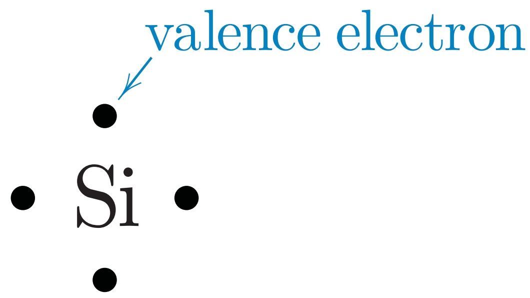
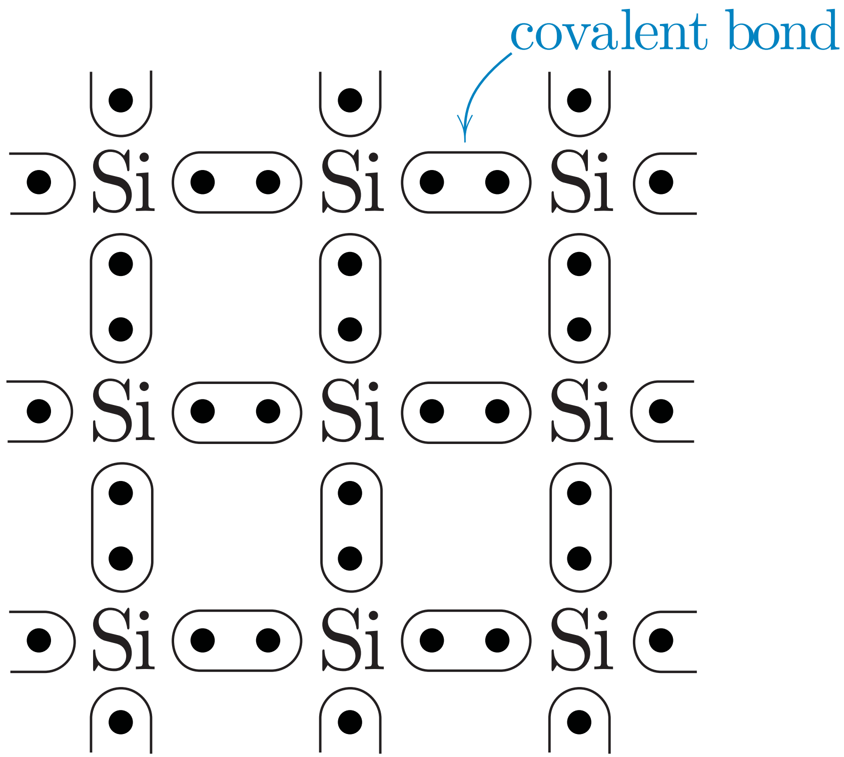
Simplified Periodic Table of the Elements

I	II	III	IV	V	VI	VII	VIII
H 1 Hydrogen							He 2 Helium
Li 3 Lithium	Be 4 Beryllium	B 5 Boron	C 6 Carbon	N 7 Nitrogen	O 8 Oxygen	F 9 Flourine	Ne 10 Neon
Na 11 Sodium	Mg 12 Magnesium	Al 13 Aluminum	Si 14 Silicon	P 15 Phosphorus	S 16 Sulfur	Cl 17 Chlorine	Ar 18 Argon
K 19 Potassium	Ca 20 Calcium	Ga 31 Gallium	Ge 32 Germanium	As 33 Arsenic	Se 34 Selenium	Br 35 Bromine	Kr 36 Krypton
Rb 37 Rubidium	Sr 38 Strontium	In 49 Indium	Sn 50 Tin	Sb 51 Antimony	Te 52 Tellurium	I 53 Iodine	Xe 54 Xenon
Cs 55 Cesium	Ba 56 Barium	Tl 81 Thallium	Pb 82 Lead	Bl 83 Bismuth	Po 84 Polonium	At 85 Astatine	Rn 86 Radon

