Electronics for Information Technology (IELe)

2nd lab

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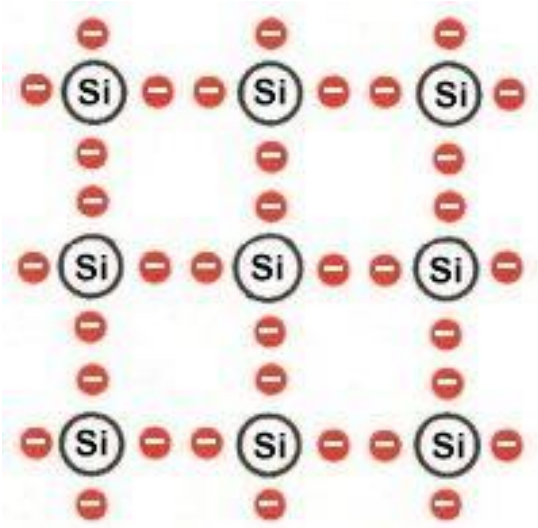
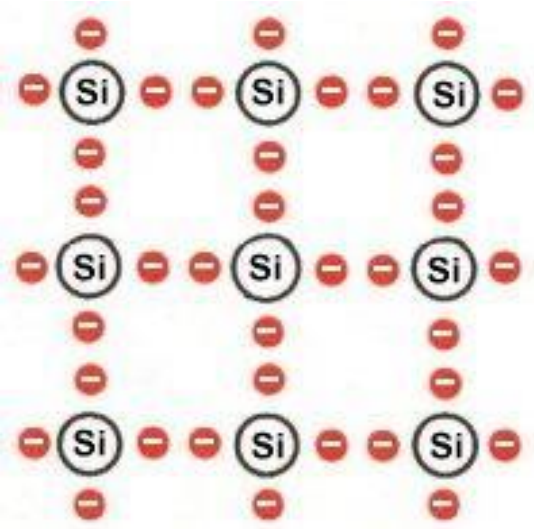
- **Diode**
  - Basics
  - **V-A characteristic**
  - **Logical addition in diode logic**

SEMICONDUCTOR DIODE

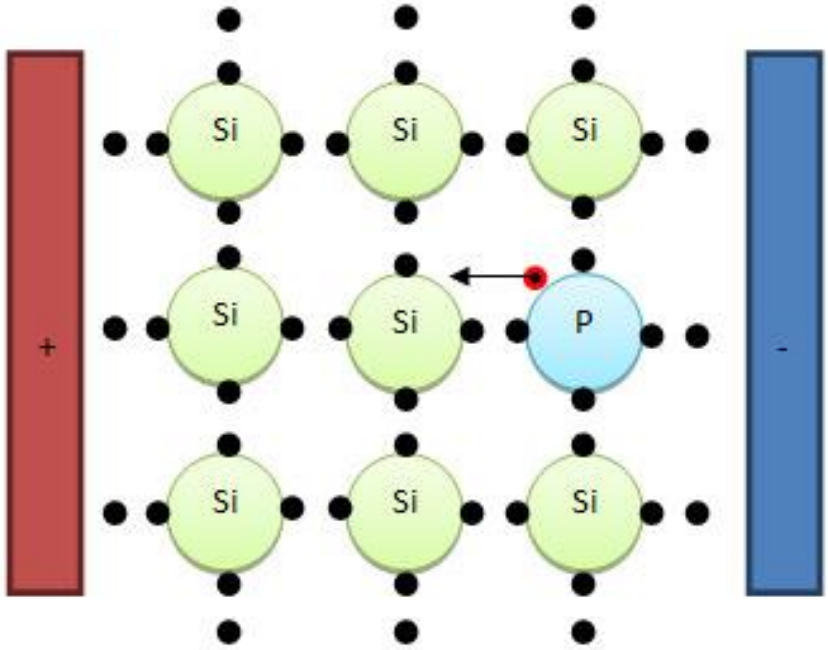
- Intrinsic and doped (extrinsic)
- **Intrinsic**
  - Silicon (Si)
  - Valence layer – 4 electrons, electrically neutral
  - By doping, neutrality is lost → 2 types of semiconductors



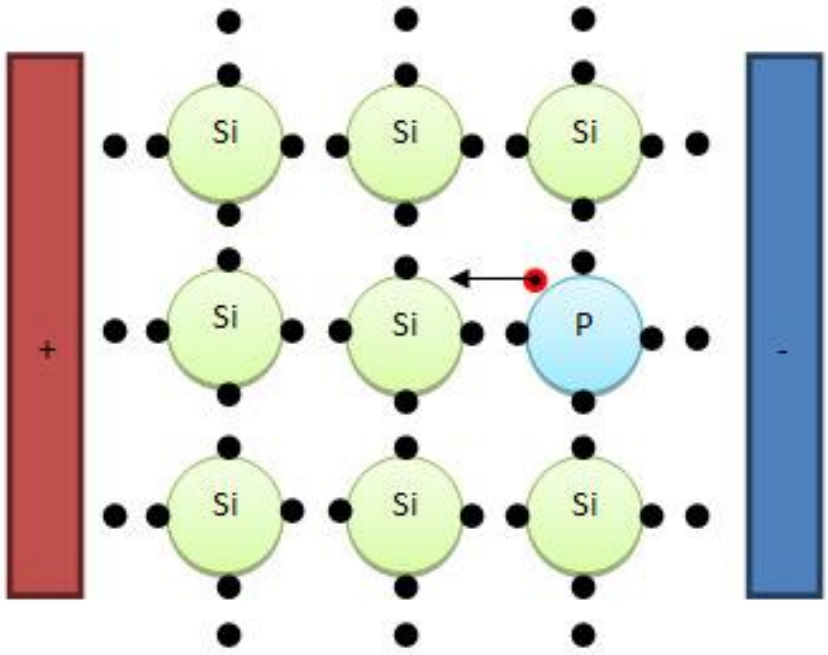
- Intrinsic and doped (extrinsic)
- **Intrinsic**
  - Silicon (Si)
  - Valence layer – 4 electrons, electrically neutral
  - By doping, neutrality is lost → 2 types of semiconductors
- **Doped (extrinsic)**
  - N type semiconductors
  - P type semiconductors



