

EEM 214

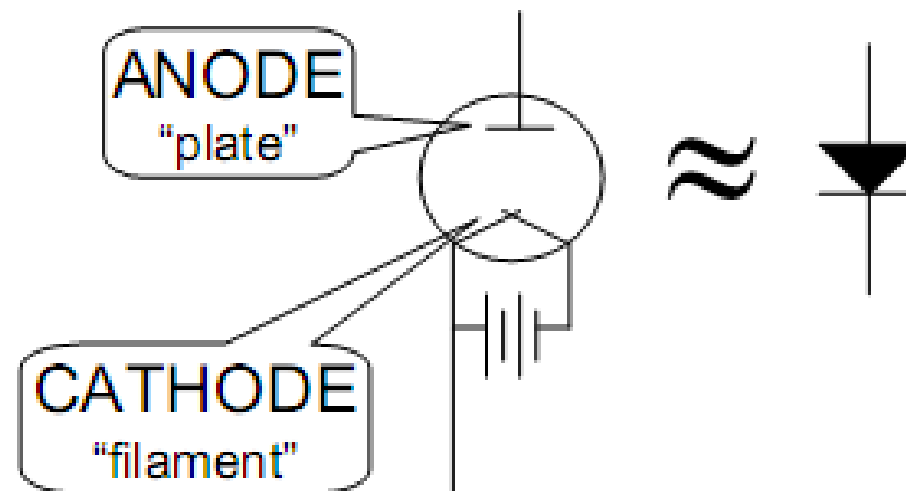
Lecture 4

Diode and Diode Models

Historical notes

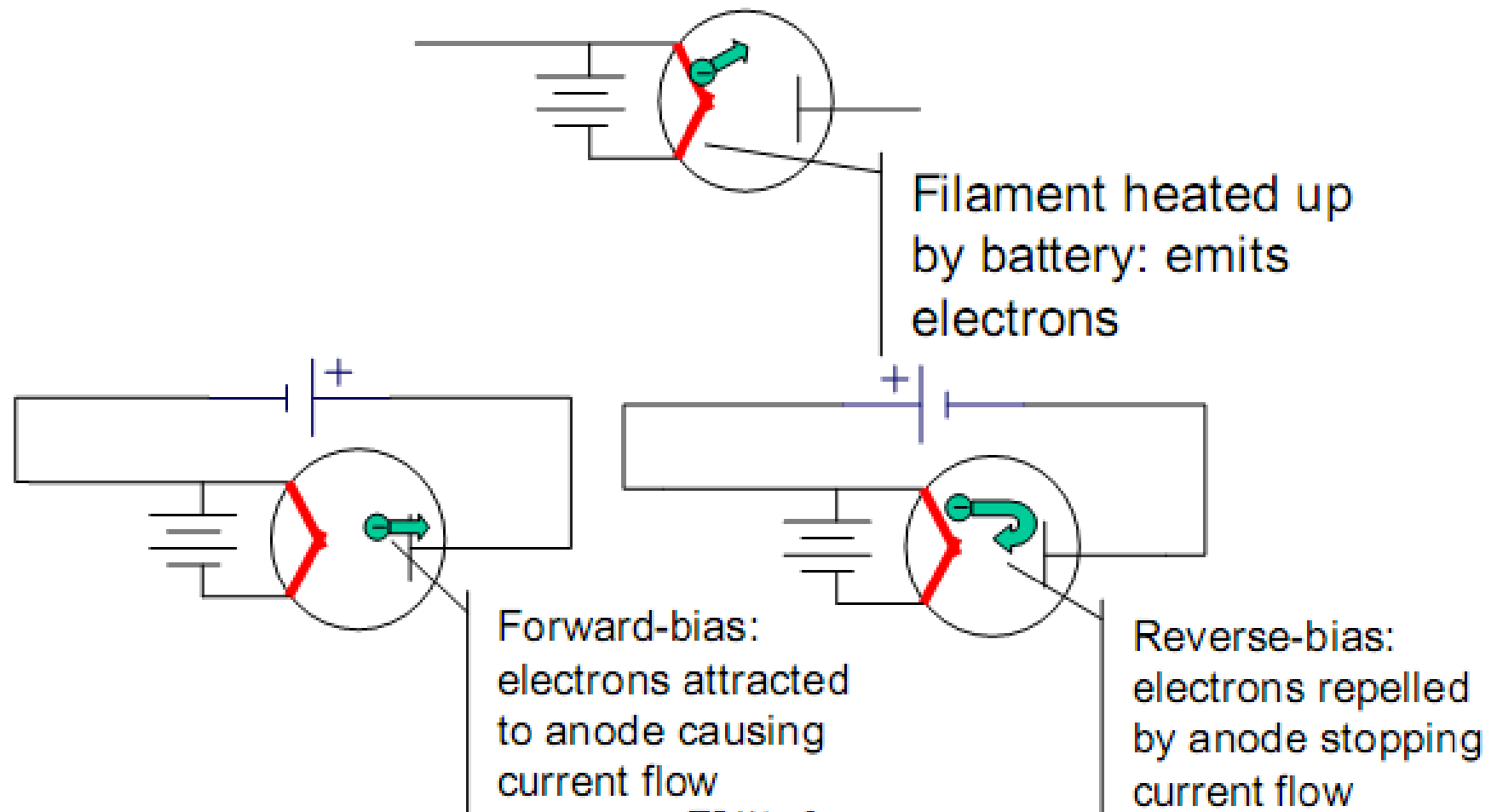
Vacuum tube diode

- Filament heats up, emits electrons, attracted or repelled by plate depending on voltage bias.



