Yrkes Akademin
Vi hjälper dig att lyckas!

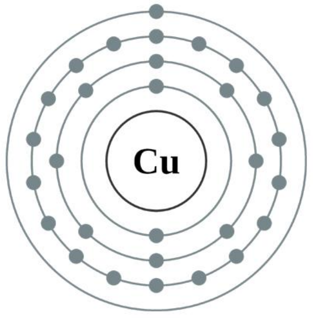
Introduction

Electrical & Electronic Circuits and Elements

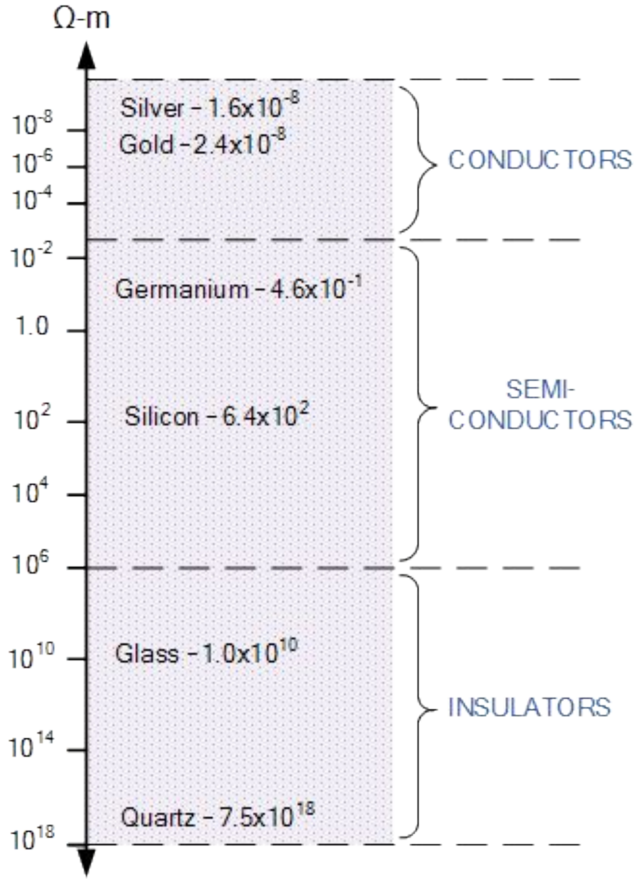
Embedded Systems & Embedded Programming

Fundamentals of Electronic Circuits (Conductors)

- ❖ Materials groups based on their resistivities
  - ➢ Conductors
  - ➢ Semiconductors
  - ➢ Insulators



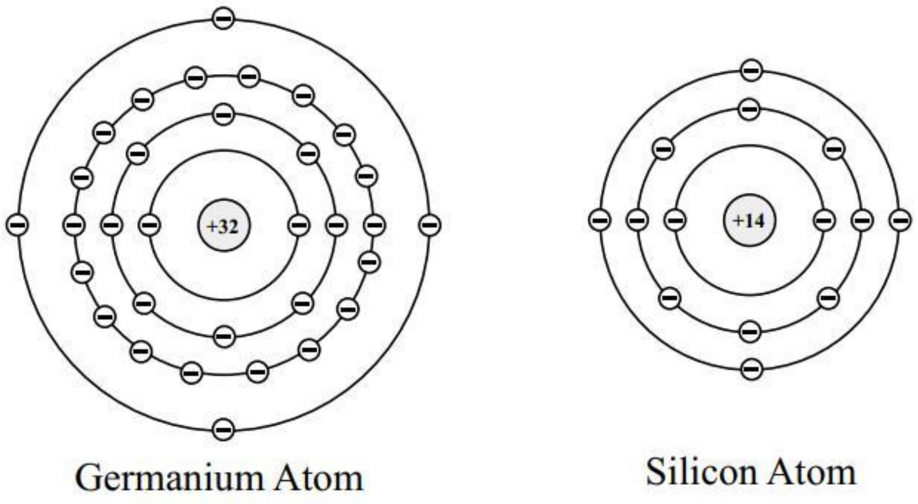
- ❖ Conductors
  - ➢ Have very low resistivities (high conductivities)
  - ➢ Electrons are the charge carriers
  - ➢ Have less than 4 electrons in their valence shell
  - ➢ Electrons in the valence shell can easily leave the atoms
  - ➢ Current can easily flow through them because of free electrons
  - ➢ By increasing temperature, their resistance increases
  - ➢ Examples: Silver, Copper and Gold. All have one valence electron.