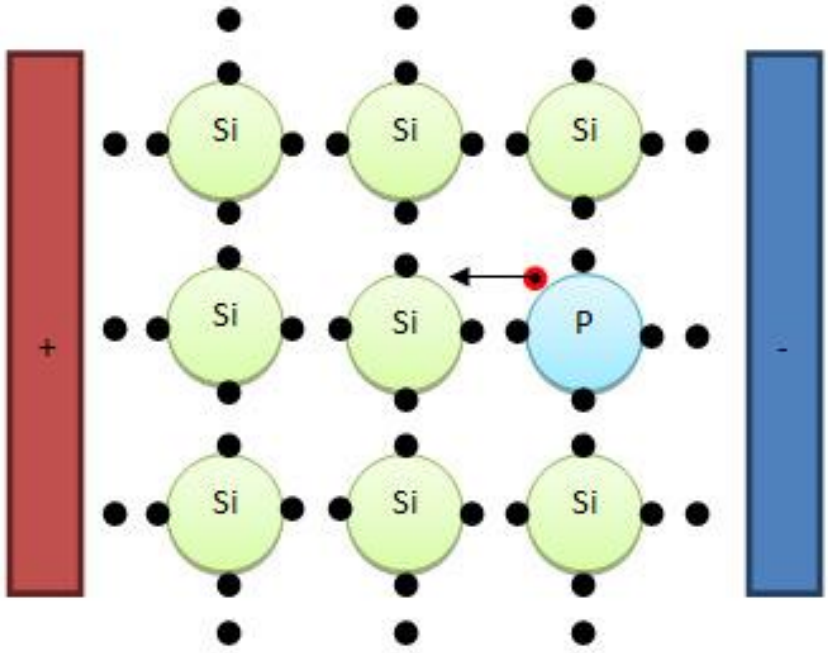
- **Type N**: electron conductivity, dopand has +1 electron
  - **Example**: phosphorus (P) – 5 electrons in the valence layer



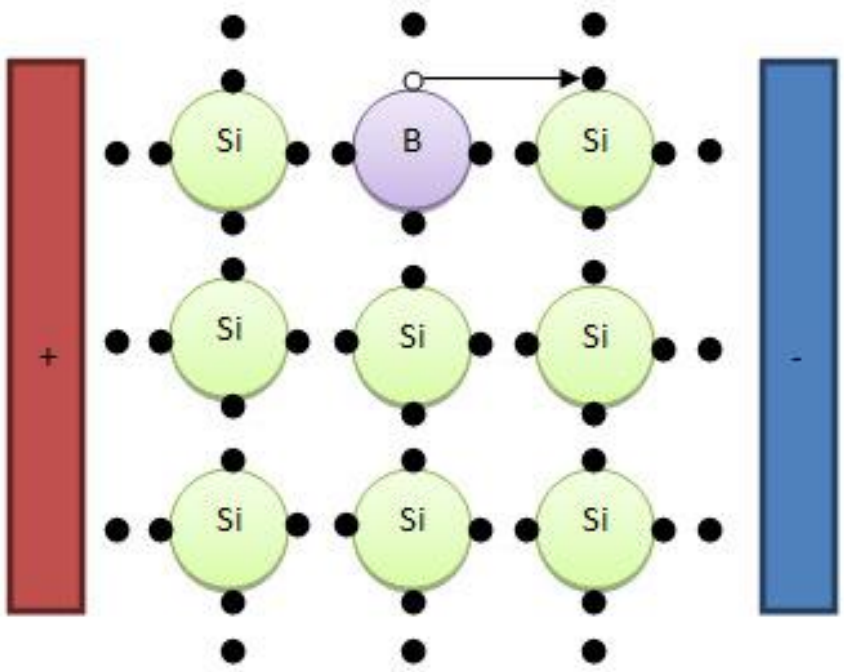
- **Type N**: electron conductivity, dopand has +1 electron
  - **Example**: phosphorus (P) – 5 electrons in the valence layer
  - Phosphorus adds 1 free electron into the crystal structure



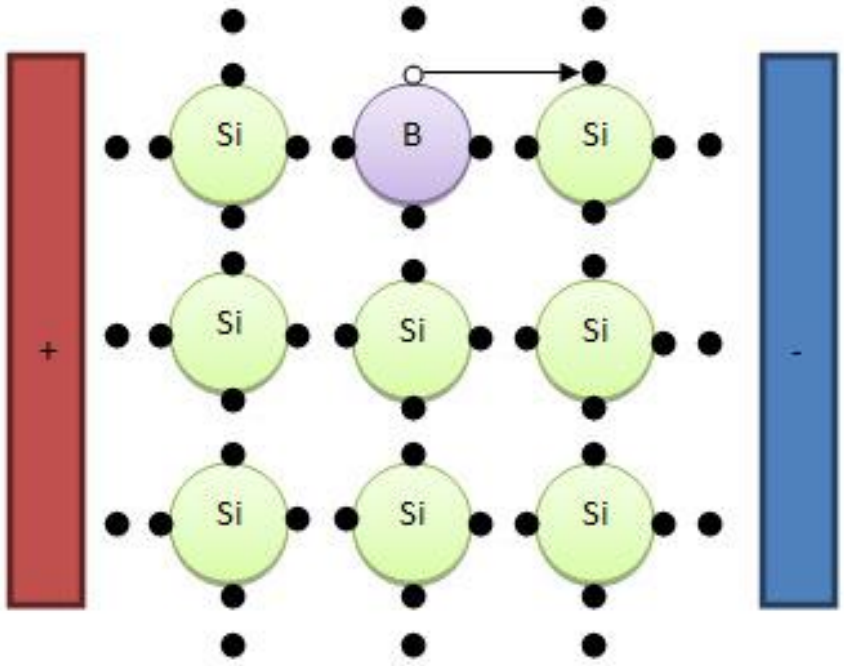
- **Type N**: electron conductivity, dopand has +1 electron
  - **Example**: phosphorus (P) – 5 electrons in the valence layer
  - Phosphorus adds 1 free electron into the crystal structure
  - Negative charge → N type semiconductor



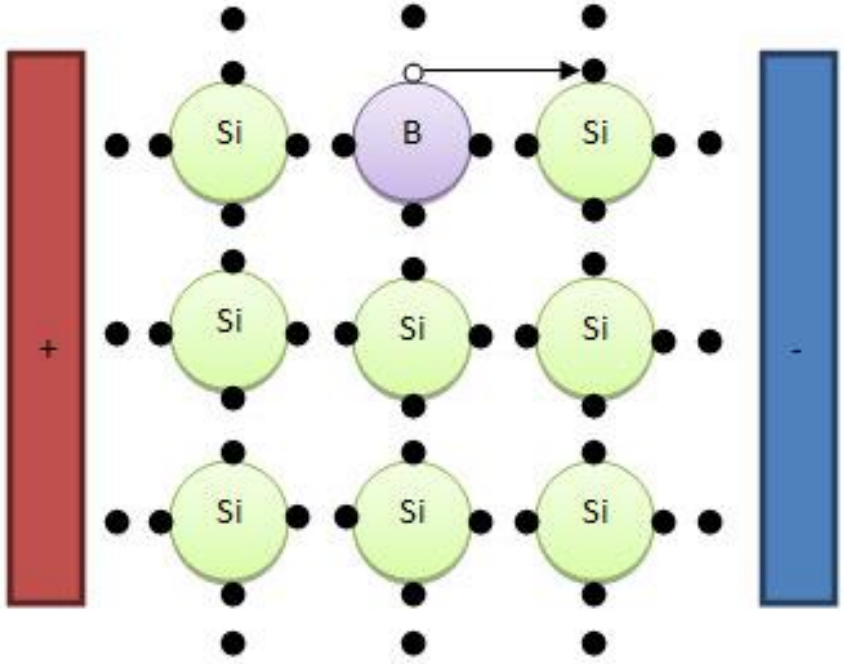
- **Type P:** electron hole conductivity, dopand has -1 electron
  - **Example**: boron (B) – 3 electrons in valence layer



