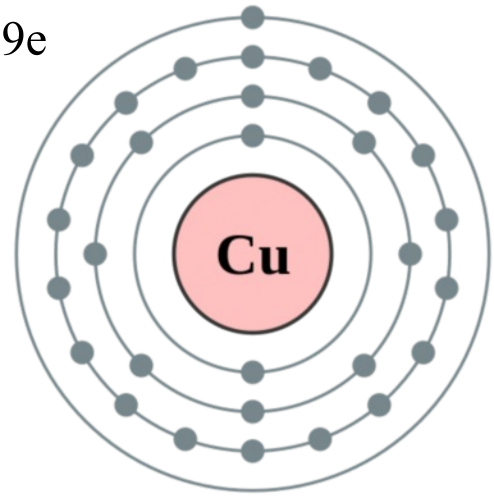
Materials can be grouped into three categories;

Conductors	
Insulators	
Semiconductors	

What is meant by free electrons?

29e



Electrons orbit the nucleus of an atom in discrete shells.

Each shell can only hold a certain amount of electrons until it is filled.

No electrons can exist in between energy levels.

The shells fill up in the following sequence:

Shell Number	1	2	3	4
Amount of electrons				

When the shell is full the electrons are all jammed in and cannot move.

They are tightly bound.

When the shell is not full then electrons can move they free to move.

The electron shells fill up according to the rule $2n^2$

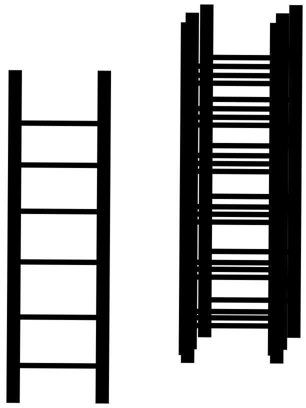
Band Theory

The energy levels of an atom can be represented very much like the rungs on a ladder.

Each run represents an energy level.

If a collection of ladders are pilled together in the hardware store then the individual rungs are harder to see.

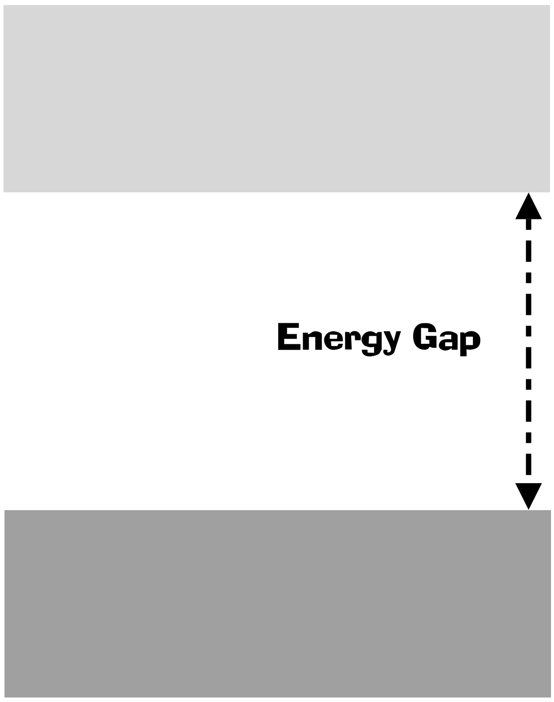
The individual rungs appear as kind of bands of rungs.



The same happens when groups of atoms form a solid.

Each individual atom’s energy levels come together like bands.

The energy levels in solids appear as bands of energy.



This band is called the ***conduction band.***

This band can be empty or partially empty which means space for the electrons to move.

This means they can move about.

This band is called the ***valence band.***
In this case it is full.

Electrons have to get to the top empty energy band, called the conduction band, for the solid to conduct.

Electrons fill up the valence band from top to bottom. The top level of the valence band is , in theory, the highest energy level that is filled by available electrons at 0 Kelvin.