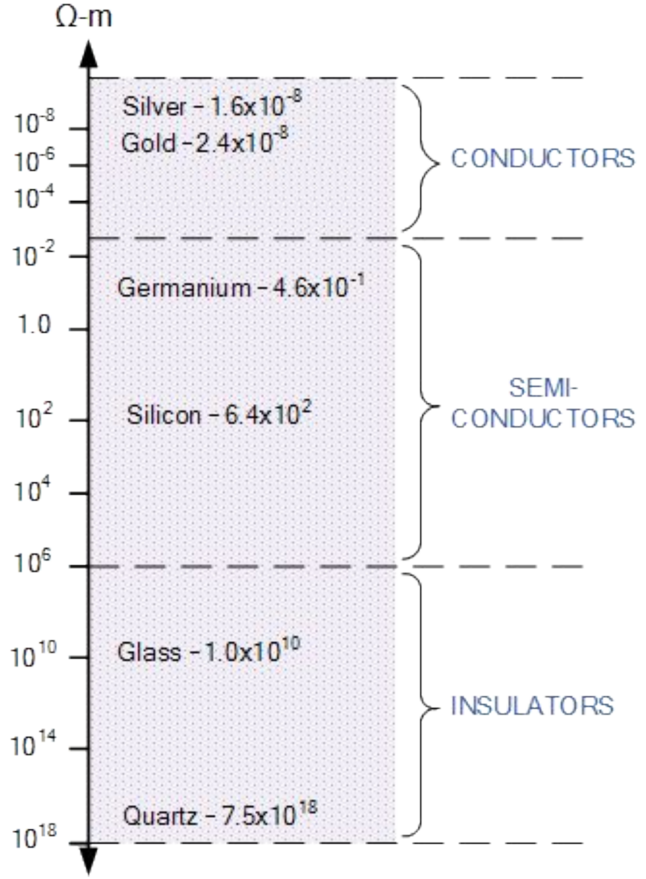


Resistivity chart of common materials

Fundamentals of Electronic Circuits (Semiconductors)

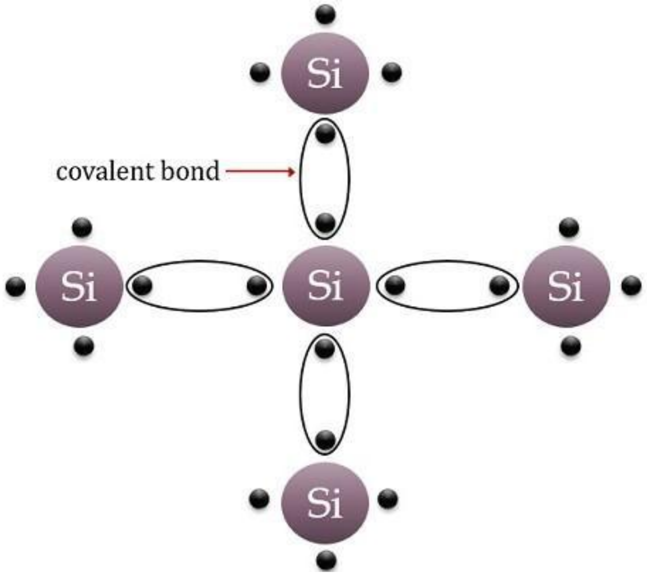
- Their electrical properties are between conductors and insulators
  - Moderate resistivity and medium conductivity
  - They are not good conductors nor good insulators
- Have 4 electrons in the valence shell
- Examples: Silicon and Germanium.