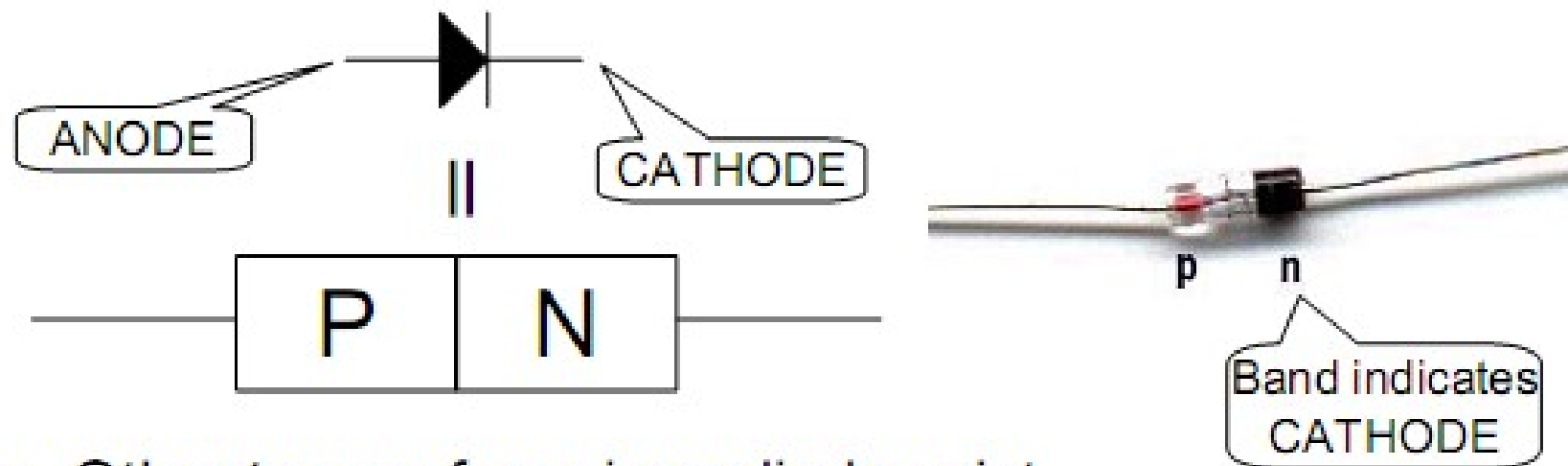
Historical notes

Vacuum tube diode operation



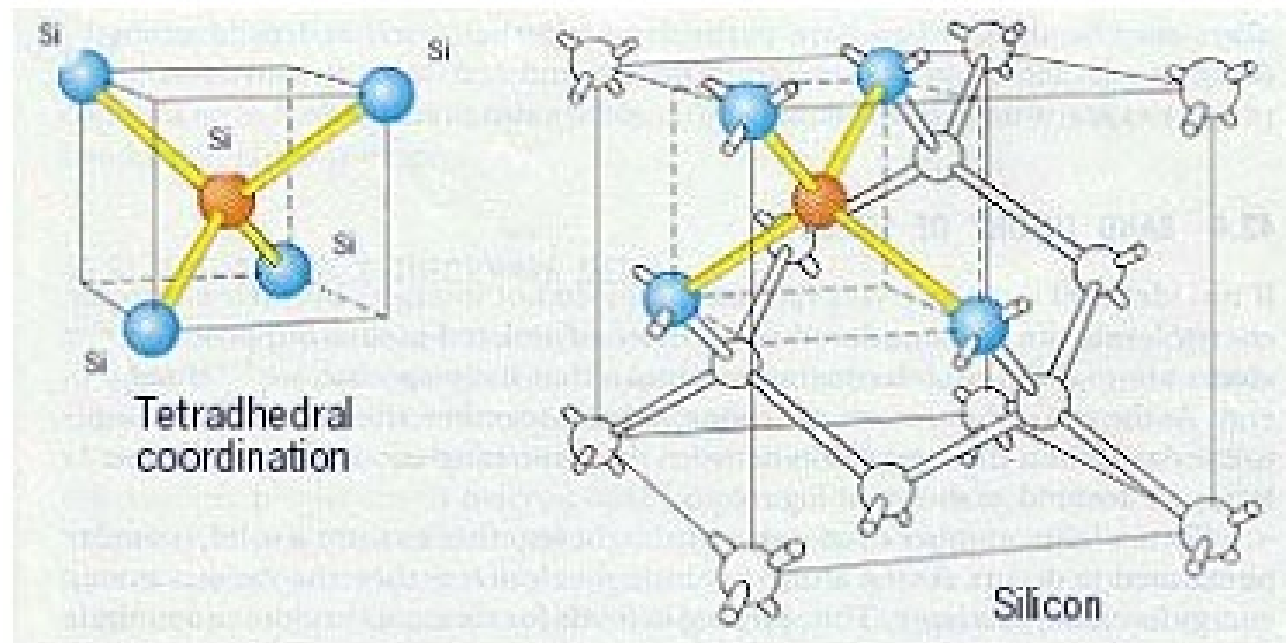
Semiconductor diode

- Junction of P-type and N-type semiconductor



- Other types of semicon diode exist
- 1940: Russell Ohl discovers that impurities in silicon determine its electrical properties
- Simplified explanation follows
(from sol.sci.uop.edu/~jfalward/semiconductordevices/semiconductordevices.html)

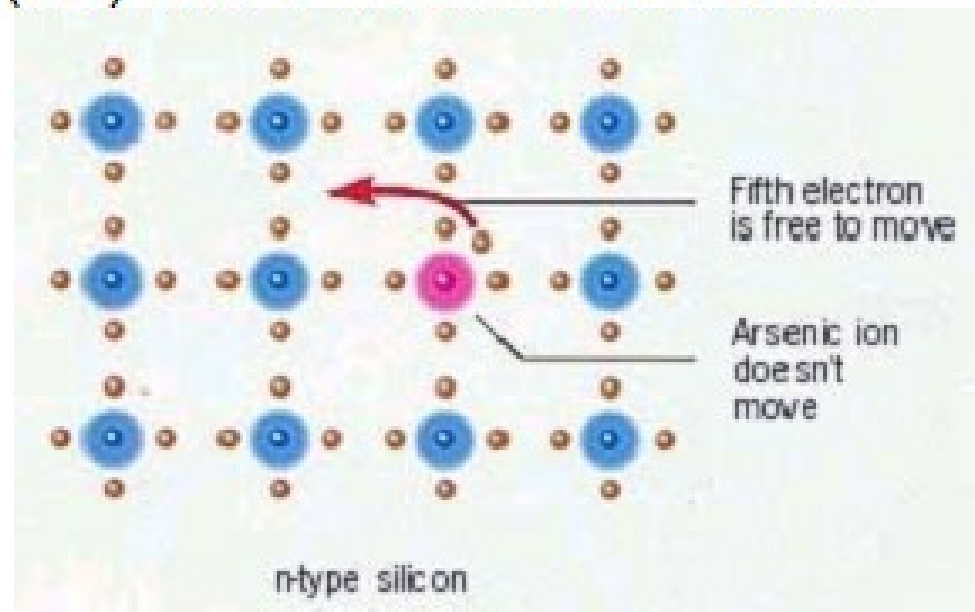
Pure silicon



- 4 valence electrons form covalent bonds with 4 adjacent silicon (Si) atoms in pure crystalline Si