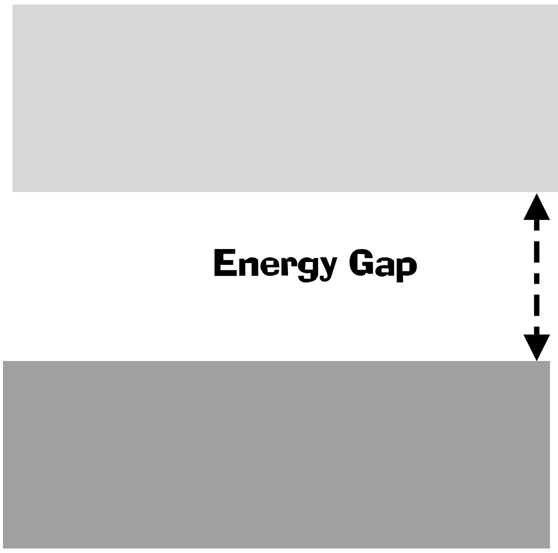
The above example shows an ***insulator***. The valence band is FULL and the conduction band is EMPTY. NO electrons have enough energy to cross the energy gap.

Band Theory for a conductor

For a conductor there is no energy gap. There is a continuous unfilled ***conduction band***.

There is plenty of free space for the electrons hence it is a good conductor.

Band Theory for a semiconductor.



For a semiconductor again the valence band is full of electrons.

However the energy gap is not as big as that of an insulator.

In fact some electrons due to ***thermal energy*** can cross the energy gap and enter the conduction band.

Here they have plenty of available empty energy levels.

The electrons that leave the valence band create a space in the valence band called a hole.

These holes help free up space for electron movement in the valence band.

Semiconductors can show increasing conductivity just by an increase in temperature.

Summary.

In solids permitted energy levels are organised into ....

The .... contains electrons that are bound to the atom. In insulators and semiconductors the .... is full.

The .... is a region of permitted energy levels that is empty in ....and ....
But partially filled in ....

Only partially filled bands can may permit electrical ....

For an insulator and semi conductor there is an .... Between the valence band and the conduction band.

No electrons can exist in this region.

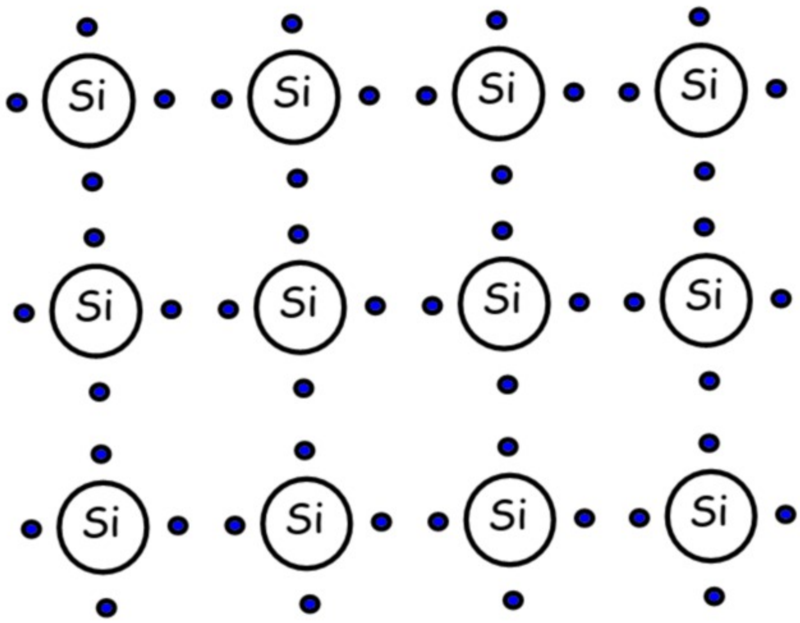
Electrons must jump the .... From the ....
.... to the .... This is not normally possible in insulators because the .... Is too big.

