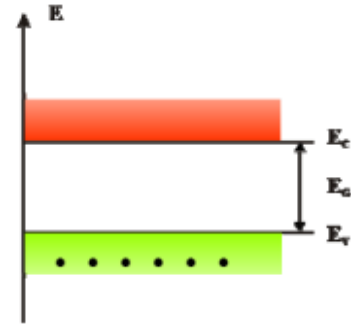
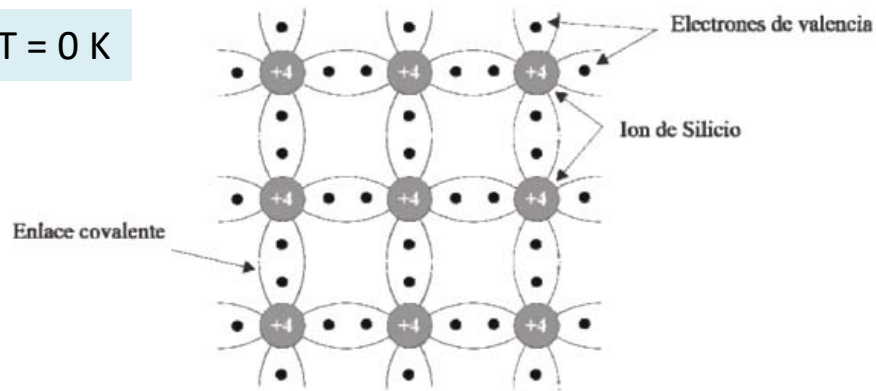


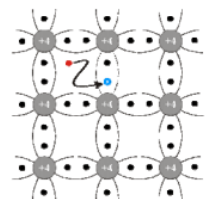
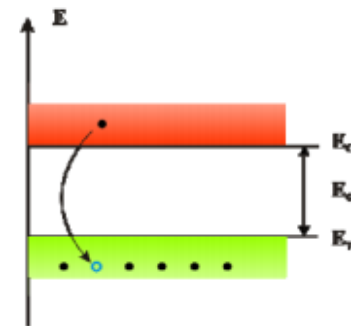
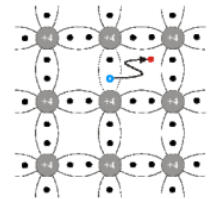
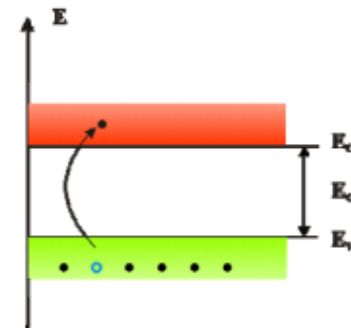
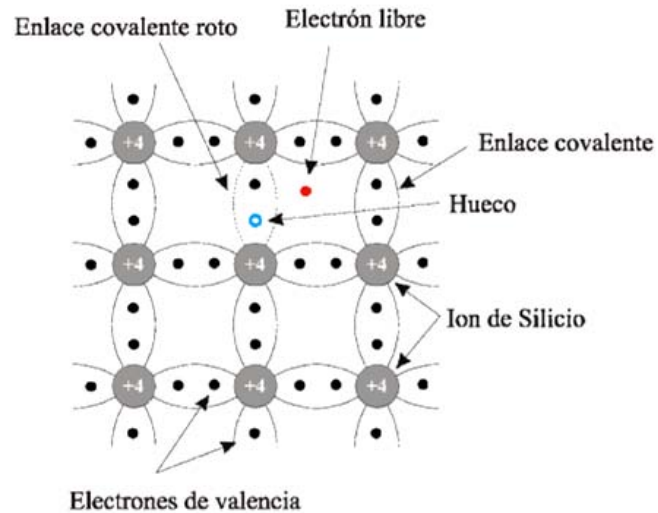
# TEMA 2: PROPIEDADES FUNDAMENTALES DE LOS SEMICONDUCTORES