Schematic Representation of a Silicon Crystal

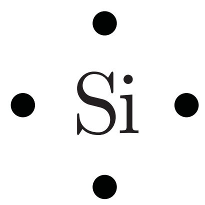


silicon atom

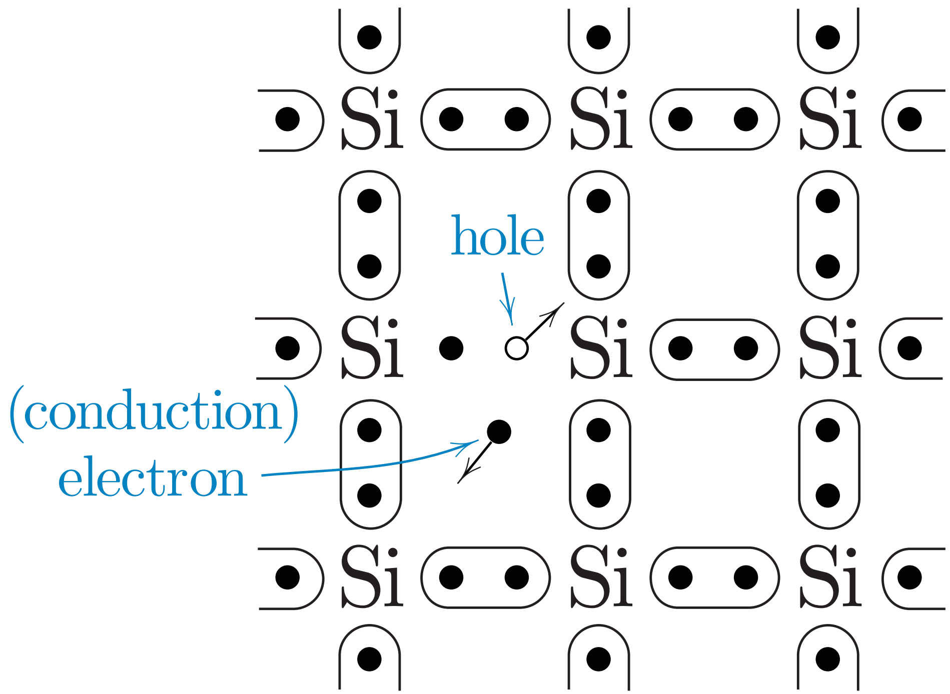


intrinsic silicon crystal

Electrons and Holes in the Silicon Crystal

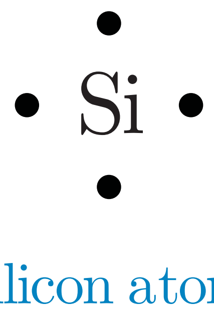


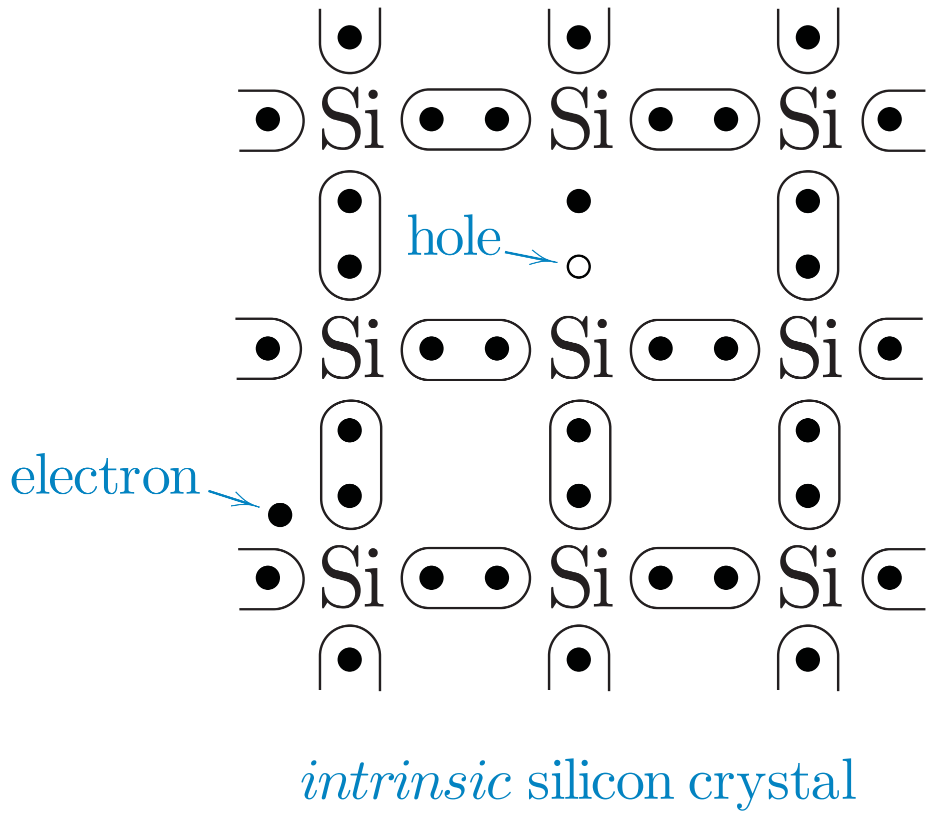