In semiconductors the energy gap is much .... And electrons can jump the energy gap to the conduction band as a result of .... energy

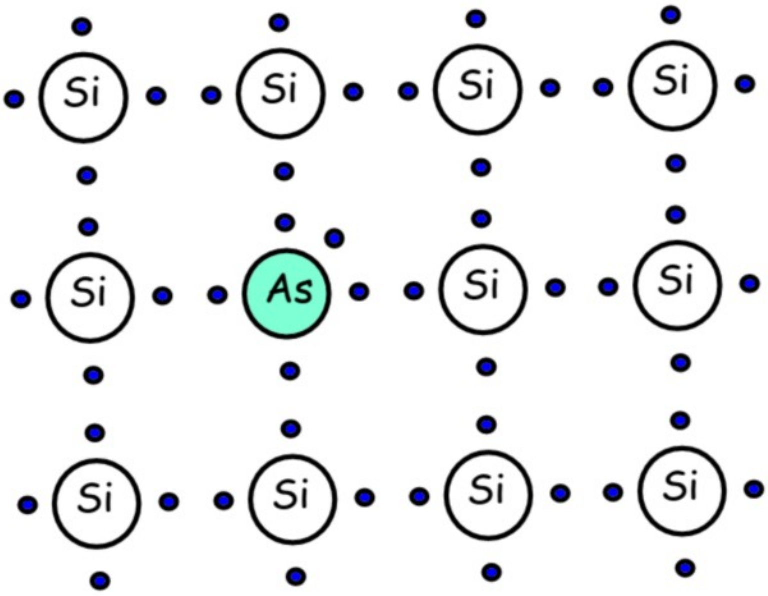
Making Semiconductors better conductors

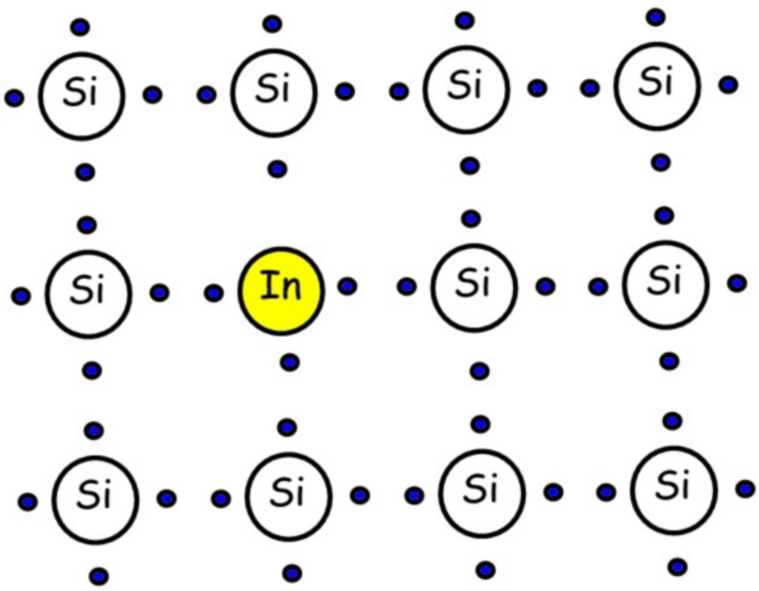
A section of the periodic table

13 III	14 IV	15 V	16 VI	17 VII	18 VIII
					helium 2 He
boron 5 B	carbon 6 C	nitrogen 7 N	oxygen 8 O	fluorine 9 F	neon 10 Ne
aluminium 13 Al	silicon 14 Si	phosphorus 15 P	sulfur/sulphur 16 S	chlorine 17 Cl	argon 18 Ar
gallium 31 Ga	germanium 32 Ge	arsenic 33 As	selenium 34 Se	bromine 35 Br	krypton 36 Kr
indium 49 In	tin 50 Sn	antimony 51 Sb	tellurium 52 Te	iodine 53 I	xenon 54 Xe
thallium 81 Tl	lead 82 Pb	bismuth 83 Bi	polonium 84 Po	astatine 85 At	radon 86 Rn