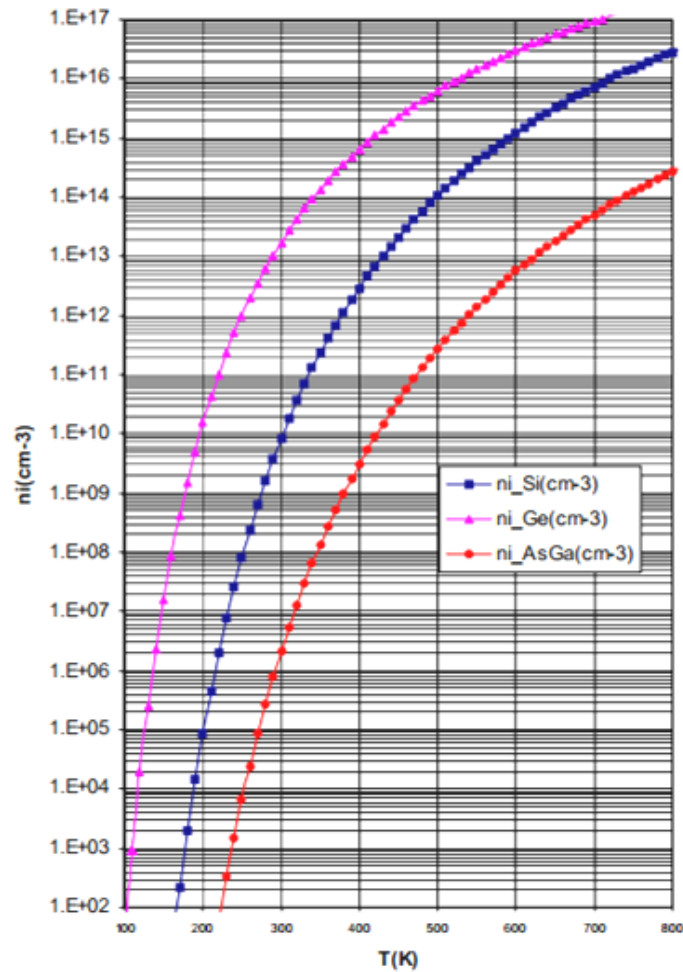
## Semiconductor Intrínseco:

$T = 0 \text{ K}$



$T > 0 \text{ K}$





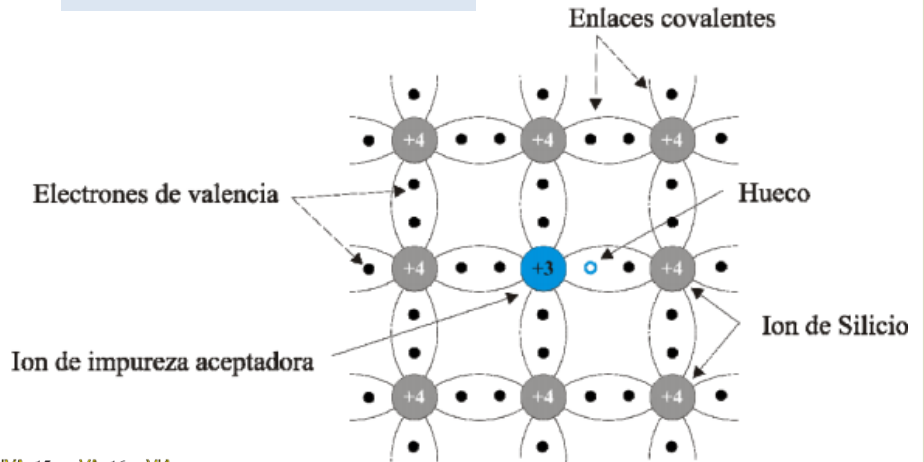
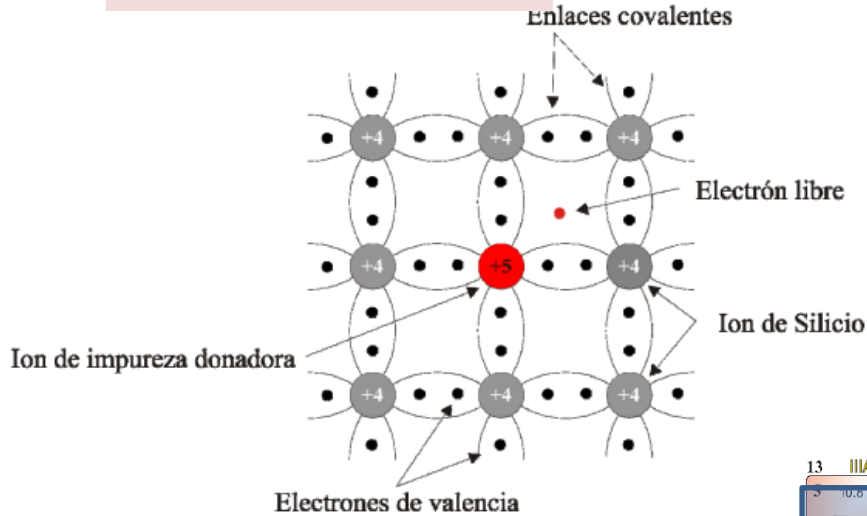
$$n_i(\text{Si})_{300\text{K}} = 1.45 \cdot 10^{10} \text{ cm}^{-3}$$