N-type silicon

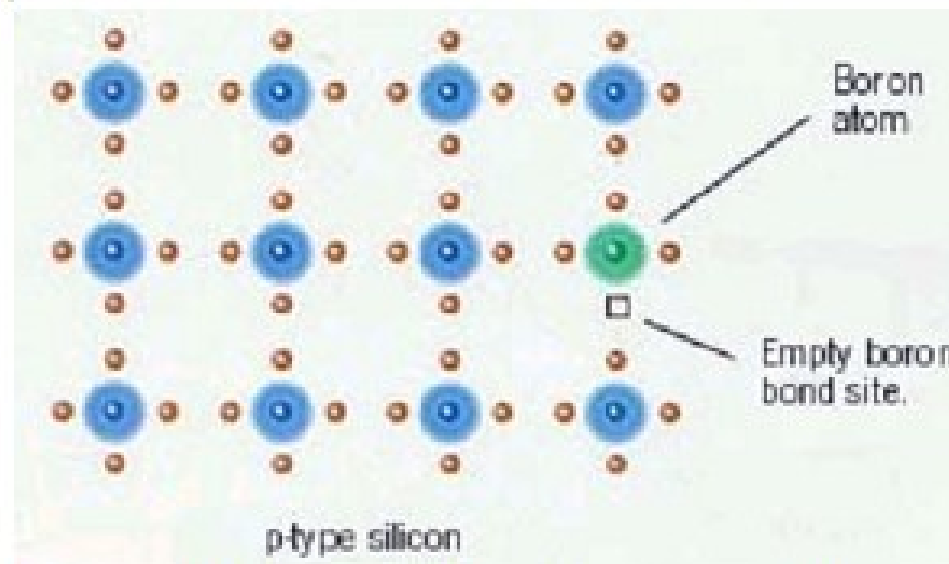
- Arsenic (As) has 5 valence electrons



- If the mobile electron leaves As, remaining As atom will have positive charge

P-type silicon

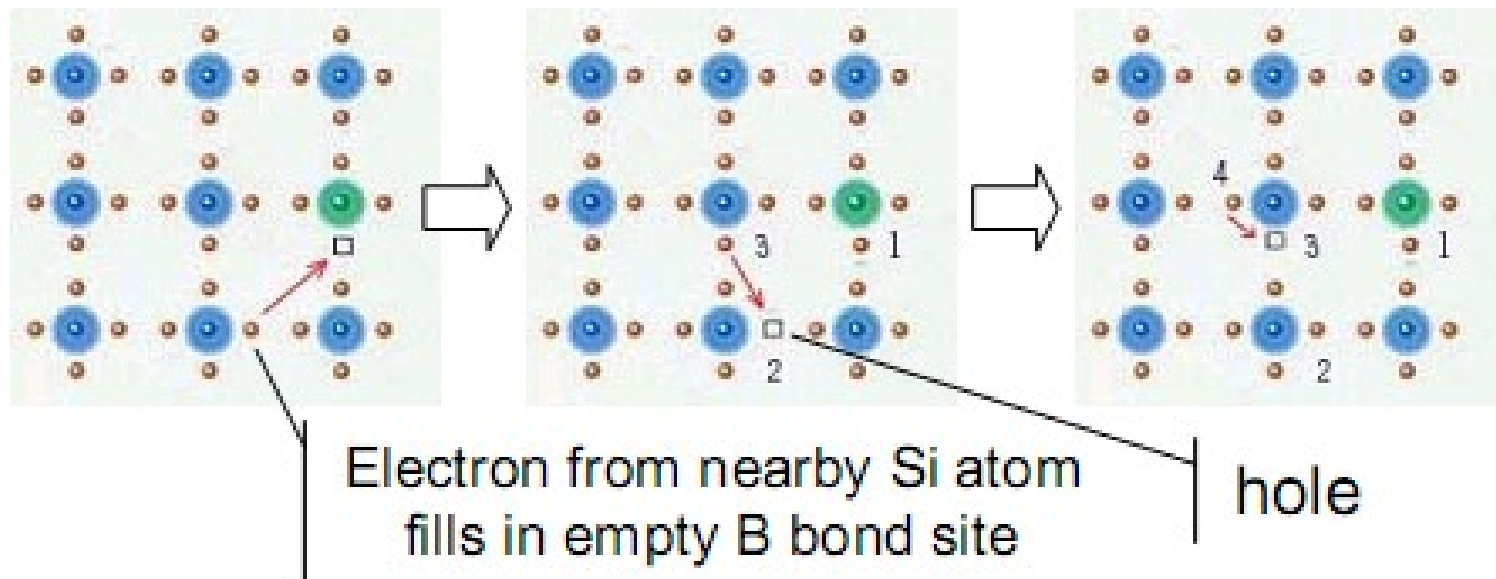
- Boron (B) has 3 valence electrons



- Electron from adjacent Si atom can fill in empty B bond site creating **hole**
- If the empty B bond site is filled, remaining B atom will have negative charge

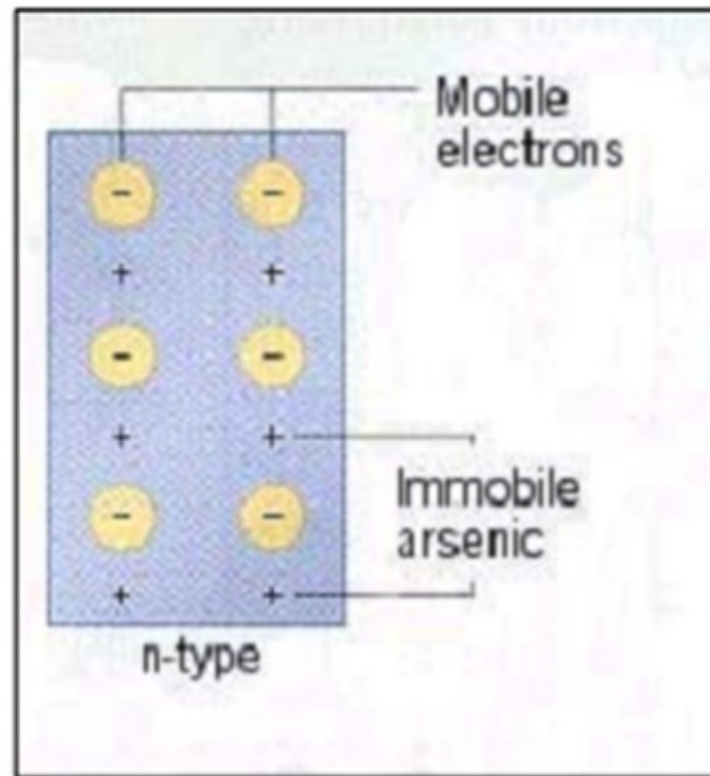
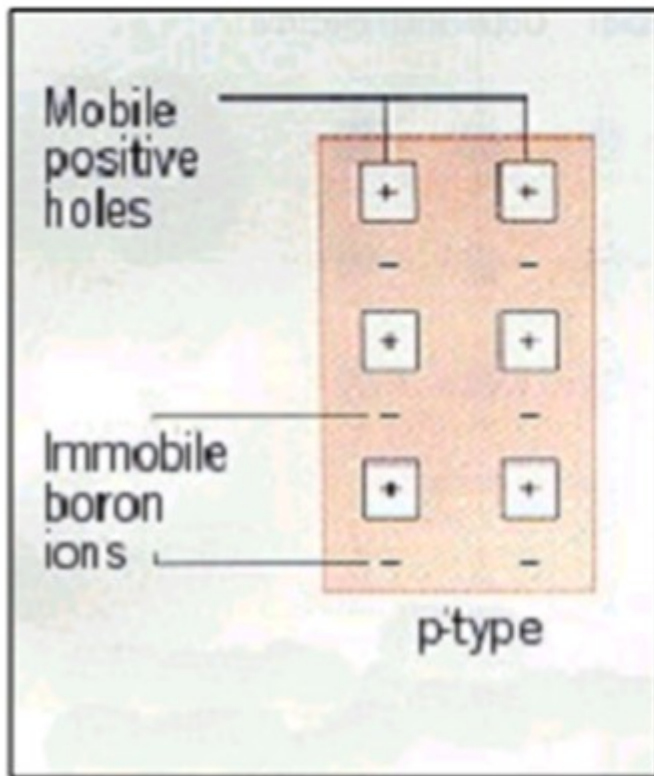
Hole movement