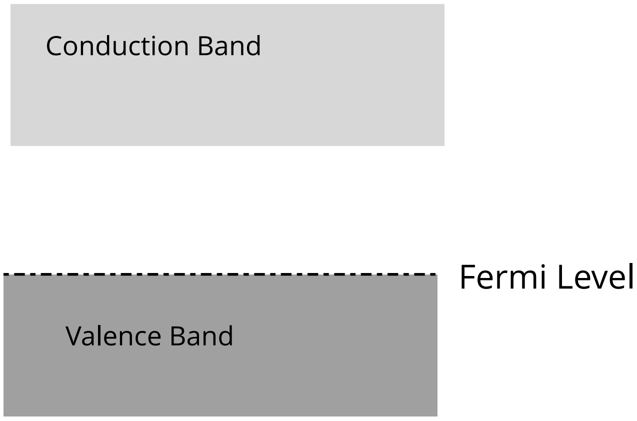


Doping the semiconductor





Doped Semiconductors and the band theory



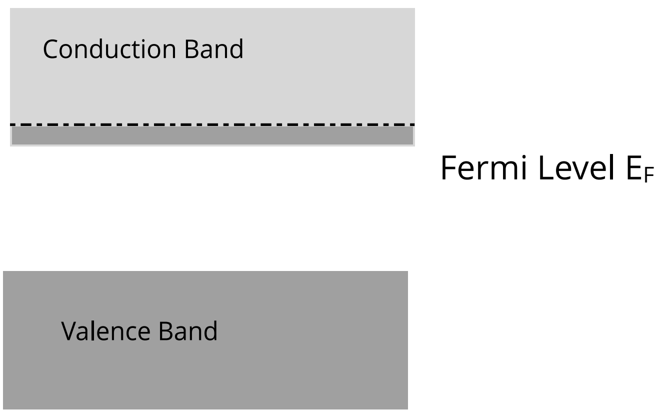
For a pure semiconductor the valence band is full and the conduction band is empty.

Some electrons can move up to the conduction band excited by thermal energy.

The Fermi Energy level is defined as the maximum level where electrons are to be found.

Heat energy can lift some electrons from the Fermi level up to the spacious conduction band

N-type semiconductor



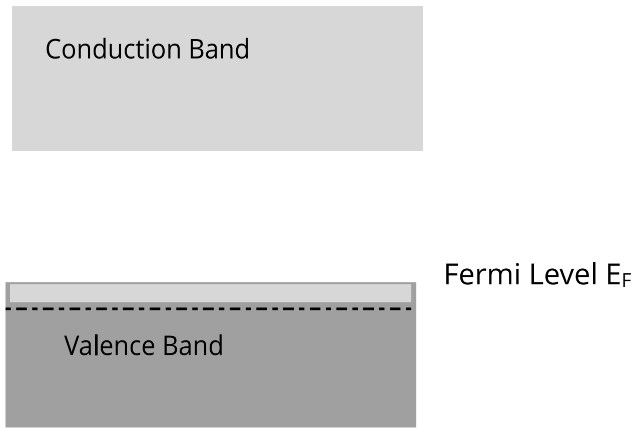
An n-type semiconductor is made by adding an extra electron by doping the semiconductor crystal with an element in group 5.

These extra electrons have to occupy the conduction band.

The fermi level goes into the conduction band.

There is more space therefore a conductor is made

p-type semiconductor



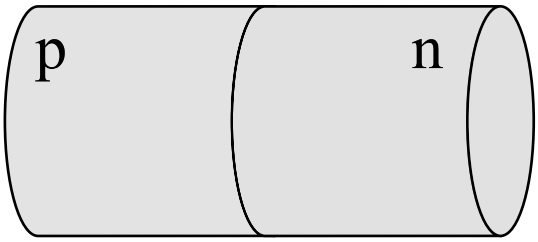
A p-type semiconductor is made by adding an element from group 3 to the silicon crystal. This creates holes in the valence band.