Dependencia de la concentración intrínseca ( $n_i$ ) de Si, Ge, GaAs en función de la temperatura

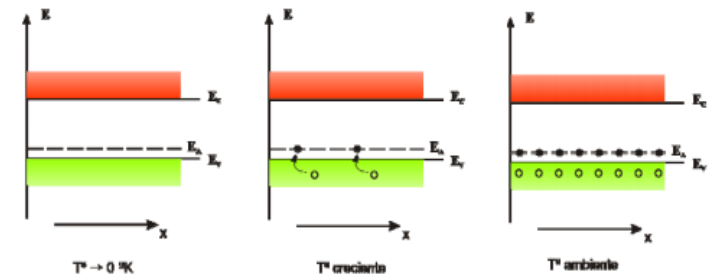
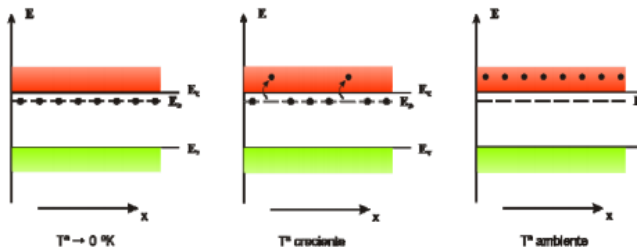
## Semiconductor Extrínseco:

• **DONADORES** ( $D \rightarrow D^+$ )

• **ACEPTORES** ( $A \rightarrow A^-$ )



	13	IIIA	14	IVA	15	VA	16	VIA		
	5	10.01	6	12.01	7	14.01	8	15.99		
		<b>B</b>		<b>C</b>		<b>N</b>		<b>O</b>		
		BORO		CARBONO		NITRÓGENO		OXÍGENO		
	13	28.982	14	28.086	15	30.974	16	32.065		
		<b>Al</b>		<b>Si</b>		<b>P</b>		<b>S</b>		
		ALUMINIO		SILICIO		FÓSFORO		AZUFRE		
3	30	65.38	31	69.723	32	72.64	33	74.922	34	78.96
		<b>Zn</b>		<b>Ga</b>		<b>Ge</b>		<b>As</b>		<b>Se</b>
		CINC		GALIO		GERMANIO		ARSENICO		SELENIO
7	48	112.4	49	114.82	50	118.71	51	121.76	52	127.60
		<b>Cd</b>		<b>In</b>		<b>Sn</b>		<b>Sb</b>		<b>Te</b>
		CADMIO		INDIO		ESTAÑO		ANTIMONIO		TELURO
7	80	200.59	81	204.38	82	207.2	83	208.98	84	(209)
		<b>Hg</b>		<b>Tl</b>		<b>Pb</b>		<b>Bi</b>		<b>Po</b>
		MERCURIO		TALIO		PLOMO		BISMUTO		POLONIO