- **Type P:** electron hole conductivity, dopand has -1 electron
  - **Example**: boron (B) – 3 electrons in valence layer
  - The missing electron creates a virtual positively charged particle (“hole”)

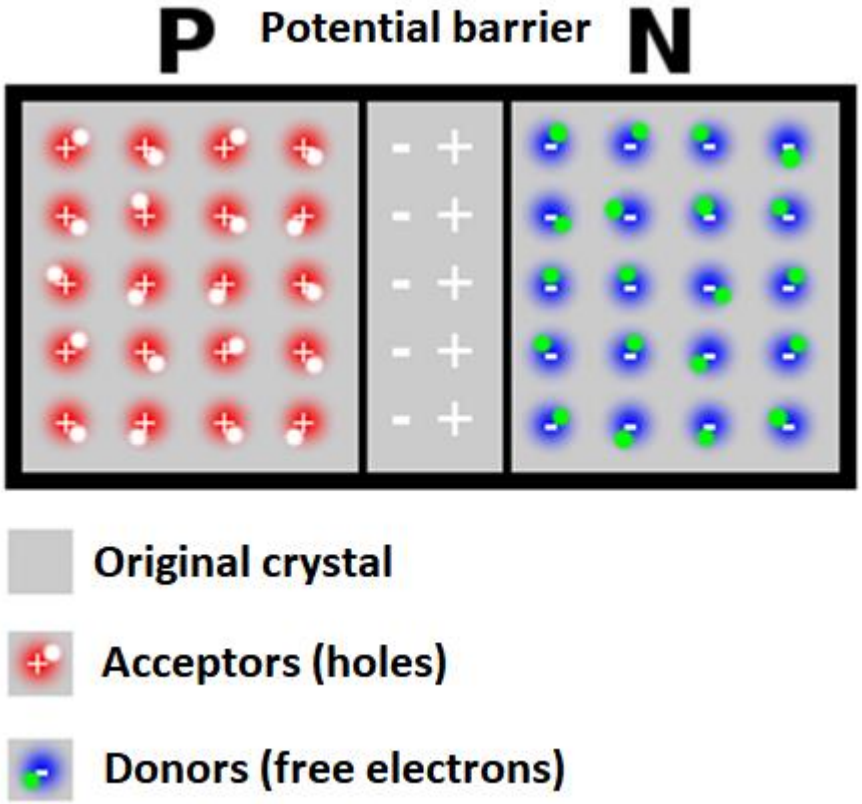


- **Type P:** electron hole conductivity, dopand has -1 electron
  - **Example**: boron (B) – 3 electrons in valence layer
  - The missing electron creates a virtual positively charged particle (“hole”)
  - Positive charge → P type semiconductor



PN junction

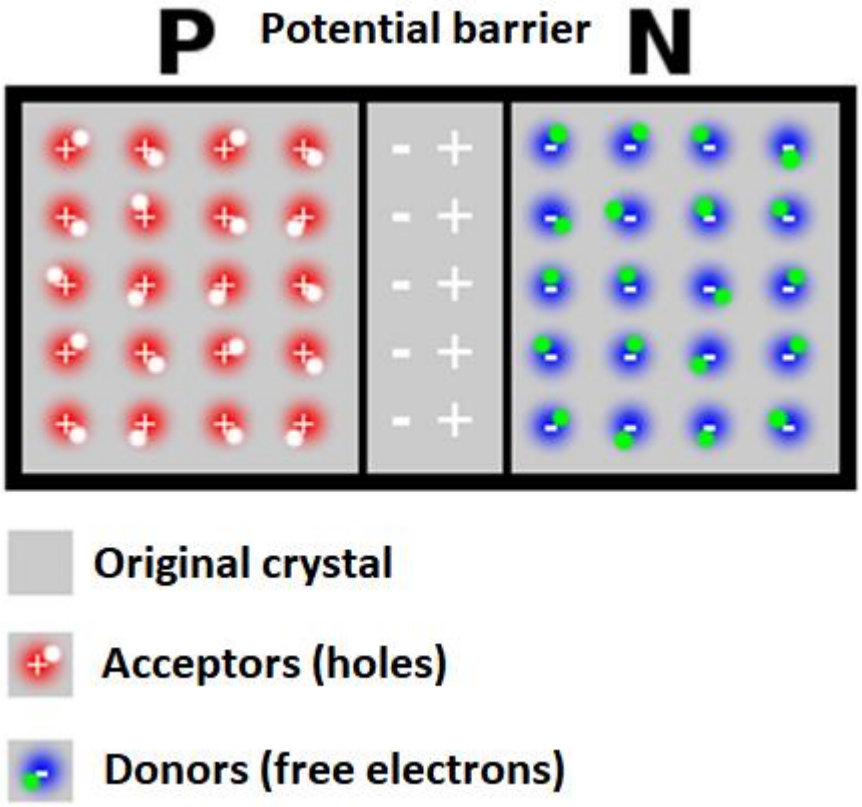
- Junction between P and N semiconductors → **potential barrier**



PN junction

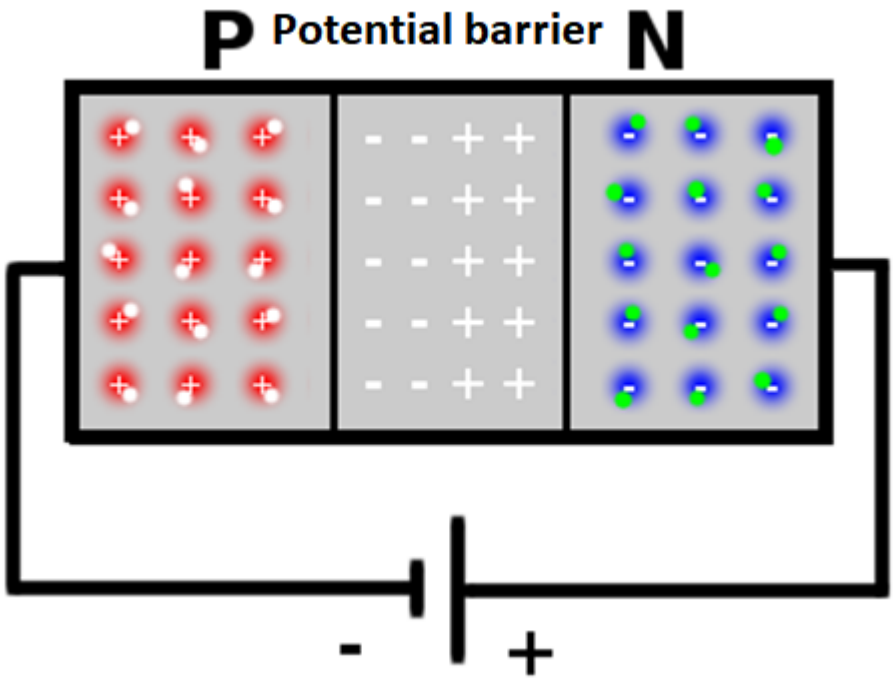
- Junction between P and N semiconductors → **potential barrier**