- Can hole “move”?
 - Electron from adjacent Si atom can fill in hole of B atom

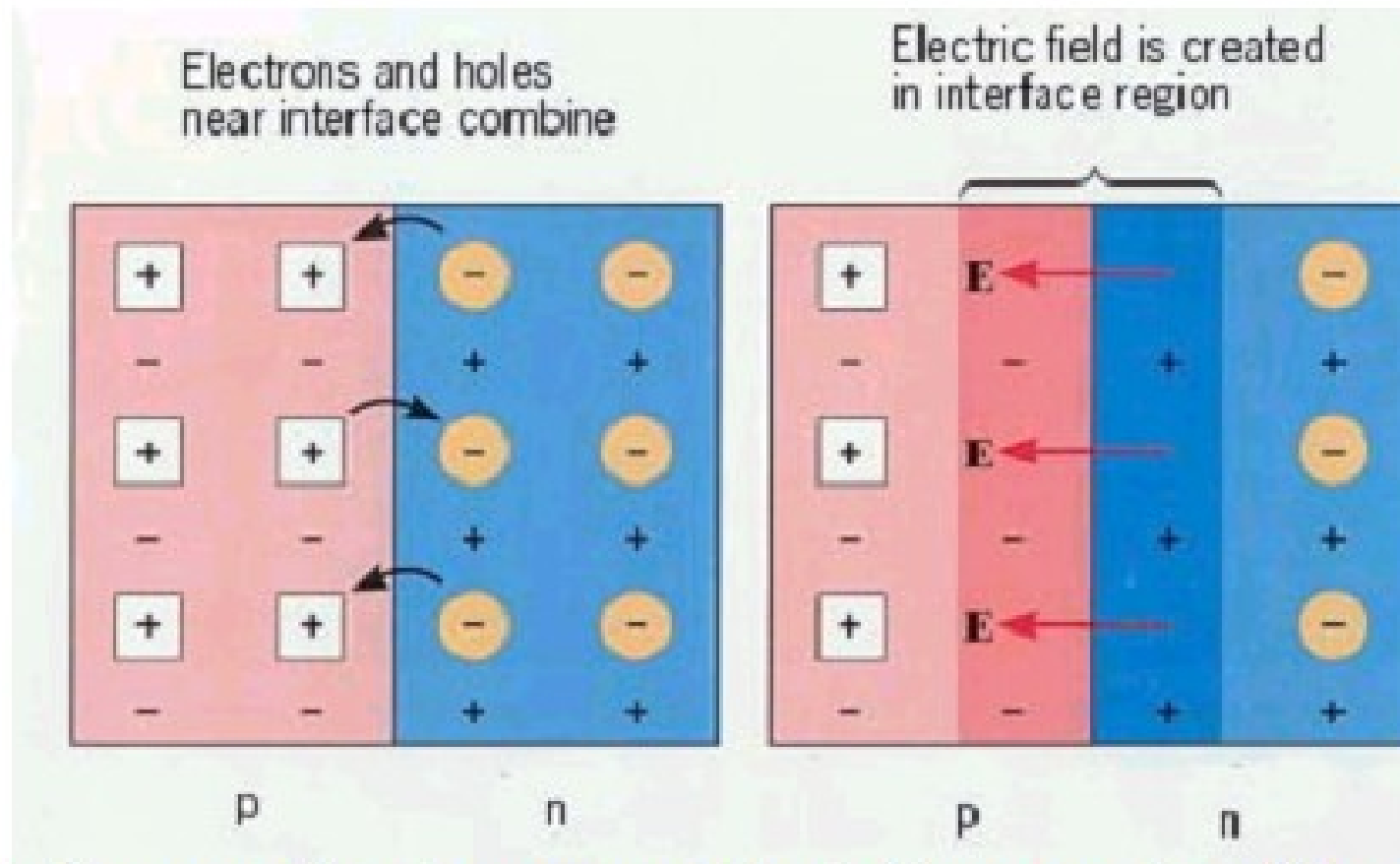


- Can think of hole as as positive charge that can move around

P- and N-type Si

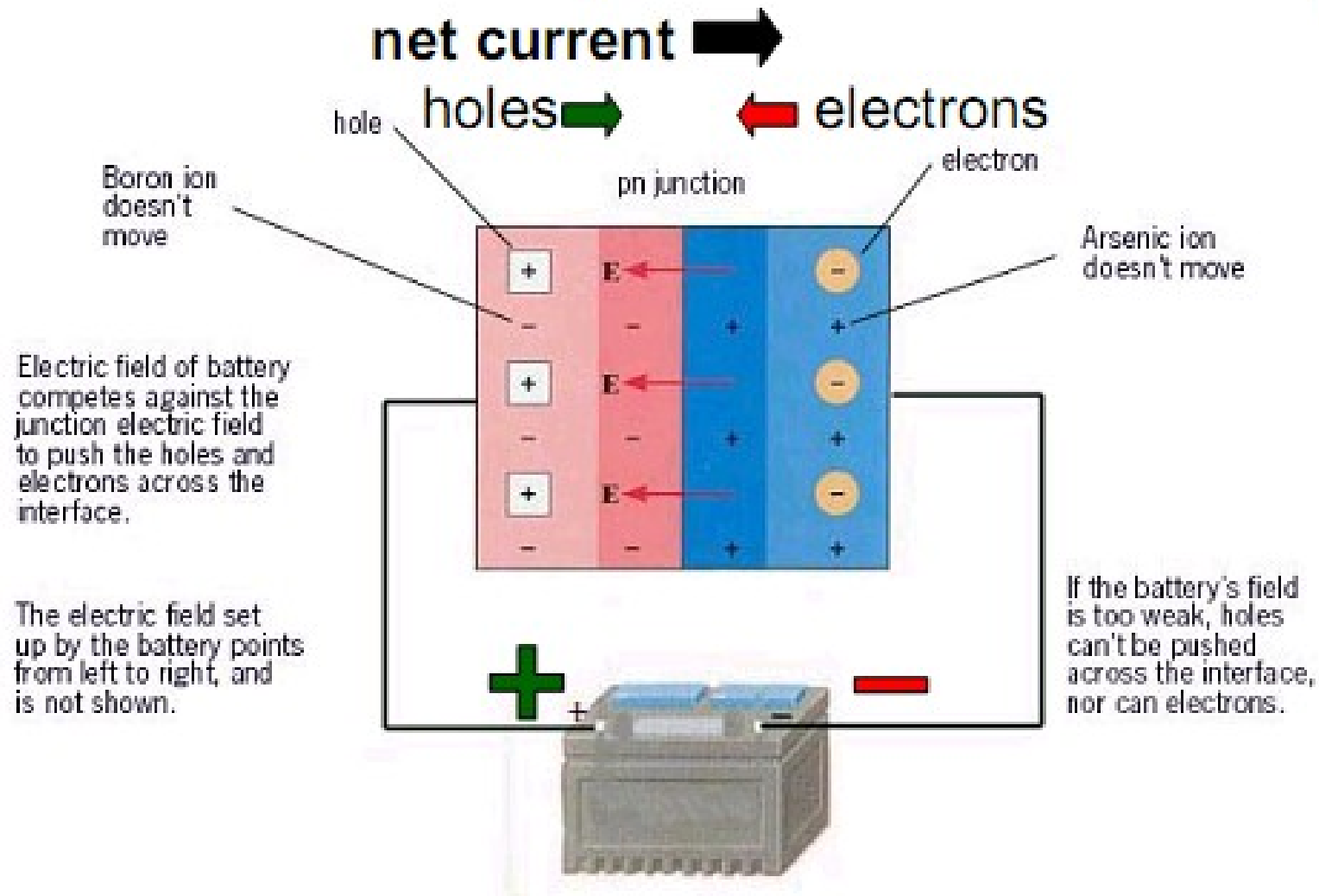


Diode in static equilibrium



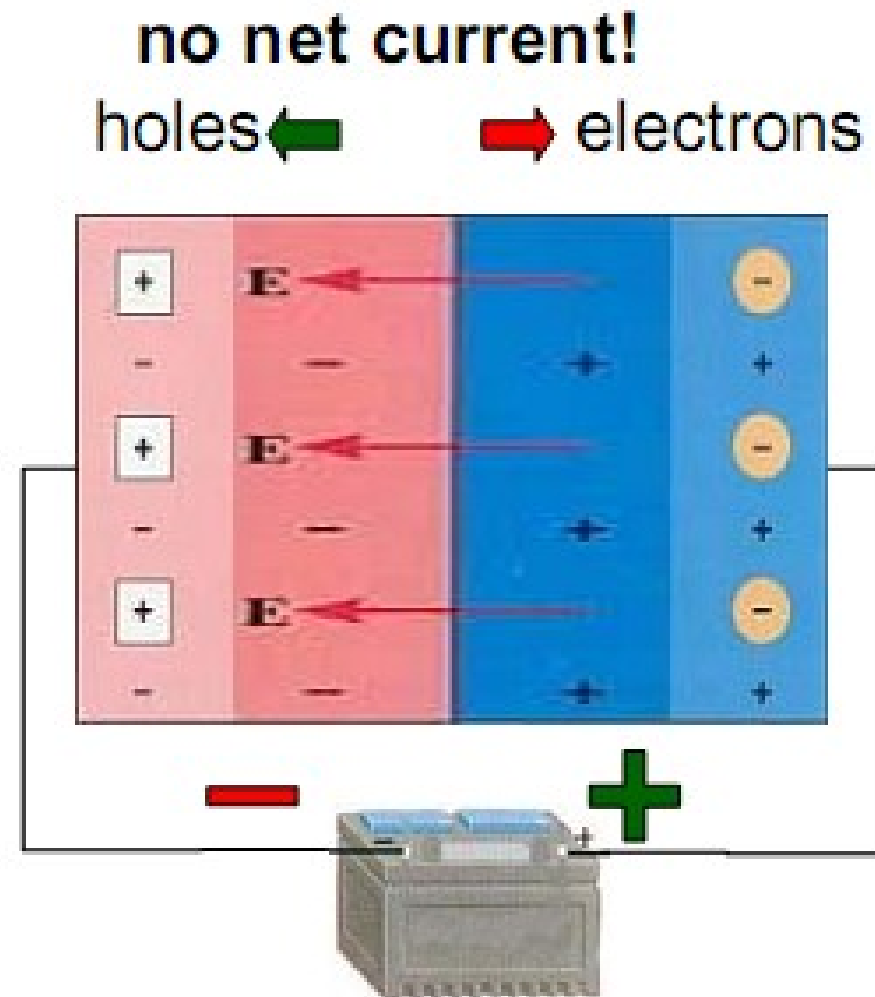