## Energías de ionización de impurezas en Si, Ge

Impureza	Si	Ge
Fósforo	0.045	0.012
Arsénico	0.05	0.0127
Boro	0.045	0.0104
Aluminio	0.06	0.0102

$$k_B T_{300K} \approx 0.0258 \text{ eV}$$

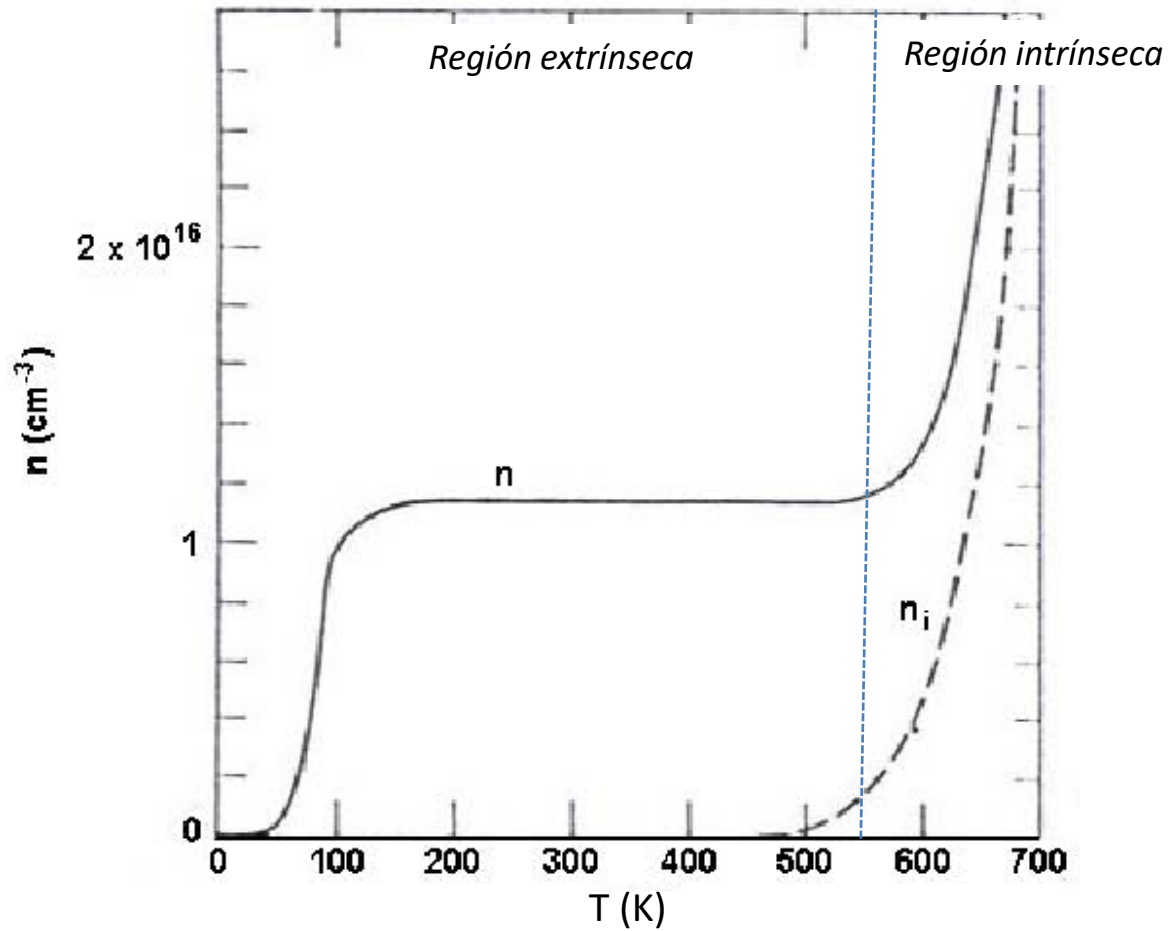
## Energías de ionización de impurezas en GaAs

