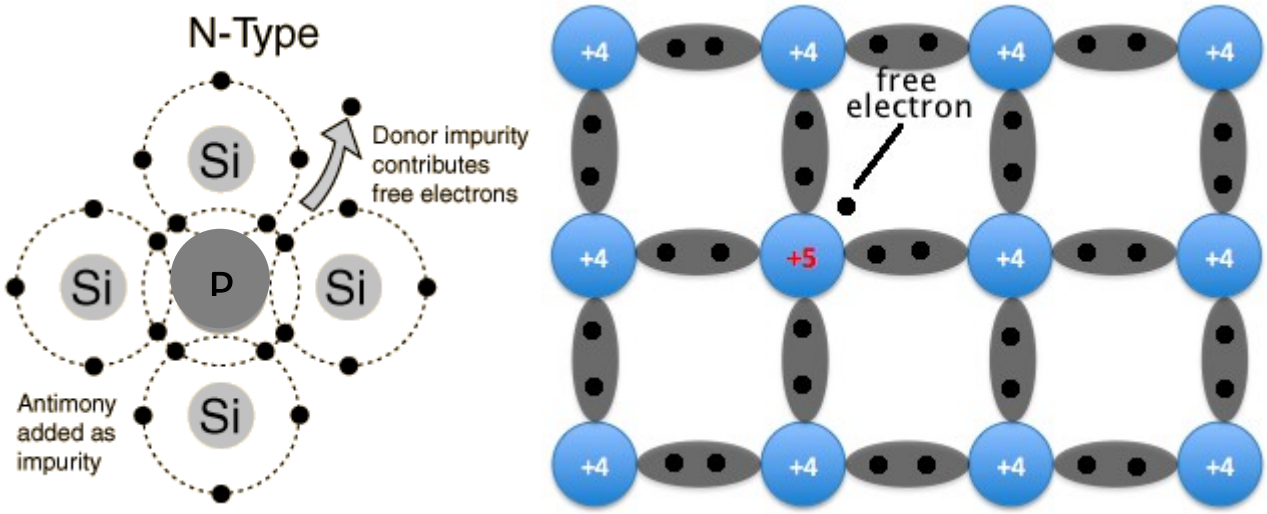
N-type semiconductor

When pentavalent impurity is added to an intrinsic or pure semiconductor (silicon or germanium), then it is said to be an n-type semiconductor. Pentavalent impurities such as phosphorus, arsenic, antimony etc are called donor impurity.

Let us consider, pentavalent impurity phosphorus is added to silicon as shown in below figure. Phosphorus atom has 5 valence electrons and silicon has 4 valence electrons. Phosphorus atom has one excess valence electron than silicon. The four valence electrons of each phosphorus atom form 4 covalent bonds with the 4 neighboring silicon atoms. The fifth valence electron of the phosphorus atom cannot able to form the covalent bond with the silicon atom because silicon atom does not have the fifth valence electron to form the covalent bond.

Thus, fifth valence electron of phosphorus atom does not involve in the formation of covalent bonds. Hence, it is free to move and not attached to the parent atom.