Fundamentals of Electronic Circuits (Semiconductors)

- The charge carriers are electrons and holes
- By increasing temperature, their resistance decreases
- Their atoms are closely grouped together in a crystal lattice
- Electrons in the valence shell can not easily leave the atoms
  - There are very few free electrons/holes
  - And therefore their resistance is high
- To improve and control their conductivities we can
  - Replace or add certain atoms to their pure crystal structures
    - These atoms (e.g. **Boron** or **Phosphorus**) are called **impurities**
    - The impurities produce more free electrons or holes
    - This process is called **doping**
- **Silicon** is the most used semiconductor



Crystal lattice of pure Silicon

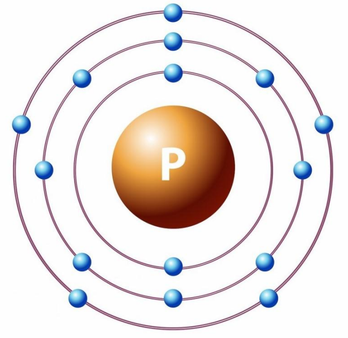
[Intrinsic Semiconductors]

[Tutorial: Doping]

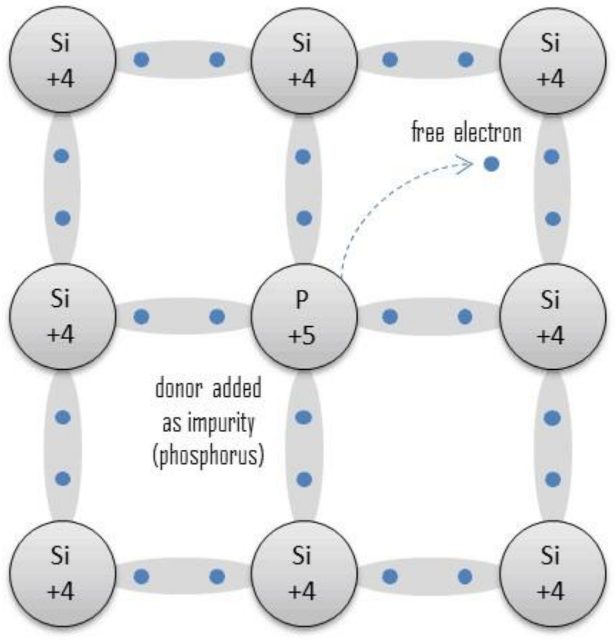
Fundamentals of Electronic Circuits (Semiconductors)

- **N-type** Semiconductors (e.g. doped with Phosphorus)
  - Phosphorus has 5 electrons in its valence shell
  - 4 of the 5 electrons make covalent bonds with its neighbouring silicon atoms
  - And leaves one “free electron” to become mobile
  - These impurities are known as **Donors**
  - The **Donors** are positively charged
- **N-type** properties
  - There are a large number of free electrons
  - Electrons are the majority carriers
  - Holes are the minority carriers
  - Electrons are negatively charged
  - Free electrons negatively charged

N-type Semiconductor



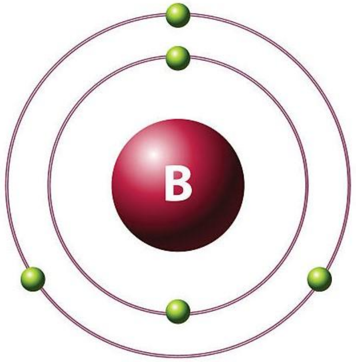
Phosphorus atom
Valence electrons: **5**
Atomic number: **15**



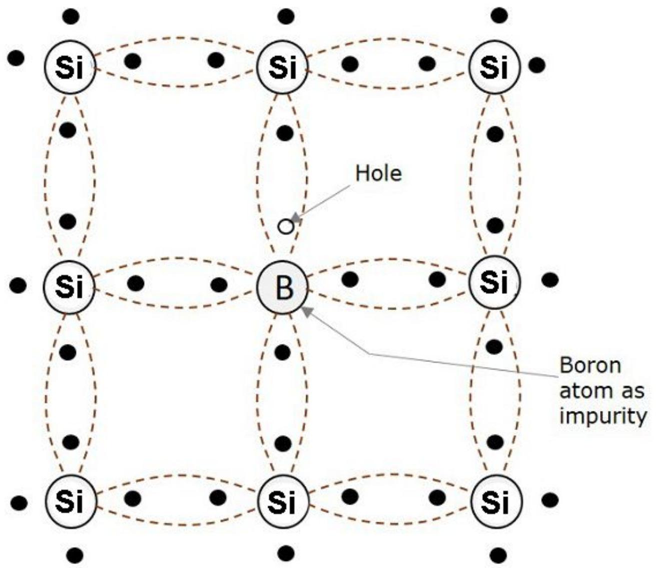
Fundamentals of Electronic Circuits (Semiconductors)