- Interface region becomes **depletion region** (devoid of mobile charges)

ON diode (forward-biased)

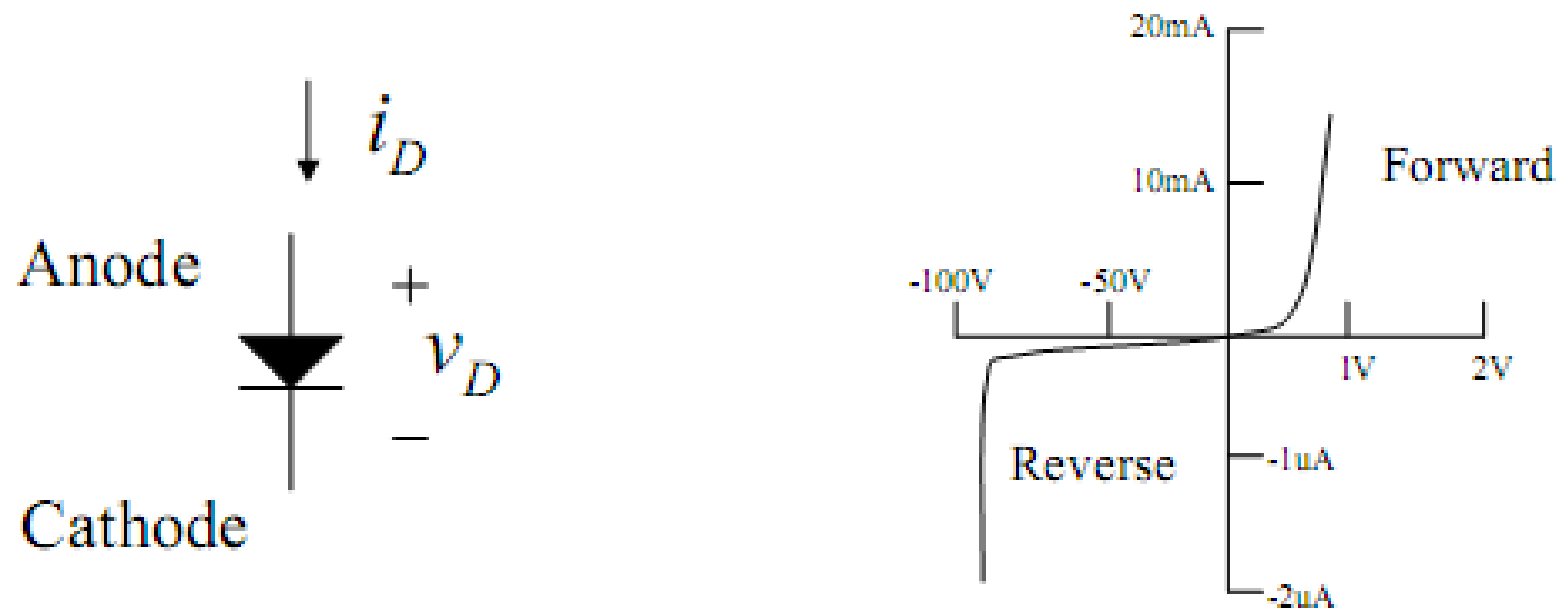


OFF diode (reverse-biased)

- Charges are attracted towards terminals and do not cross the depletion region
- Depletion region widens