- Free electrons (-) are attracted to the holes (+)
  - **Recombination** – destruction of the pair (electron srandomly meets with a hole, looses part of his energy and fills the hole)



Closed PN junction

- Connected voltage source
- **Positive polarity (+)** of the voltage source **attracts electrons** (-)



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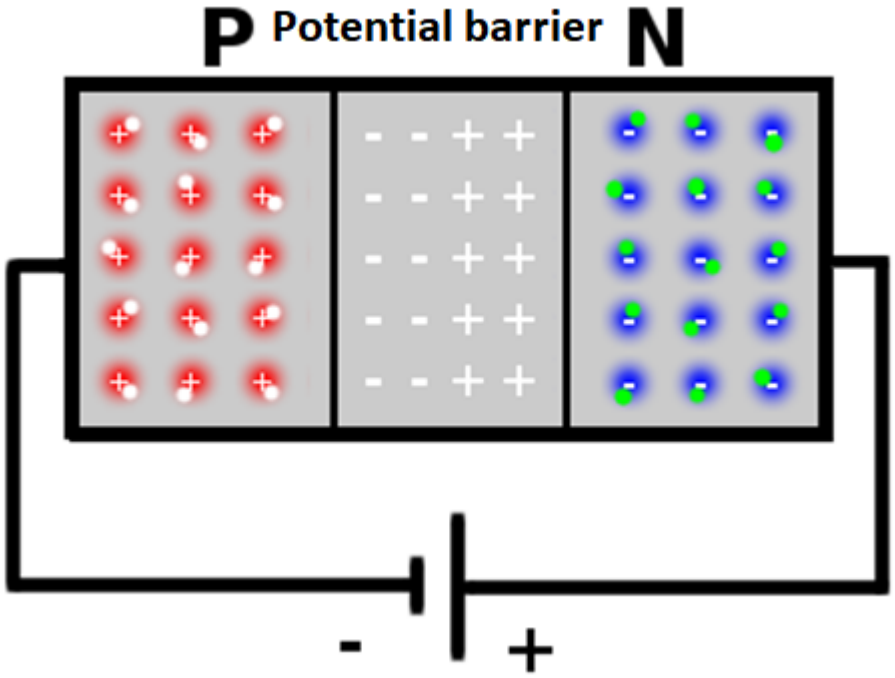

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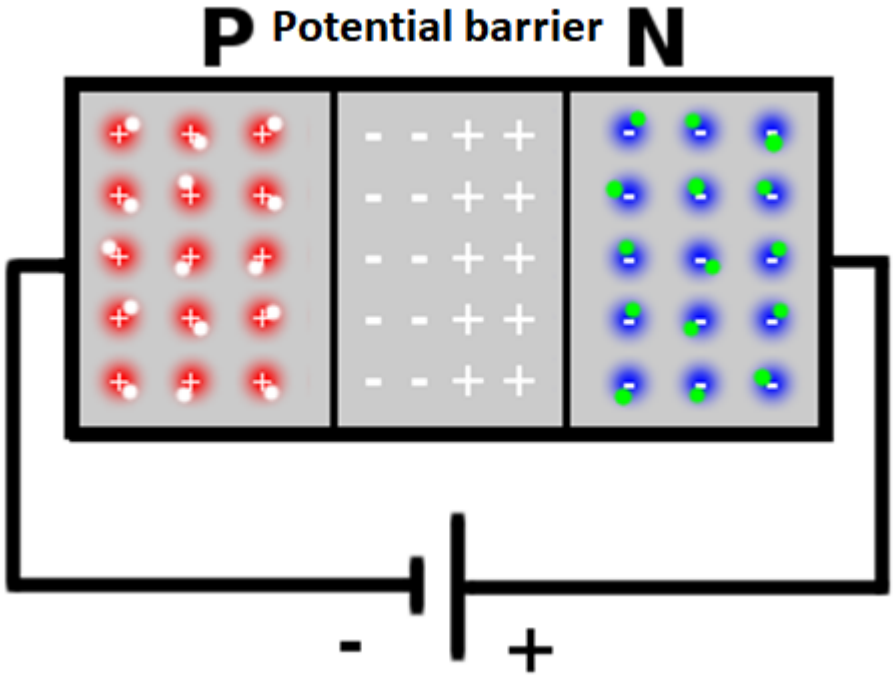
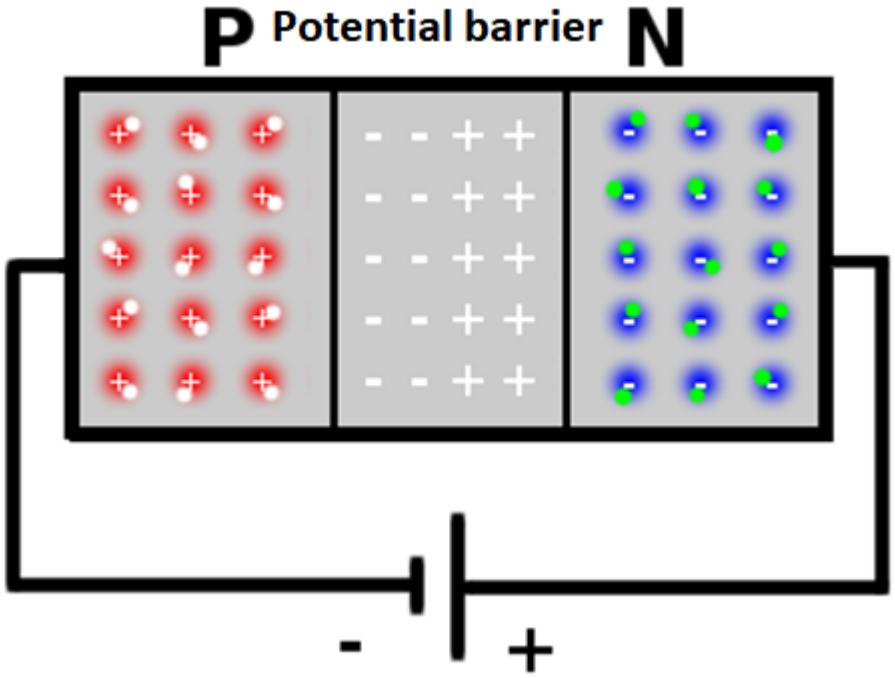