[P-type Semiconductor]

- **P-type** Semiconductors (e.g. doped with Boron)
  - Boron has 3 electrons in its valence shell
  - Valence electrons form covalent bonds with its neighbouring silicon atoms
  - Gives the semiconductor a positively charged carrier known as **hole**
  - These impurities are known as **Acceptors**
  - The **Acceptors** are negatively charged
- **P-type** properties
  - There are a large number of holes
  - Holes are the majority carriers
  - Electrons are the minority carriers
  - Holes are positively charged
  - Free electrons negatively charged

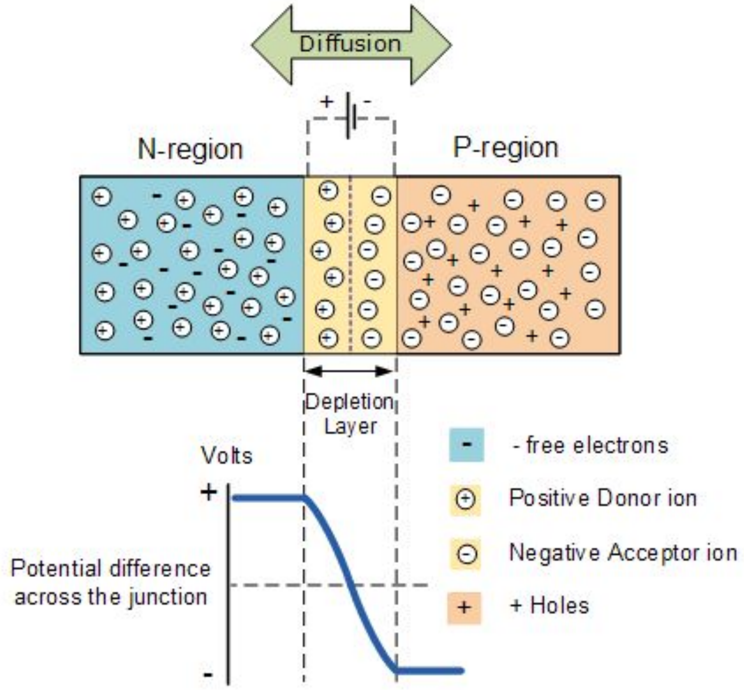


Boron atom
Valence electrons: **3**
Atomic number: **5**



Fundamentals of Electronic Circuits (PN Junction)

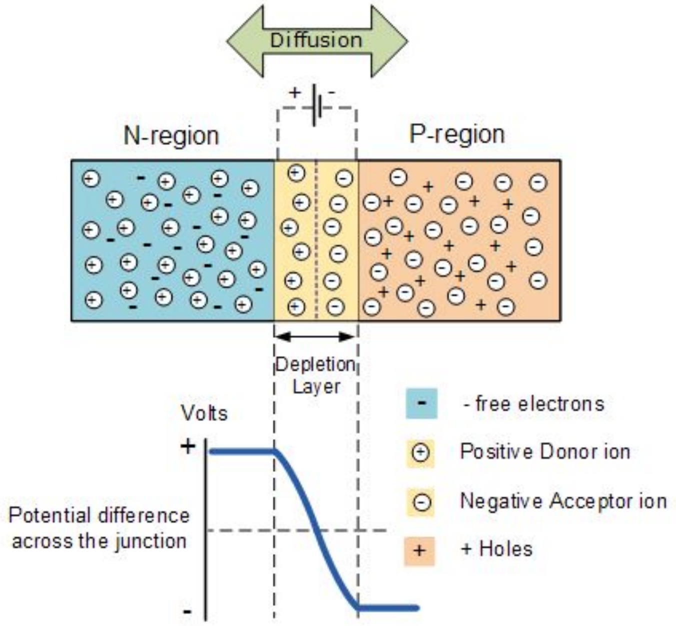
- **PN Junction** is produced by fusing (joining) a p-type and a n-type semiconductors
- Some of the **free electrons** start moving across the junction from the **N-type** to the **P-type** silicon
  - They fill some holes in the P-type material
  - They produce some negatively charged ions in the P-type
  - They leave some positively charged ions in the N-type
- The charge transfer of electrons and holes across the PN junction is known as **diffusion**
- Eventually diffusion is stopped when the electrons crossed the junction have a large enough electrical charge to repel or prevent any more charge carriers from crossing the junction