Impureza	Donadoras
Selenio	0.0059
Teluro	0.0058
Silicio	0.0058
Germanio	0.0061

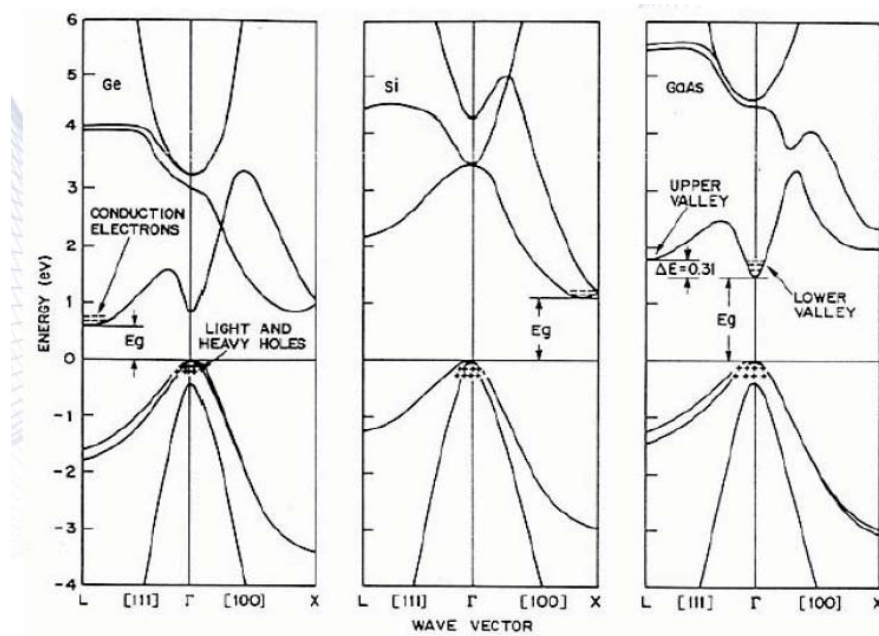
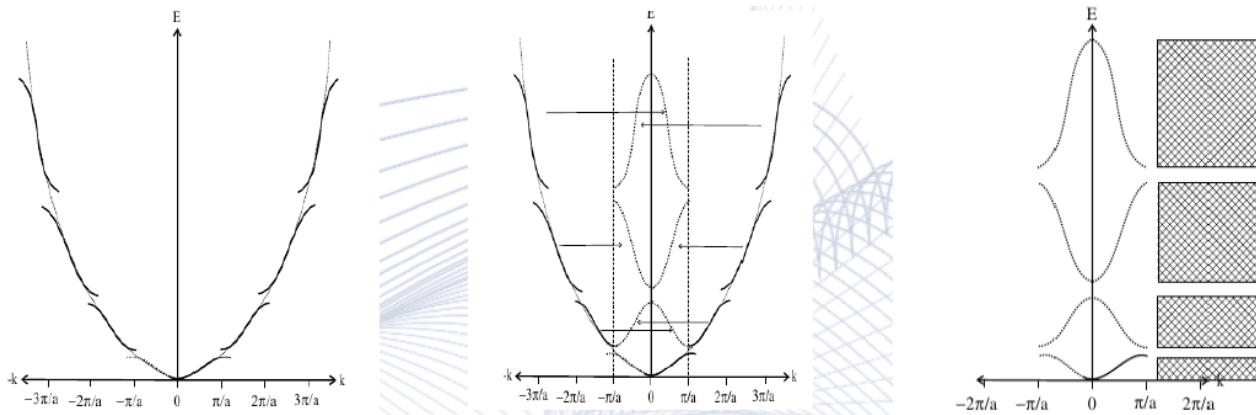
Impureza	Aceptoras
Berilio	0.028
Zinc	0.0307
Cadmio	0.0347
Silicio	0.0345
Germanio	0.0404

- Impurezas donadoras tipo (VI) que tienden a sustituir al As (tipo V)
- Impurezasceptoras (tipo II) que tienden a sustituir al Ga (tipo III)
- Impurezas anfóteras (tipo IV), pueden sustituir al Ga (donadoras) o al As (aceptoras)