silicon atom



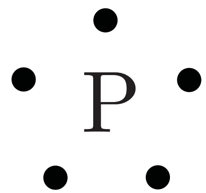
intrinsic silicon crystal

Electrons and Holes in the Silicon Crystal

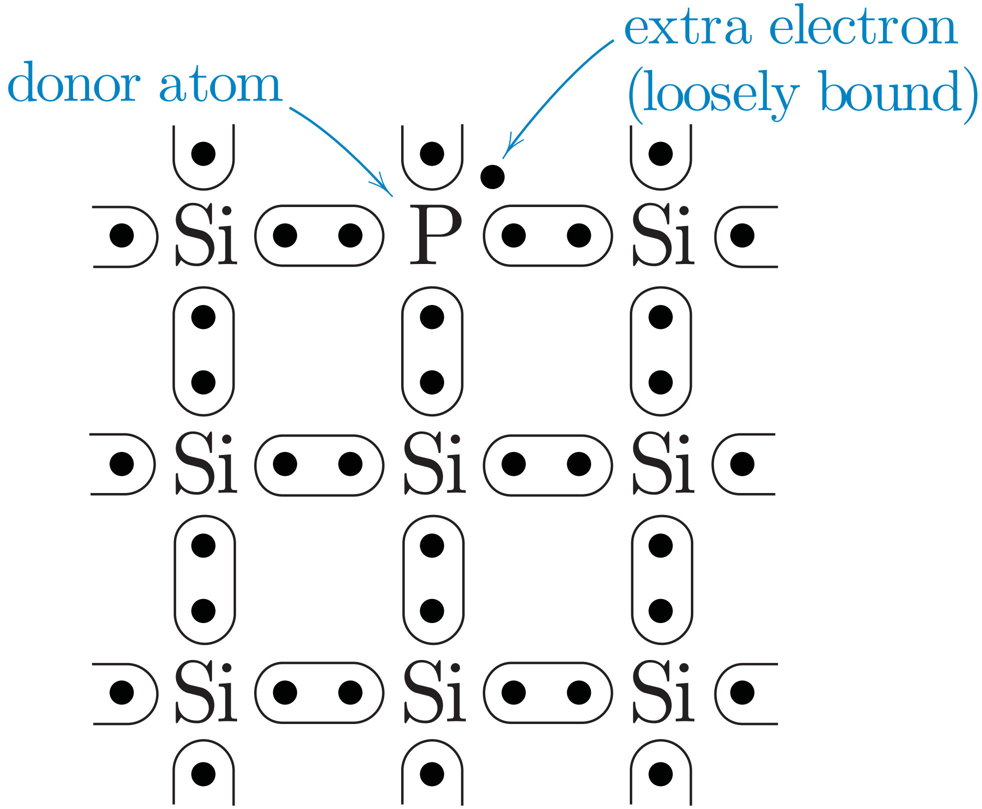




Silicon Crystal Doped with Donor Impurities

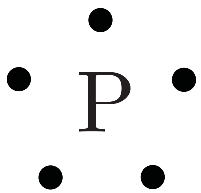


phosphorus atom
(*donor* for silicon)