Fundamentals of Electronic Circuits (PN Junction)

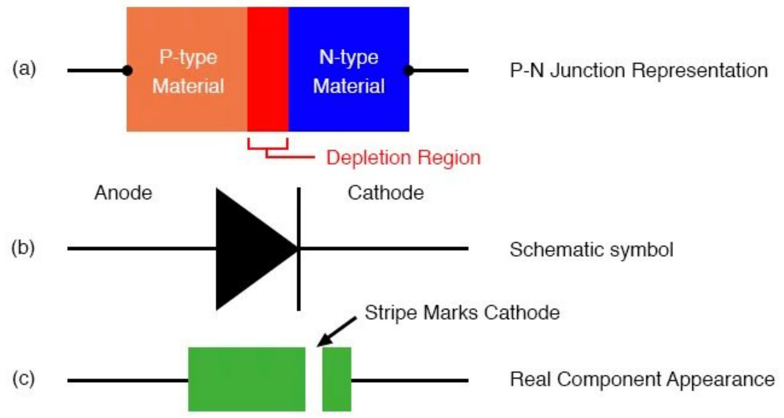
- A **potential barrier** (electric field) zone around the junction is formed
  - The donor atoms repel the holes
  - The acceptor atoms repel the electrons
- A region with no free charge carriers (electron/holes) is formed around the junction
  - This region is called **depletion region**
  - The voltage across the depletion region att 25 °C for
    - Silicon is about 0.6 – 0.7 volts
    - Germanium is about 0.3 – 0.35 volts
- The **potential barrier** will always exist
  - Even if the device is not connected to any external power source
- This device is called PN junction **Diode**

[PN Junction Theory]



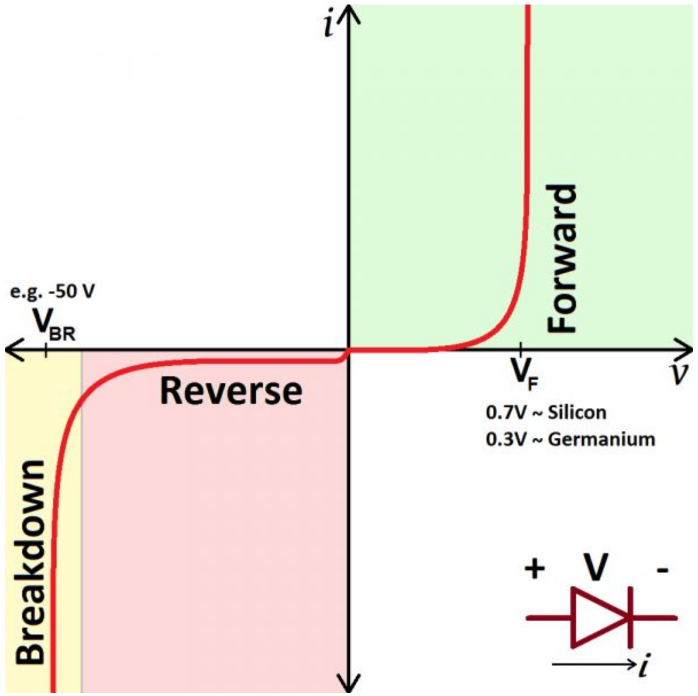
Fundamentals of Electronic Circuits (Diodes)