## SEMICONDUCTORES EN EQUILIBRIO

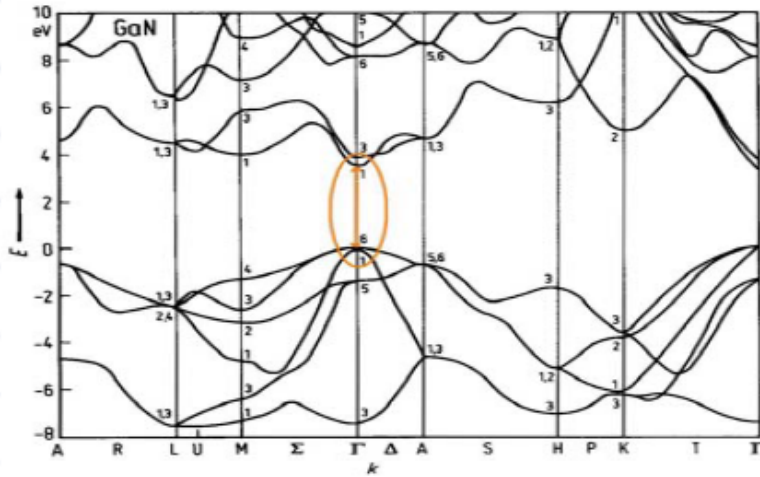


Concentración de electrones en silicio tipo n, en función de la temperatura.

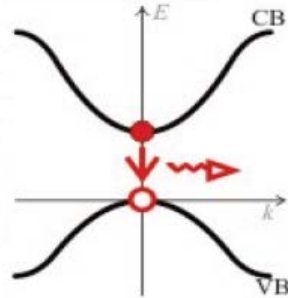


ENERGY-BAND STRUCTURES OF Ge, Si, and GaAs

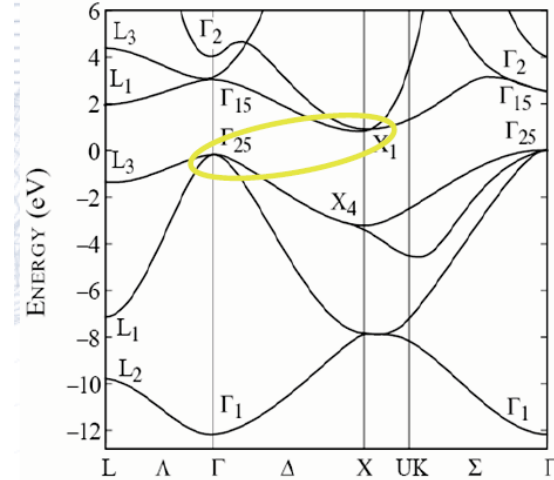
## GAP directo



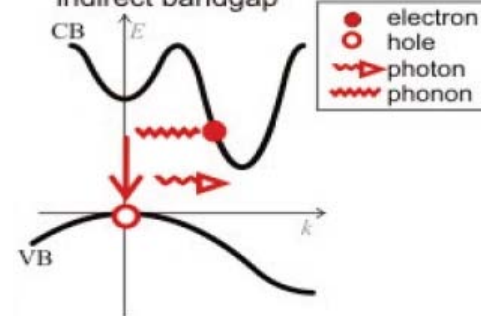
direct bandgap



## GAP indirecto



indirect bandgap





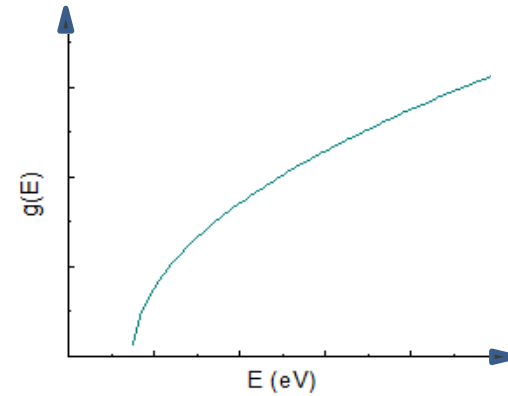
## Concentración de portadores en diferentes tipos de semiconductores

Semiconductor	Concentración de portadores	
tipo $n$	$n \approx N_D$	$p \approx n_i^2/N_D$
tipo $p$	$p \approx N_A$	$n \approx n_i^2/N_A$
(*) tipo $n$ ( $N_D > N_A$ )	$n \approx N_D - N_A$	$p \approx n_i^2/N_D - N_A$
(*) tipo $p$ ( $N_A > N_D$ )	$p \approx N_A - N_D$	$n \approx n_i^2/N_A - N_D$
(*) Compensado ( $N_A = N_D$ )	$n = p = n_i$	