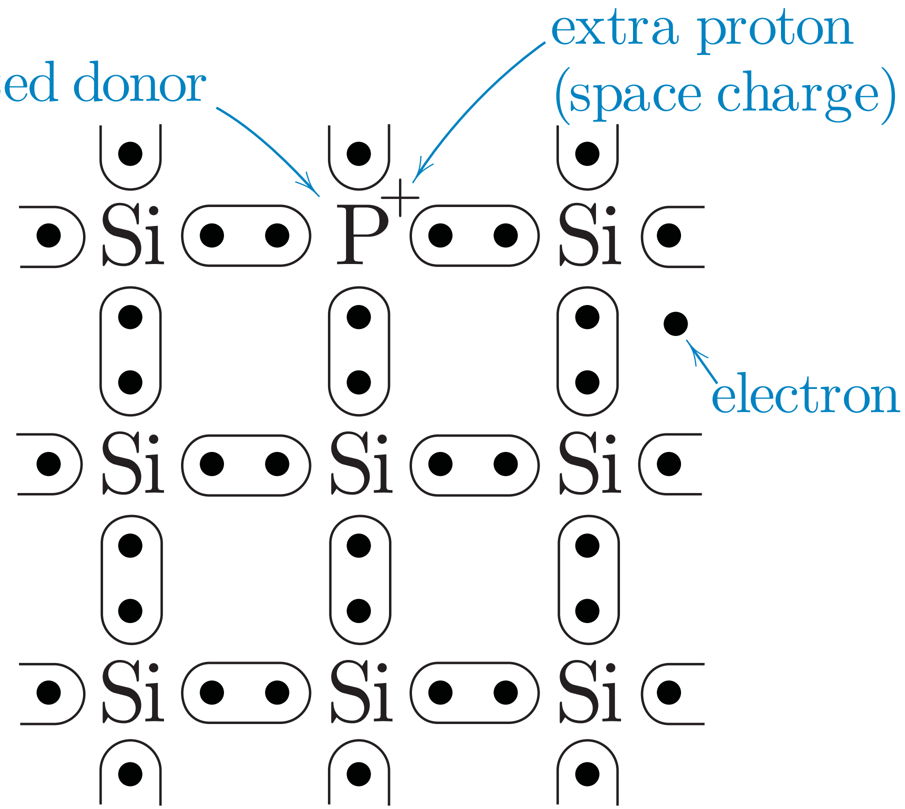


doped silicon crystal: *n*-type

Silicon Crystal Doped with Donor Impurities

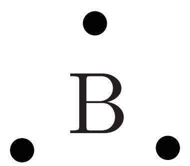


phosphorus atom
(*donor* for silicon)