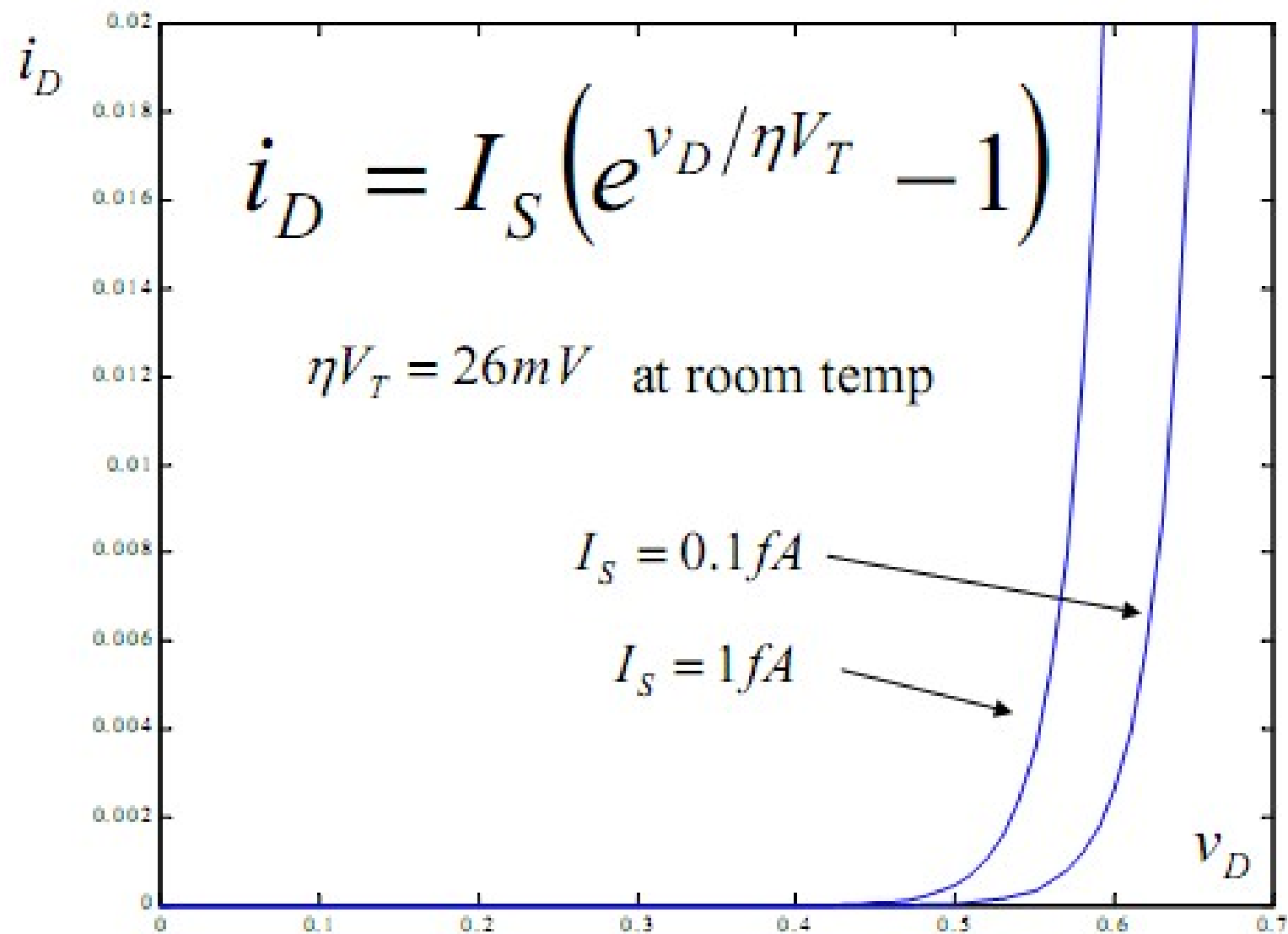


Diode terminal characteristics

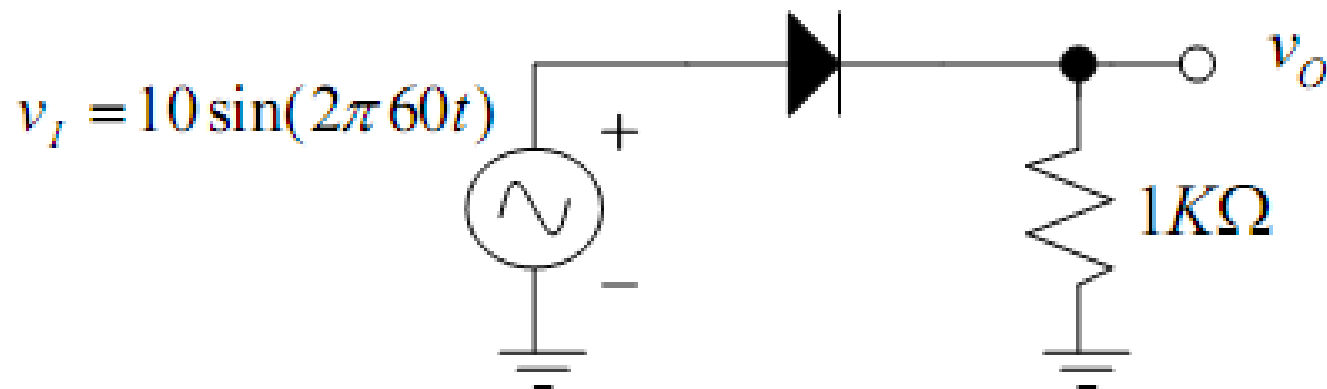


- Q: What's the I-V curve of a resistor? Voltage source? Current source? Short circuit? Open circuit?