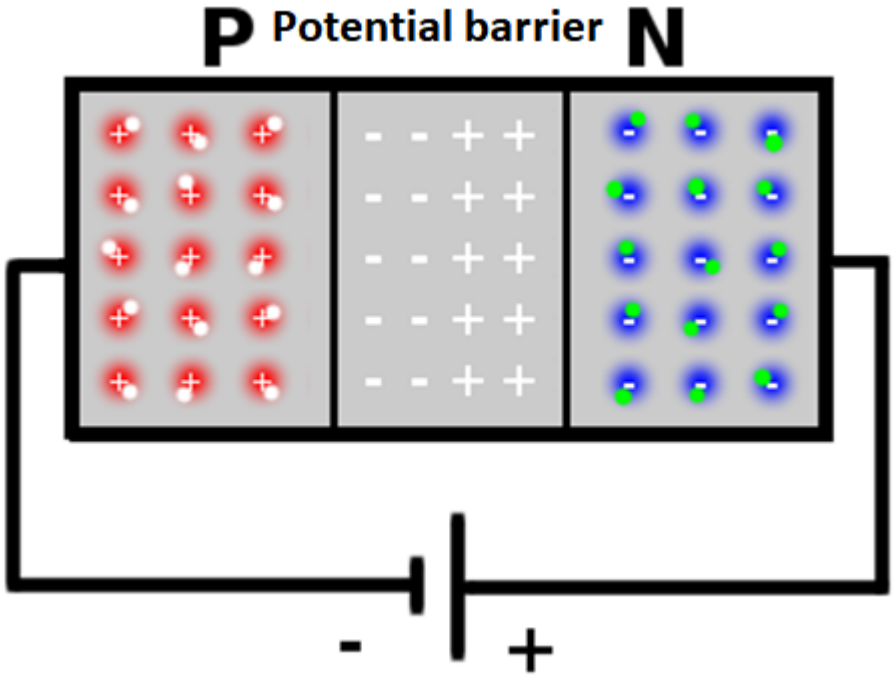
Closed PN junction

- Connected voltage source
- **Positive polarity (+)** of the voltage source **attracts electrons** (-)
- **Negative polarity (-)** of the voltage source **attracts holes** (+)



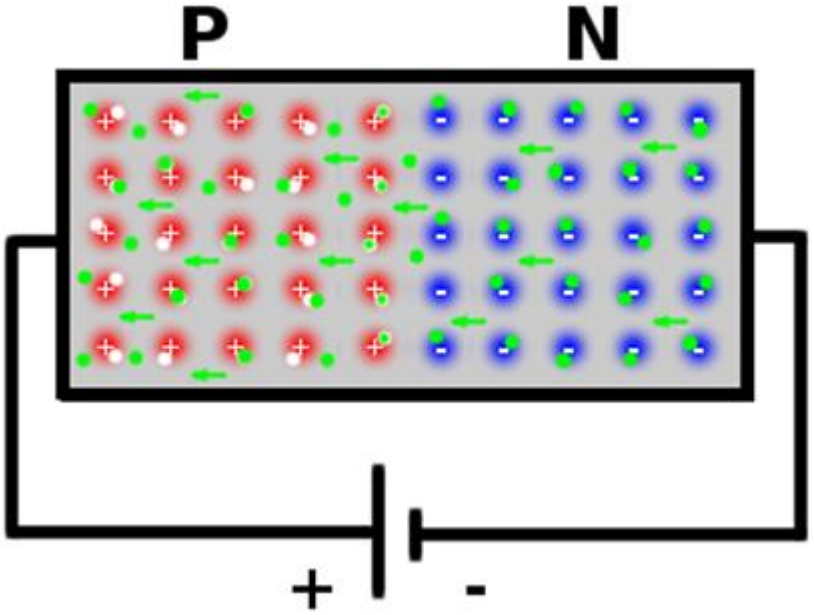
Closed PN junction

- Connected voltage source
- **Positive polarity (+)** of the voltage source **attracts electrons** (-)
- **Negative polarity (-)** of the voltage source **attracts holes** (+)
- **Larger potential barrier, almost no current**



Open PN junction

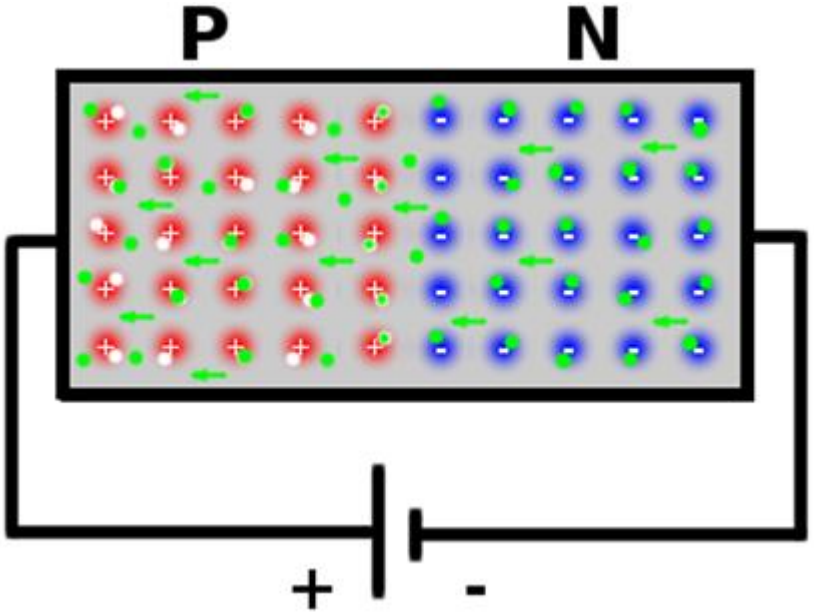
- Connected external voltage source



Recombination of holes and electrons

Open PN junction

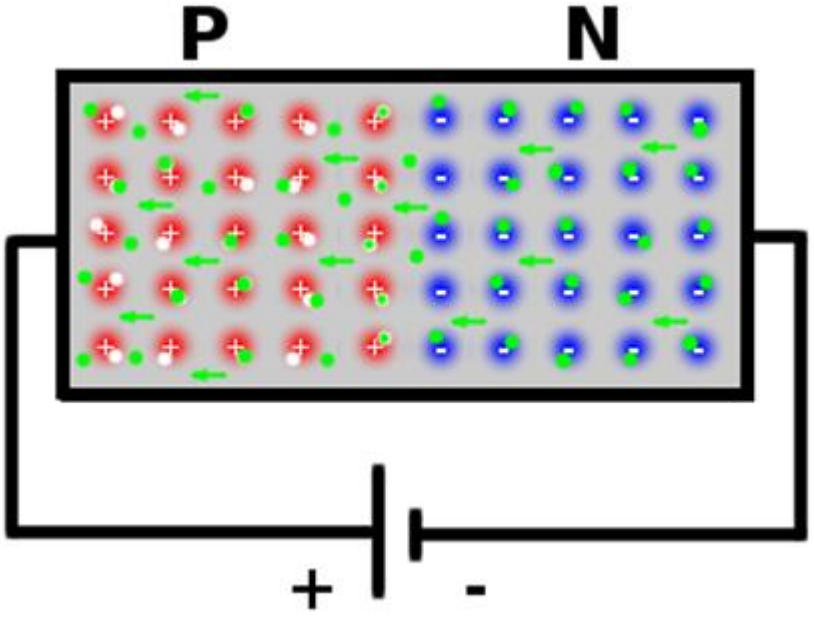
- Connected external voltage source
- **Positive polarity (+)** of the voltage source **repels the holes** (**+**)