- **Diode** is a non-linear active element that controls the flow of current
  - Current can only flow through in one direction (**forward direction**)
  - Current trying to flow the **reverse direction** is blocked
  - If the voltage across a diode is negative (**reverse biased**), no current can flow
    - Ideally it looks like an open circuit (OFF)
  - If the positive voltage across the diode (**forward biased**) is more than the forward voltage
    - It conducts current and ideally acts like a short circuit (ON)
- Types
  - Signal Diode (Normal Diode)
  - Rectifier or power diode
  - Light-Emitting Diode (LED)
  - Schottky Diode
  - Zener Diode
  - Photodiode



Fundamentals of Electronic Circuits (Diodes, i-v)

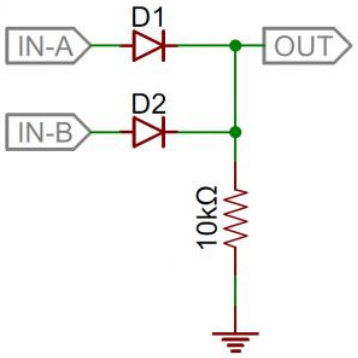
- A diode operates in one of three regions:
- **Forward bias**: The applied voltage is positive
  - Current can flow through the diode. In order to have a significant current, the voltage should be greater than the forward voltage
- **Reverse bias**: The applied voltage is negative
  - In this mode current flow is (mostly) blocked
  - A very small amount of current (few nA) is able to flow
  - Tis current **reverse saturation current**
- **Breakdown**: The applied voltage is very large and negative
  - Lots of current will flow in the reverse direction, from cathode to anode
  - This large negative voltage is called the **breakdown voltage**
  - The breakdown voltage normally is around -50V to -100V, or more



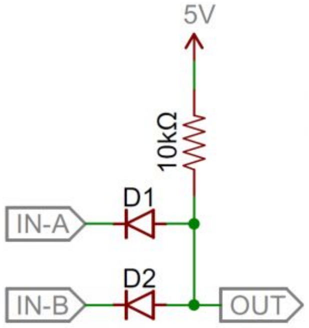
[How does a Diode Work?]

Fundamentals of Electronic Circuits (Diodes)

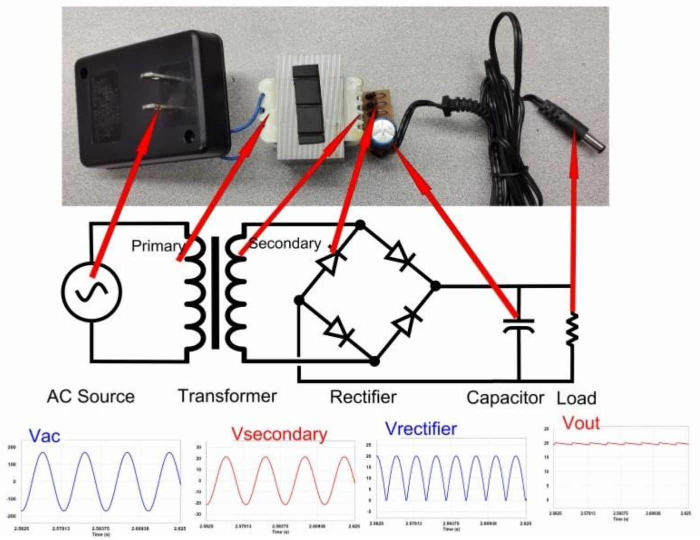
- Diode Applications
  - Rectifiers
  - Reverse Current Protection
  - Logic Gates
  - Voltage Spike Suppression (Flyback Diodes)
  - Sensor (Photodiode)
- Useful links:
  - Sparkfun - Diodes
  - How do Solar cells work?
  - LED Basics
  - The LED - How LEDs work?
  - Diodes - What Are Diodes?
  - Working Principle of Diode



OR logic gate



AND logic gate



Fundamentals of Electronic Circuits

- Some useful links
  - [Semiconductor Basics]
  - [Basic Introduction, N type vs P type Semiconductor]
  - [Semiconductor introduction]
  - [Electrons and Holes in Semiconductors]
  - [Extrinsic Semiconductors]
  - [Light Emitting Diode (LED) Working Principle]
  - [How diodes, LEDs and solar panels work]
  - [How Does an LED Work?]
  - [Effect of Temperature on Resistance]