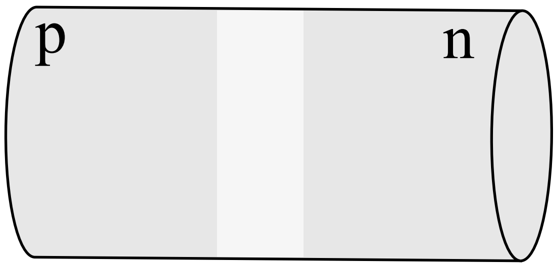
These holes in the valence band give space for electrons to move!

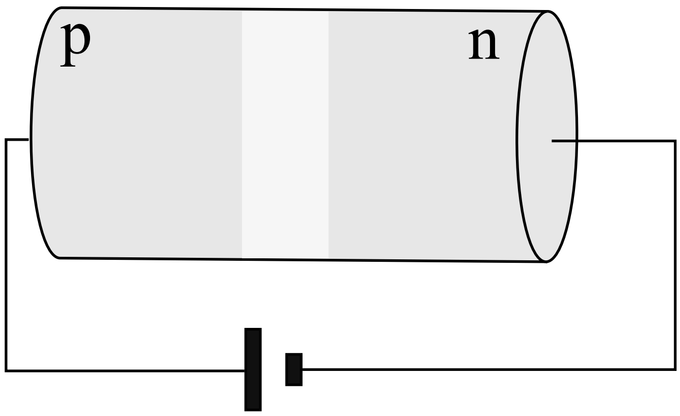
The fermi level goes down into the valence band

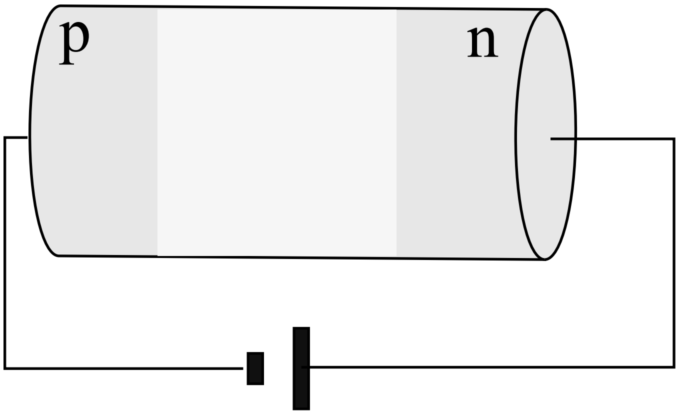
So a conductor is made again from the semiconductor.