Recombination of holes and electrons

Open PN junction

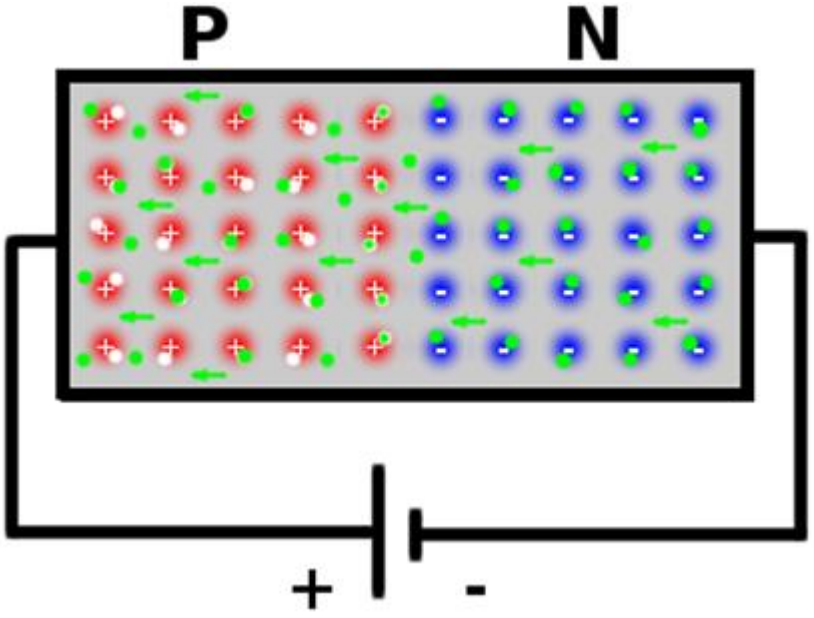
- Connected external voltage source
- **Positive polarity (+)** of the voltage source **repels the holes** (**+**)
- **Negative polarity (-)** of the voltage source **repels the electrons** (**-**)



Recombination of holes and electrons

Open PN junction

- Connected external voltage source
- **Positive polarity (+)** of the voltage source **repels the holes** (+)
- **Negative polarity (-)** of the voltage source **repels the electrons** (-)



- **Potential barrier shrinks, current flows**

Recombination of holes and electrons

- Analytical solution

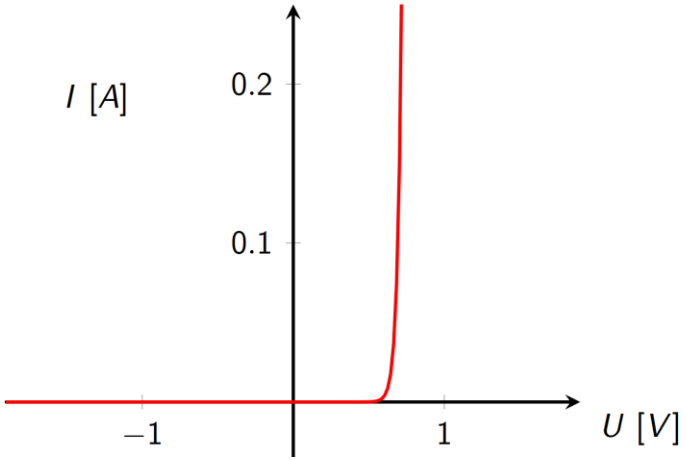
$$I = I_0(e^{\frac{eU}{kT}} - 1)$$

where:

e charge of a electron ($1.6x10^{-19}C$),

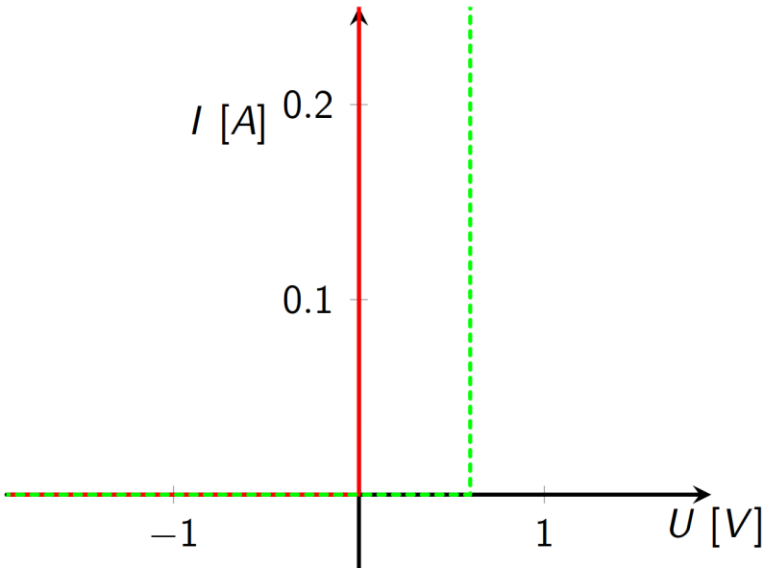
k Boltzmann constant ($1.38x10^{-23}JK^{-1}$),

T temperature of the PN junction ($300K$)