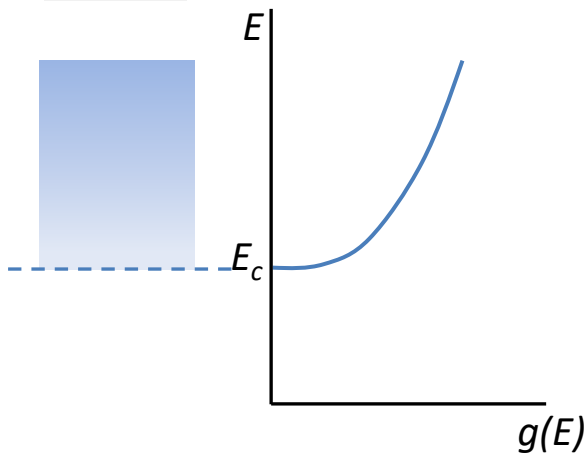
(\*)  $|N_A - N_D| \gg n_i$

## Función densidad de estados

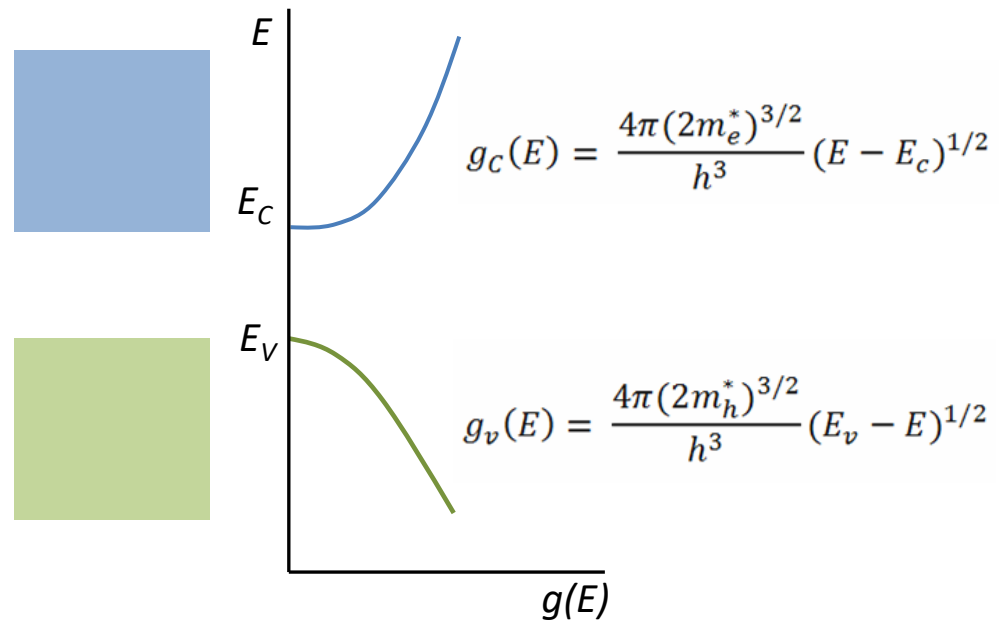
$$g(E) = \frac{4\pi(2m)^{3/2}}{h^3} E^{1/2} \quad (3D)$$