Diode equation



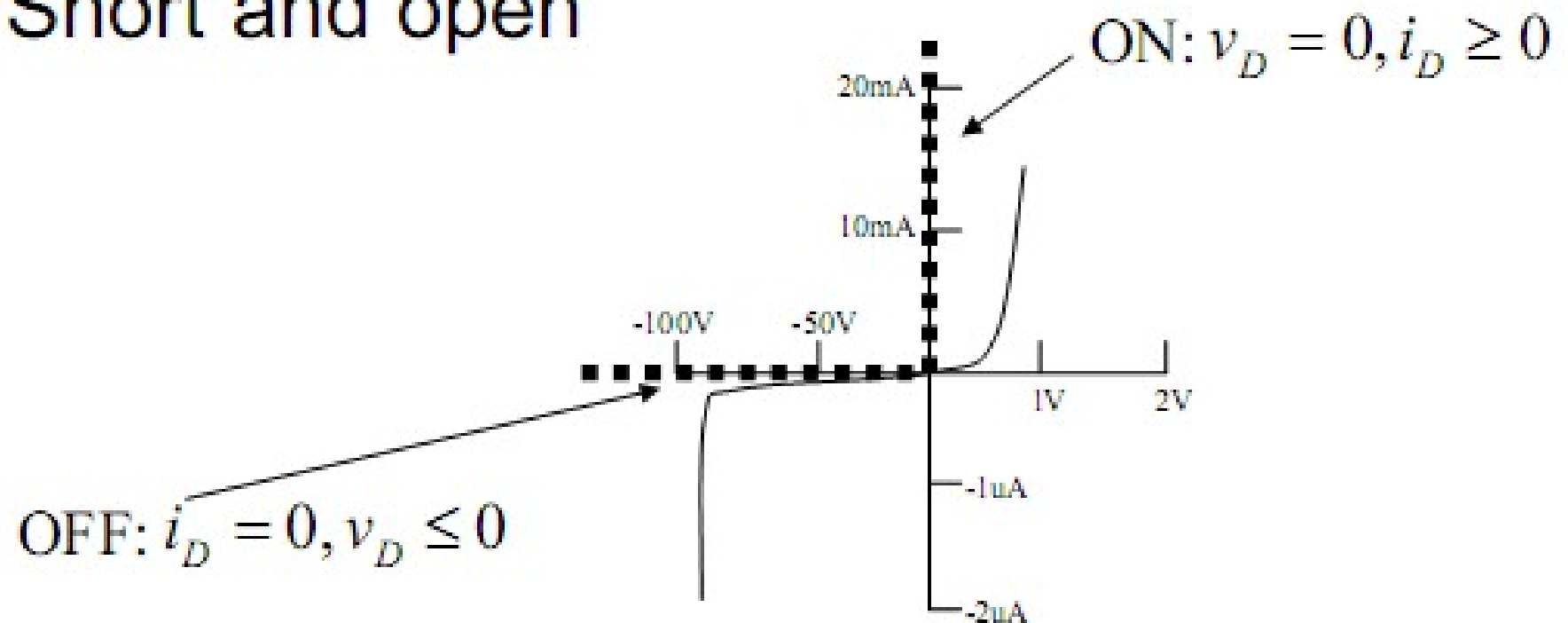
A simple diode circuit



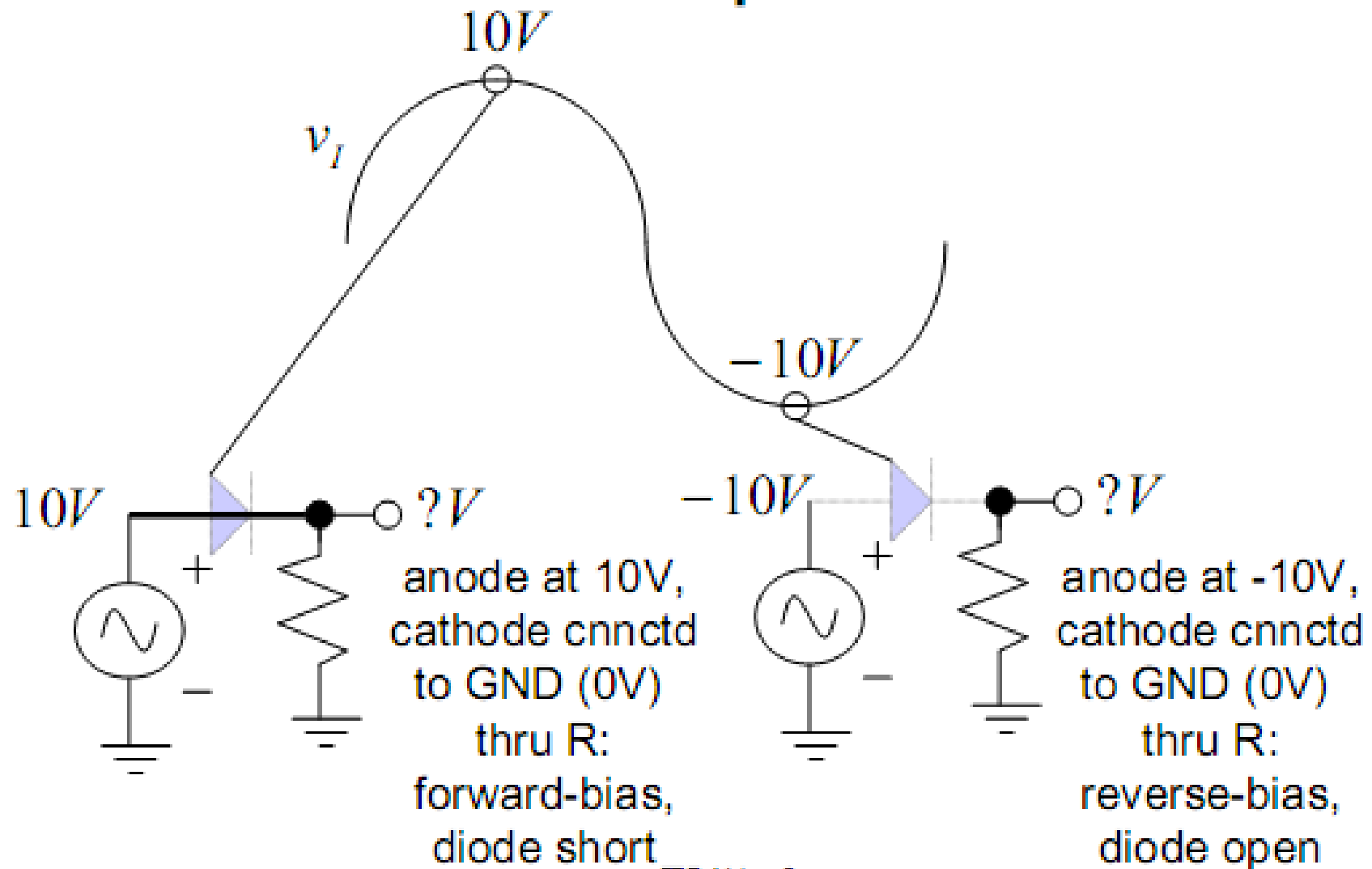
- Half wave rectifier
- Q: What's the output voltage? What's the diode voltage/current?