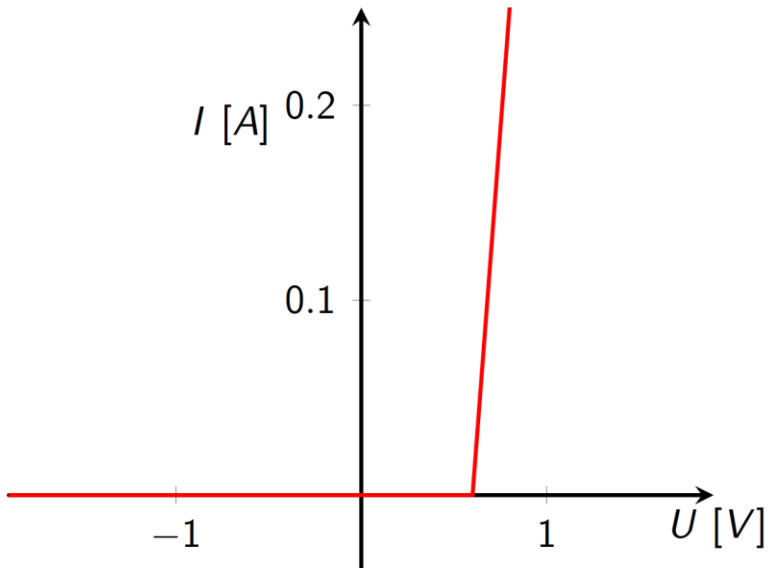


- We can approximate the analytical solution

model1: switch; model2: $0.7V$+switch



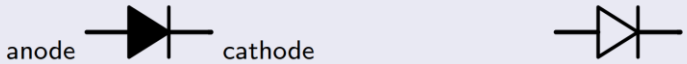
model3: $0.6V+R_d$+switch



Typical usage of the PN junction – **diode**

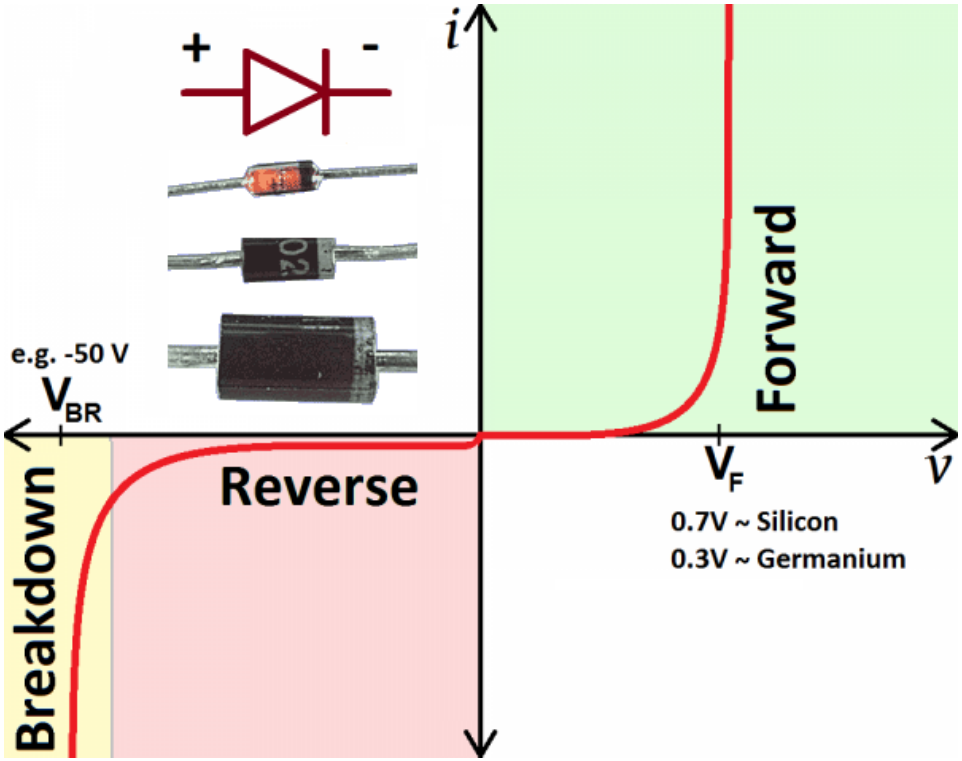
- Diode:

Symbol: (anode=P, cathode=N)



- Packaged **PN junction**
- Two electrodes
  - Positive: **anode, P**
  - Negative: **cathode, N**

- Real characteristic of the diode:

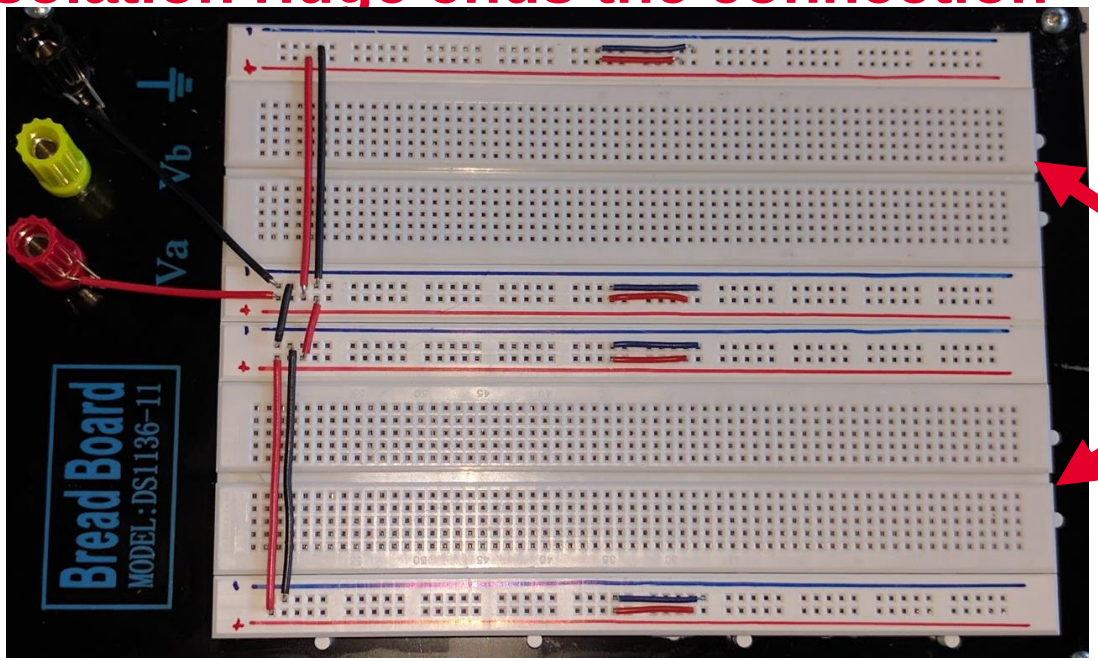


- Current flows even if the diode is connected in reverse. If the reverse current exceeds the maximum allowed value
  - Destructive breakdown of the diode and its destruction (exception – **Zener diode**)

EQUIPMENT

Solderless board

- You will connect the parts using the solderless board and measure the voltages (or currents) using the multimeter
- Solderless board **– columns are conductively connected**
  - **Isolation ridge ends the connection**



