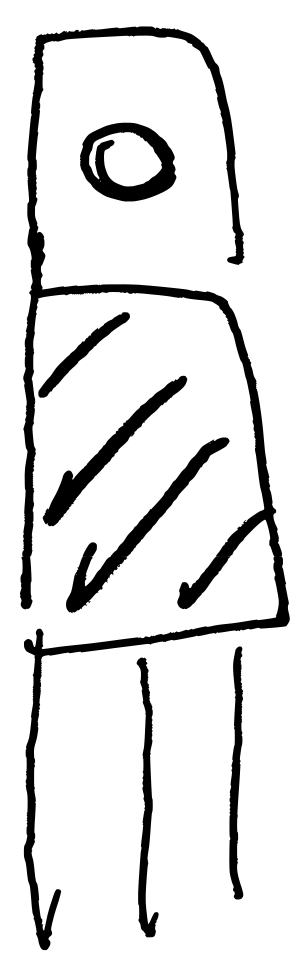
Zener Diode


ideal
zener
diode
I
real
zener
diode
zener
voltage
V_z
V
operating
point
current-voltage relationship

Zener Diode: Voltage regulator

Most of the time we use specific IC for voltage regulation

- LM78XX



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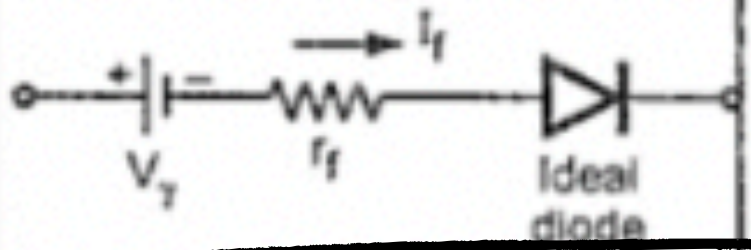
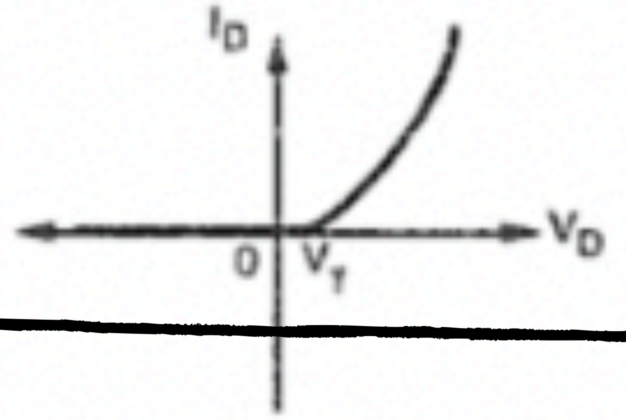
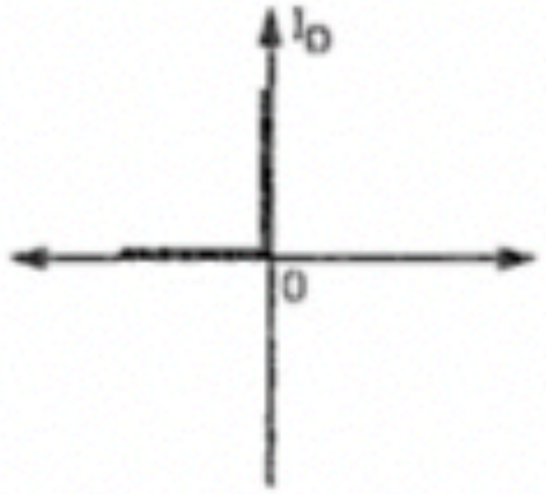
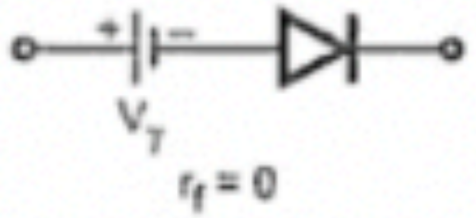
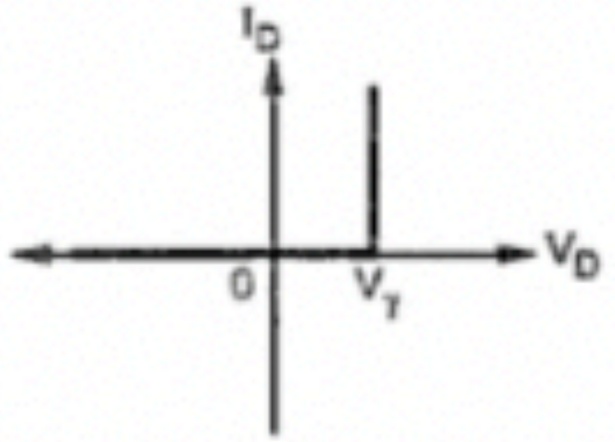
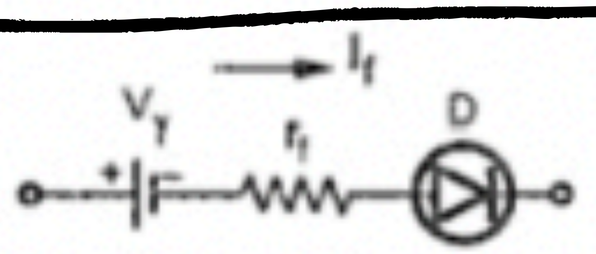
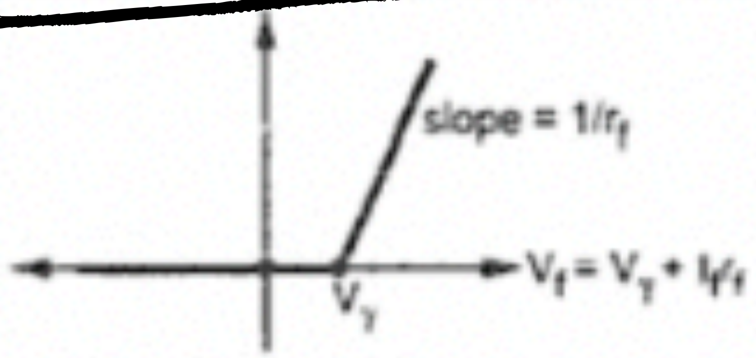
Models for diodes

Type	Model in forward biased	V-I characteristics	Drop across diode
Practical diode			$V_f = V_\gamma + I_f r_f$
Ideal diode			$V_f = 0$
Piecewise linear with $r_f = 0\,\Omega$			$V_f = V_\gamma$
Piecewise linear with finite r_f			$V_f = V_\gamma + I_f r_f$