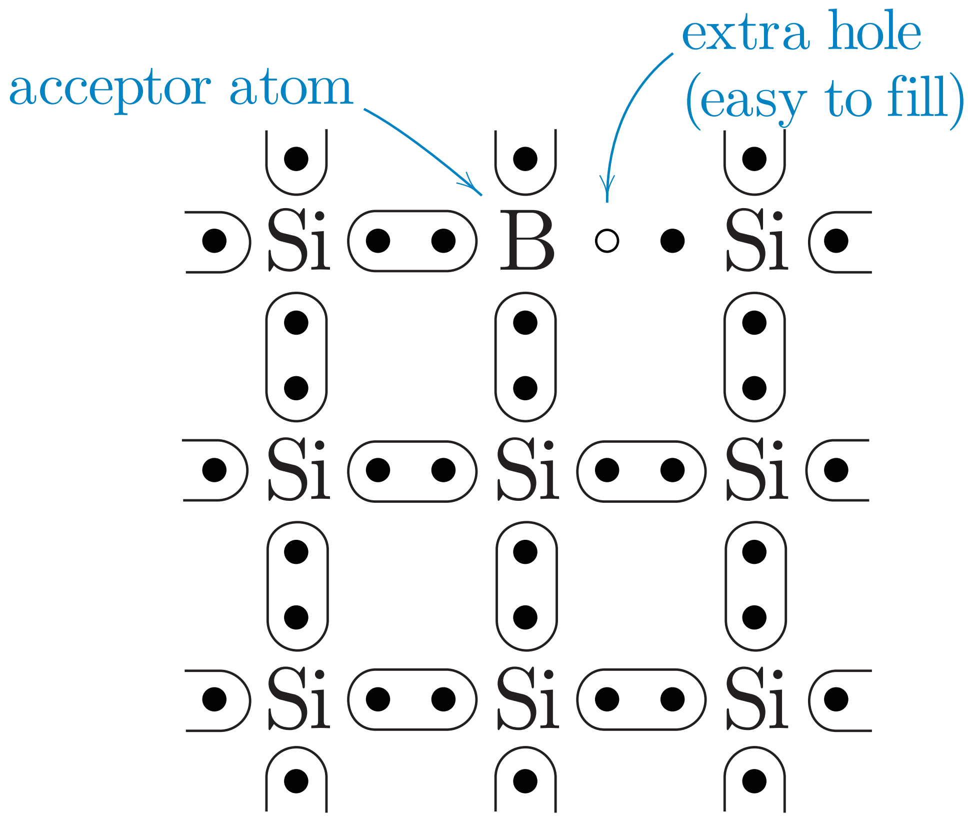


doped silicon crystal: n-type

Silicon Crystal Doped with Acceptor Impurities

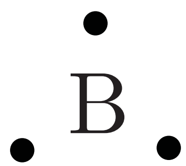


boron atom
(*acceptor* for silicon)

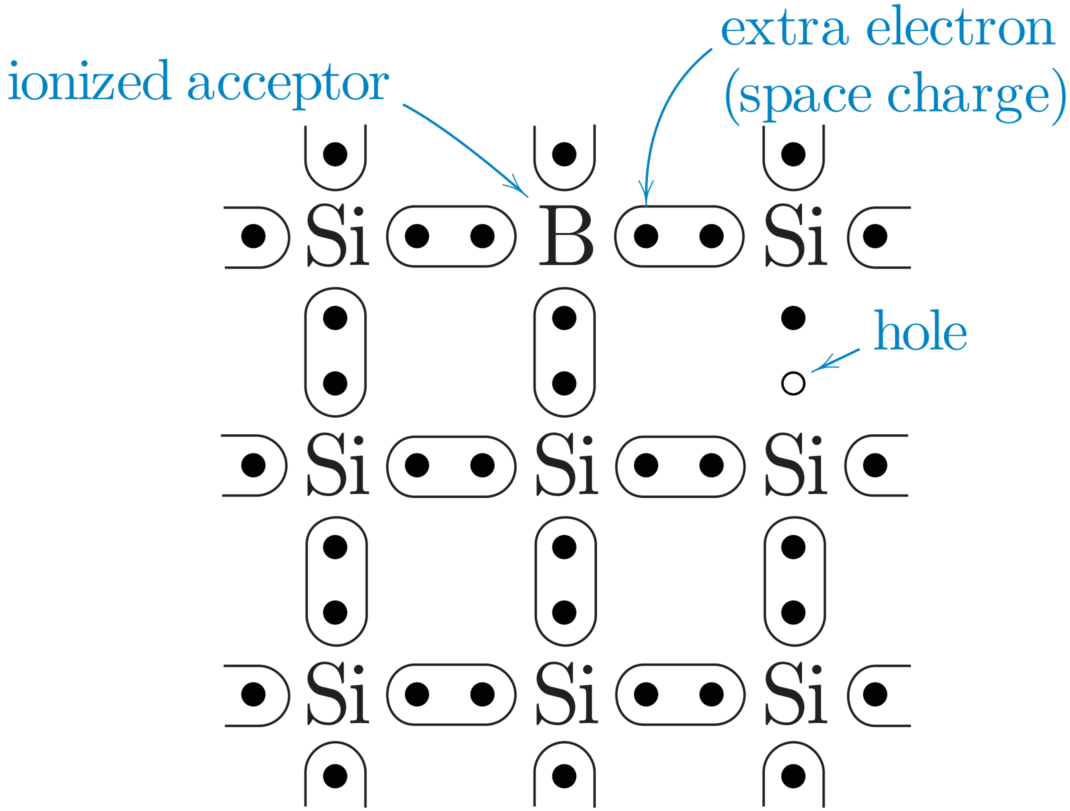


doped silicon crystal: *p*-type

Silicon Crystal Doped with Acceptor Impurities



boron atom
(*acceptor* for silicon)



doped silicon crystal: p-type

Electrostatics in 1-D

- Relationship between E-field and charge density (Gauss' Law):

$$\frac{\partial E}{\partial x} = \frac{\rho}{\epsilon}$$

- Relationship between electrical potential (voltage) and E-field:

$$\frac{\partial \psi}{\partial x} = -E$$

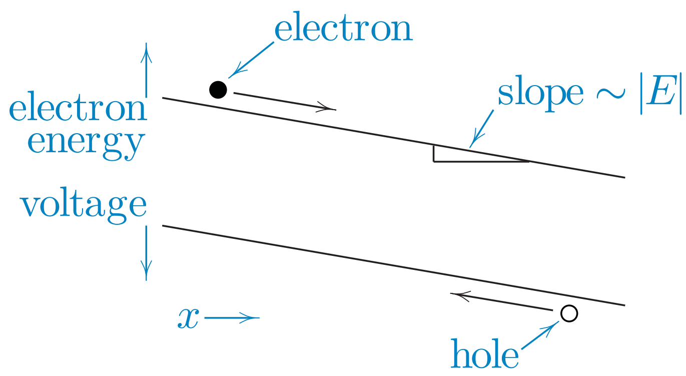
- E-field boundary condition at a dielectric interface:

$$\epsilon_1 E_1 = \epsilon_2 E_2$$

Mechanisms of Carrier Transport

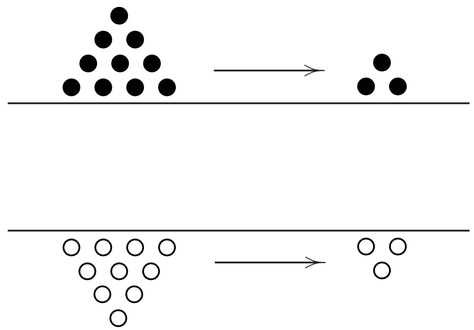
Drift: movement of charge carriers due to an external E-field.

$$I_{\text{drift}} = qn\mu E$$



Diffusion: movement of carriers due to a concentration gradient.

$$I_{\text{diff}} = qD\frac{\partial n}{\partial x}$$



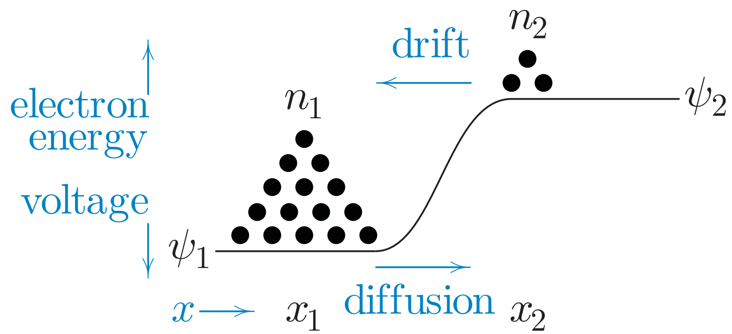
Einstein relation: $$\boxed{\frac{D}{\mu} = \frac{kT}{q} \equiv U_{\text{T}}}$$ thermal voltage

Equilibruim at a Potential Barrier

$$I_{\text{drift}} = qn\mu E = -qn\mu\frac{\partial\psi}{\partial x}$$

$$I_{\text{diff}} = qD\frac{\partial n}{\partial x}$$

$$I_{\text{drift}} + I_{\text{diff}} = 0$$



$$\Rightarrow \quad -qn\mu\frac{\partial\psi}{\partial x} + qD\frac{\partial n}{\partial x} = 0 \quad \Rightarrow \quad D\frac{\partial n}{\partial x} = n\mu\frac{\partial\psi}{\partial x} \quad \Rightarrow \quad \frac{1}{n}\cdot\frac{\partial n}{\partial x} = \frac{\mu}{D}\cdot\frac{\partial\psi}{\partial x}$$

$$\Rightarrow \quad \int_{x_1}^{x_2}\frac{1}{n}\cdot\frac{\partial n}{\partial x}dx = \frac{1}{U_{\text{T}}}\int_{x_1}^{x_2}\frac{\partial\psi}{\partial x}dx \quad \Rightarrow \quad \int_{n_1}^{n_2}\frac{dn}{n} = \frac{1}{U_{\text{T}}}\int_{\psi_1}^{\psi_2}d\psi$$

$$\Rightarrow \quad \log\frac{n_2}{n_1} = \frac{\psi_2 - \psi_1}{U_{\text{T}}} \quad \Rightarrow \quad \boxed{\frac{n_2}{n_1} = e^{(\psi_2-\psi_1)/U_{\text{T}}}}$$

Boltzmann distribution