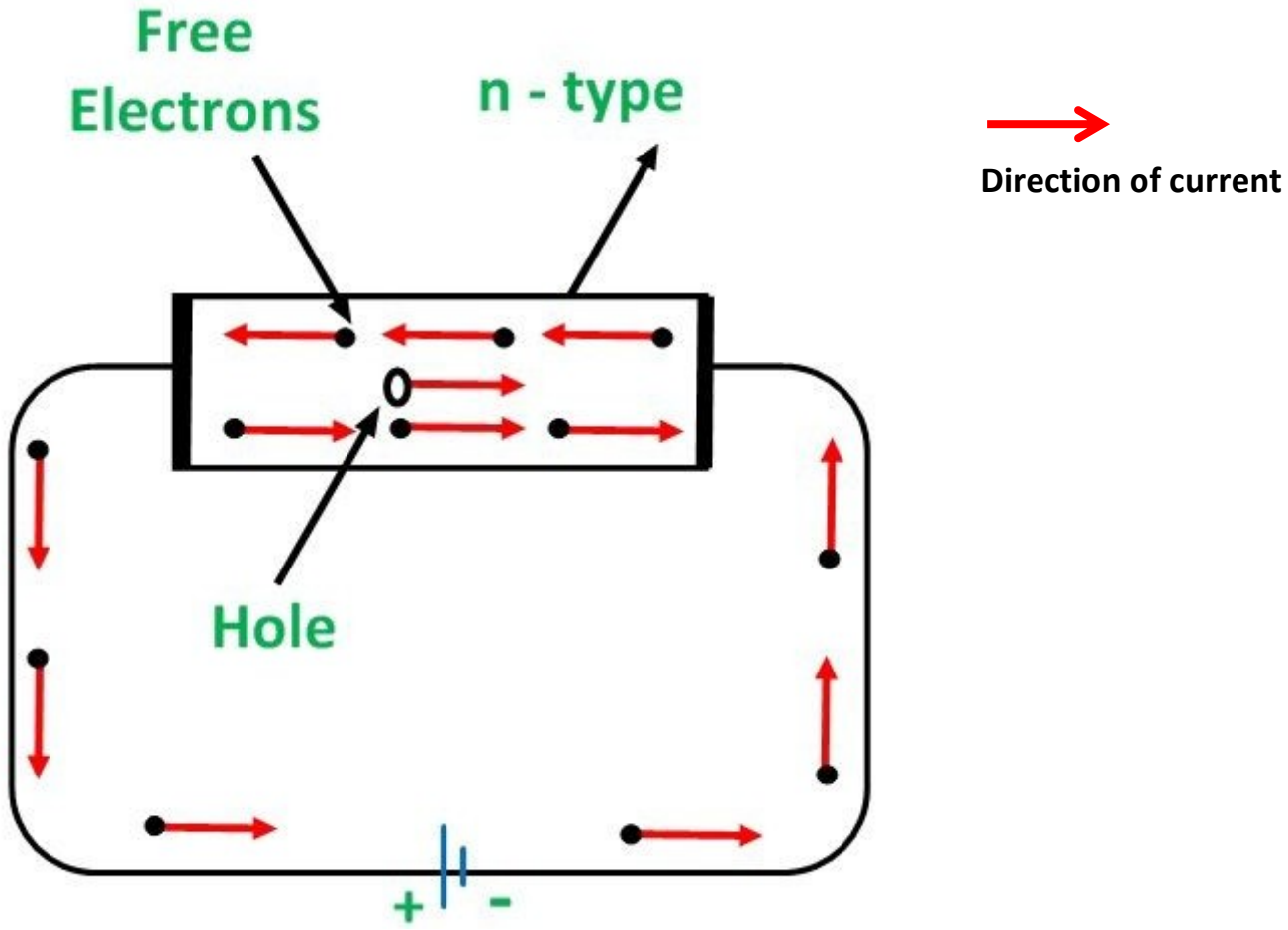
This shows that each phosphorus atom donates one free electron. Therefore, all the pentavalent impurities are called donors. The number of free electrons are depends on the amount of impurity (phosphorus) added to the silicon. A small addition of impurity (phosphorus) generates millions of free electrons.

Charge on n-type semiconductor

So many people think that n-type semiconductor has large number of free electrons. So, the total electric charge of n-type semiconductor is negative. But this assumption is wrong. Even though n-type semiconductor has large number of free electrons, but these free electrons is given by the pentavalent atoms that are electrically neutral. Therefore, the total electric charge of n-type semiconductor is also neutral.

Conduction in n-type semiconductor

Let us consider an n-type semiconductor as shown in below figure. When voltage is applied to n-type semiconductor; the free electrons moves towards positive terminal of applied voltage. Similarly holes moves towards negative terminal of applied voltage.



In n-type semiconductor, the population of free electrons is more whereas the population of holes is less. Hence in n-type semiconductor free electrons are called majority carriers and holes are called minority carriers. Therefore, in a n-type semiconductor conduction is mainly because of motion of free electrons.

e.g.:

A Si (Silicon) - semiconductor doped by As (Arsenic) ;

Atomic Density of Si (Silicon) = 10^{23} cm^{-3}

Intrinsic Carrier density of Si (Silicon) at room temperature = 10^{10} cm^{-3}

Doping ratio - As : Si = $1:10^6$

i) Calculate atomic density of As (Arsenic)
ii) Calculate Majority carrier density
iii) Calculate Minority Carrier Density

i) As : Si = $1 : 10^6$

Density of Si (Silicon) = 10^{23}

So; As (Arsenic) $= \frac{1}{10^6} \times 10^{23}$

$= \underline{10^{17}\ cm^{-3}}$

ii) $10^{10} + 10^{17} = 10^{10}(1+10^7)$

$= \underline{10^7\ cm^{-3}}$

iii) $= \underline{10^{10}\ cm^{-3}}$