Isolation ridge

Set before the measurement

DCV
direct voltage

Ω
resistanc

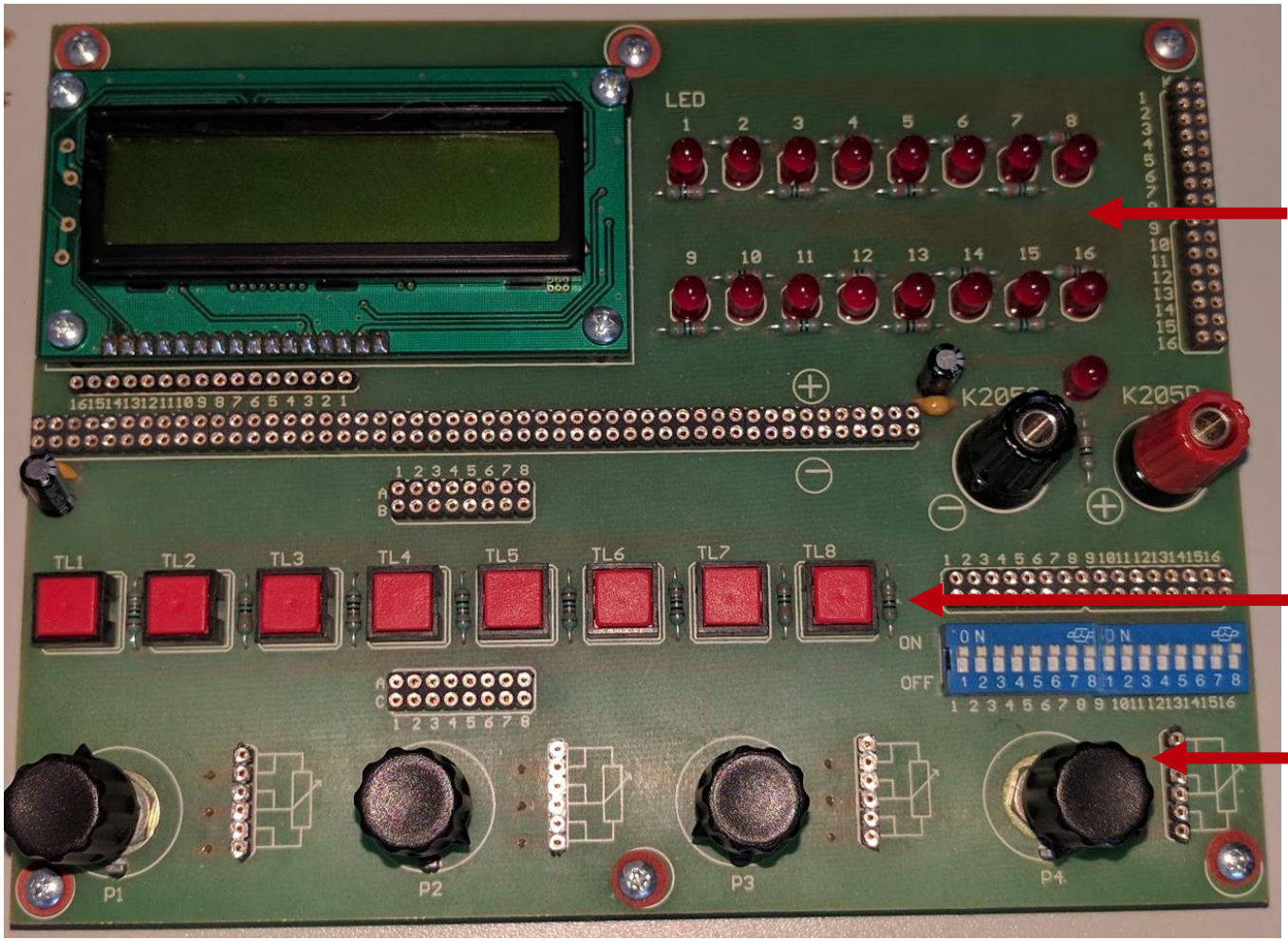
Ground
(GND)

DCA
direct current

Test wire

Measure
(U, I, R)

Green kit



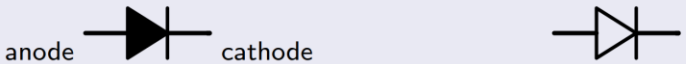
LED diodes

Switches

Variable resistors

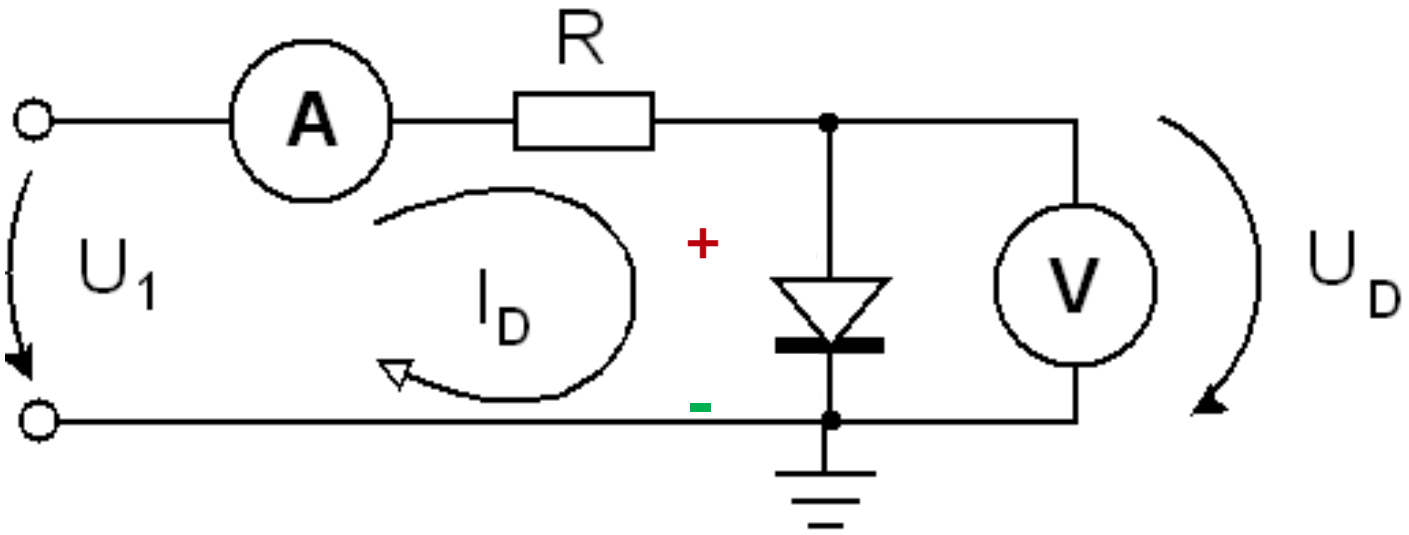
red **black**

Symbol: (anode=P, cathode=N)



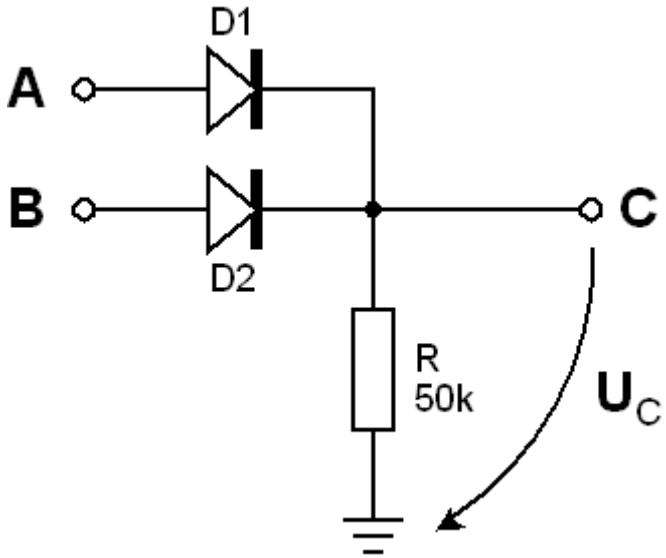
V-A CHARACTERISTIC OF DIODE

V-A characteristic



LOGICAL OPERATION IN DIODE LOGIC

- Check, if the the following circuit is realizing the logical operation **OR** (addition)



Addition (OR)

- **Voltage** in points **A, B** are inputs, **C** is the output (inputs are either 0V or 5V)
- Logical 0 in range **0 – 1 V**, logical 1 in range **3 – 5V**

Thank you for your attention!