Diode model: 1st approx

- Short and open



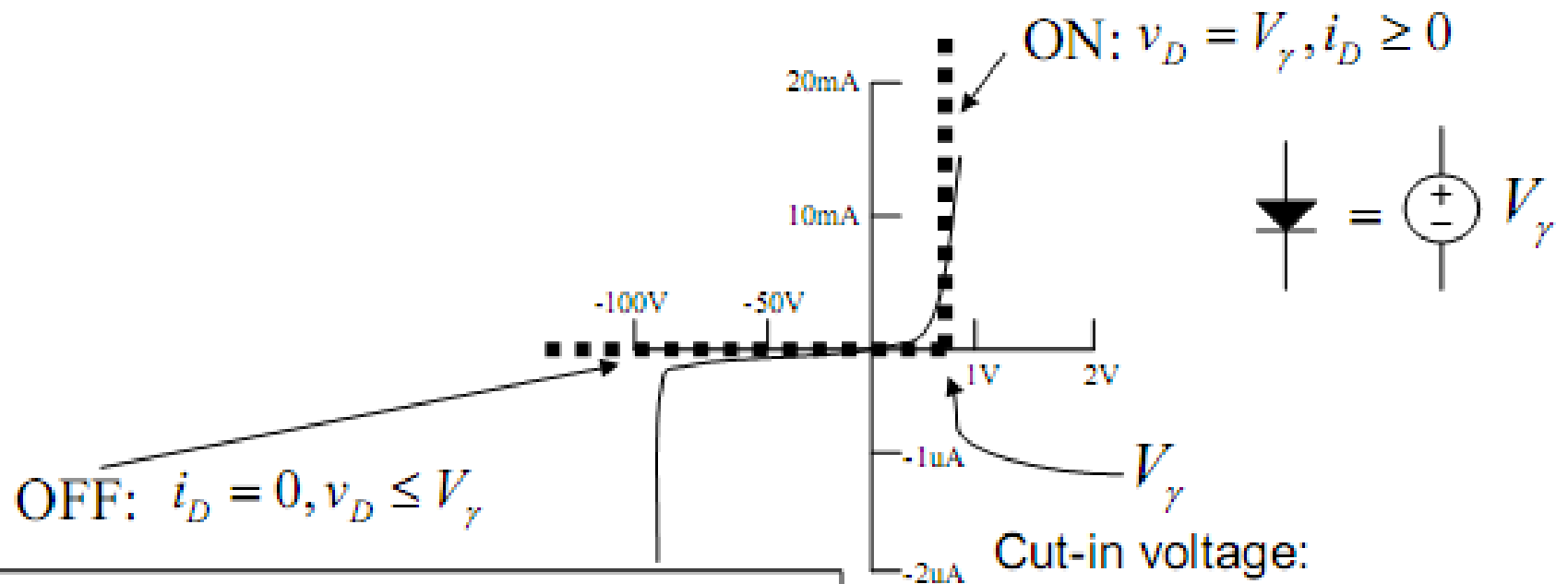
Circuit operation



Circuit analysis with diodes

- Guess the state of the diode(s)
- Replace the diode(s) with corresponding linear model(s)
- Verify if state is consistent with model
 - if assumed OFF, check if voltage neg
 - if assumed ON, check if current pos

Diode model: 2nd approx

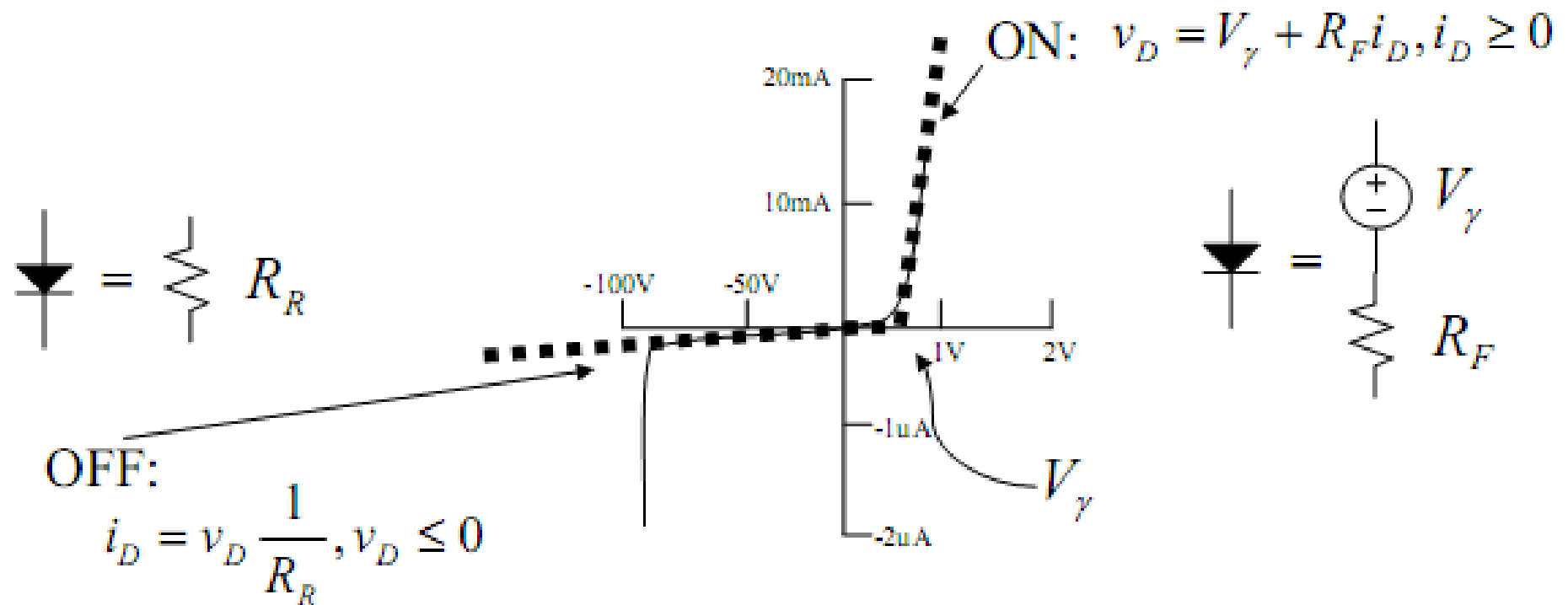


Note: Assume higher cut-in voltages for larger currents (e.g. $>1A$), smaller for lower currents (e.g. $<1mA$)

~0.7V Si diode
~0.3V Ge/Schottky diode
~2V LED

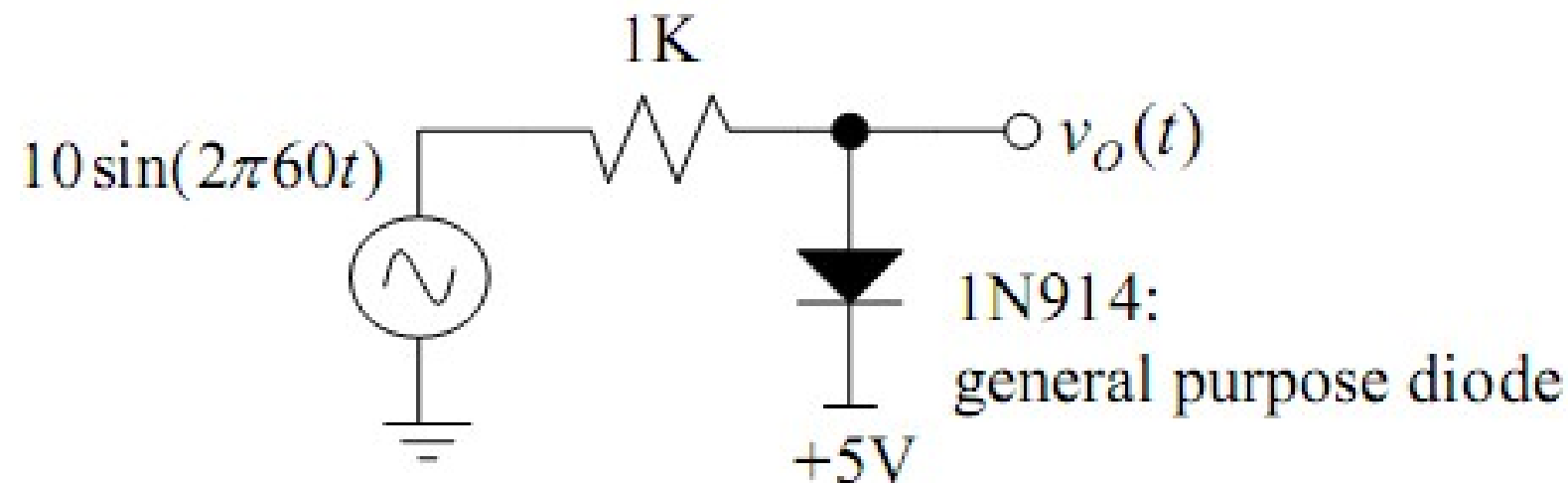
- Q: Determine the output of the simple diode circuit using 2nd approx.

Diode model: 3rd approx



- Q: Determine the output of the simple diode circuit using 3rd approx.

Voltage clipper



- Q: What's the output voltage?
- Q: Design a circuit that keeps the voltage above 3V.