The pn junction

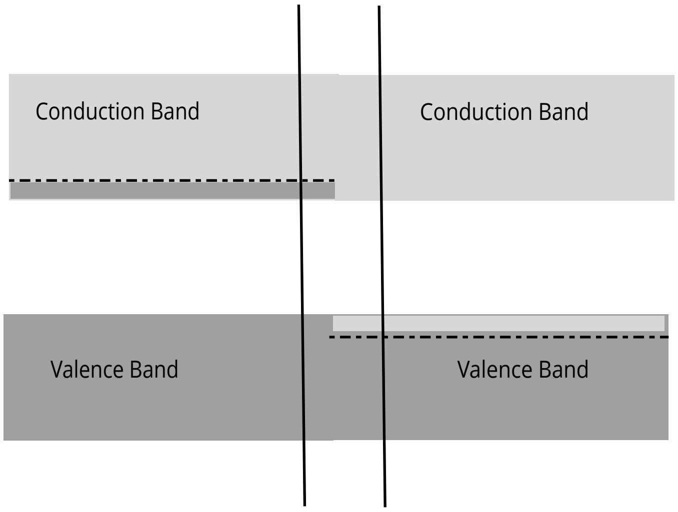


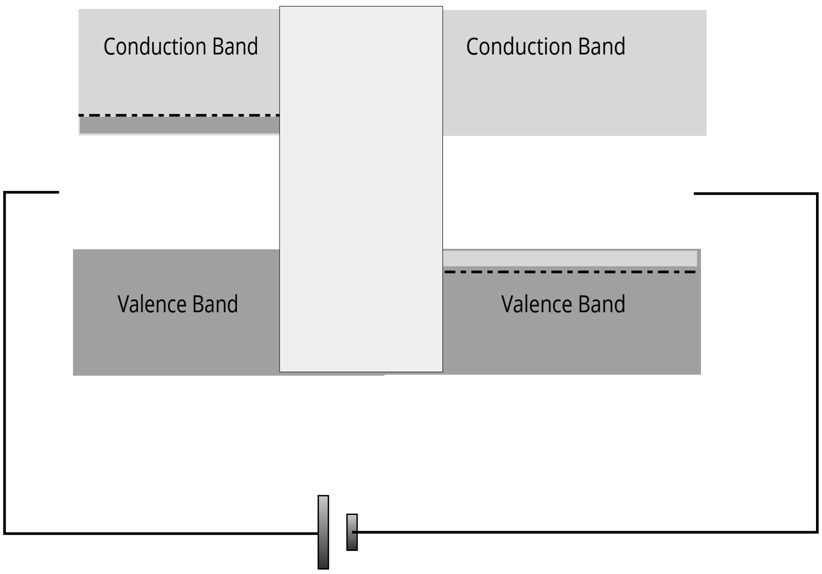


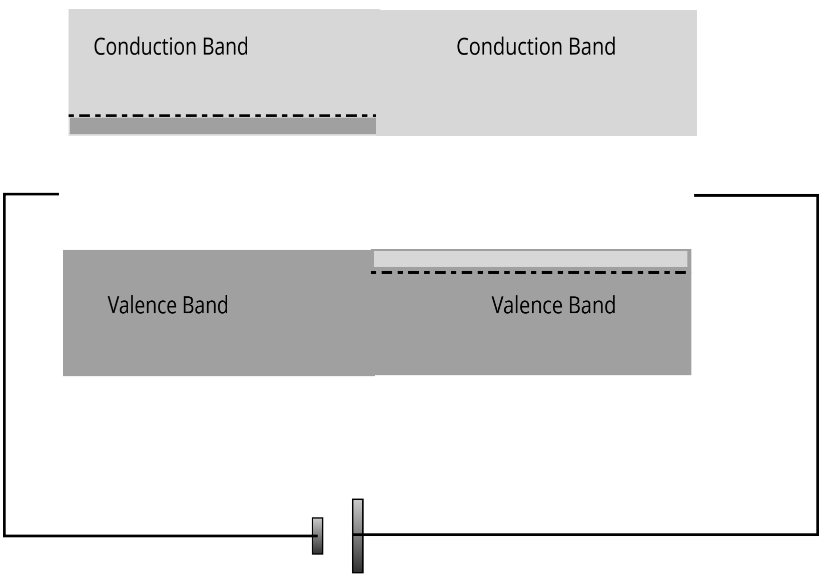




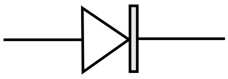
The pn junction with band theory

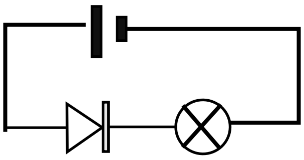


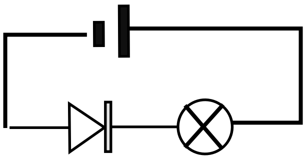




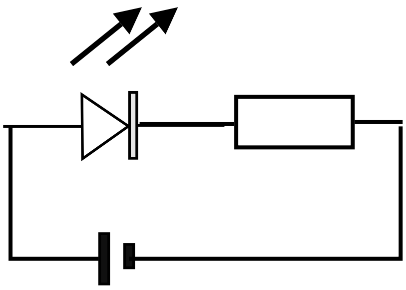
The diode

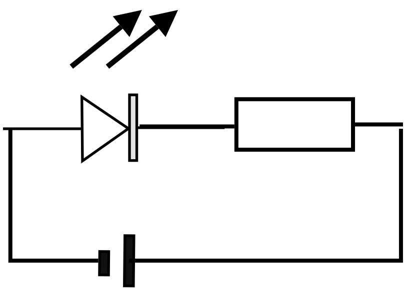






The LED





The LED Theory