### METAL

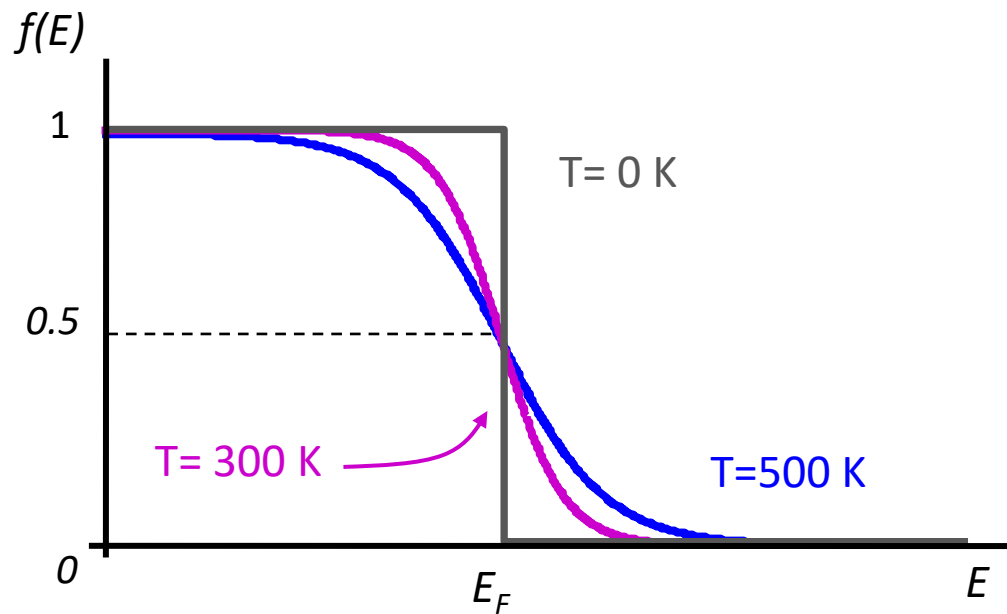


### SEMICONDUCTOR

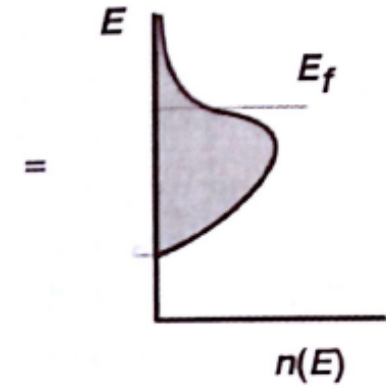
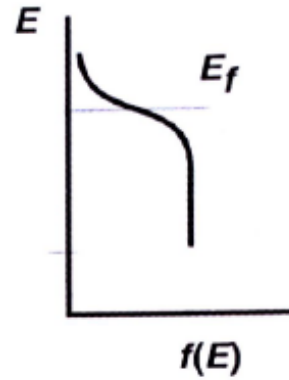
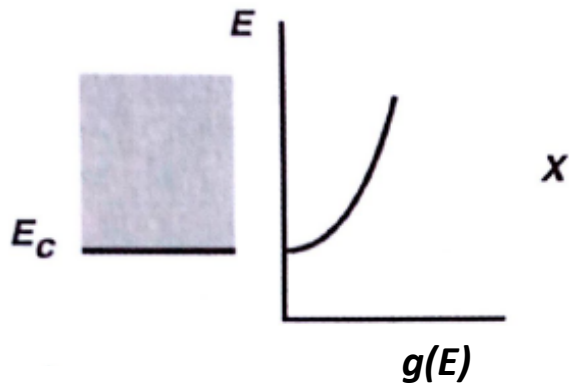


## Función de probabilidad de Fermi-Dirac

$$f(E) = \frac{1}{1 + \exp\left(\frac{E - E_F}{KT}\right)}$$



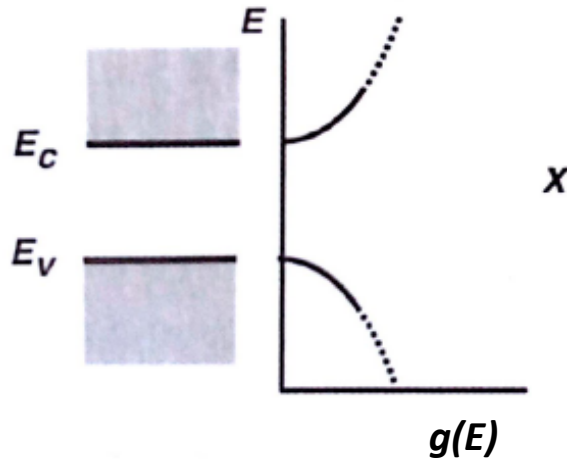
METAL



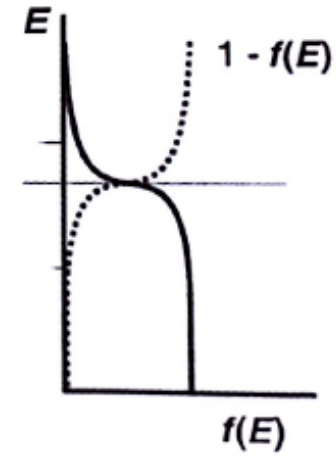
$\times$

$=$

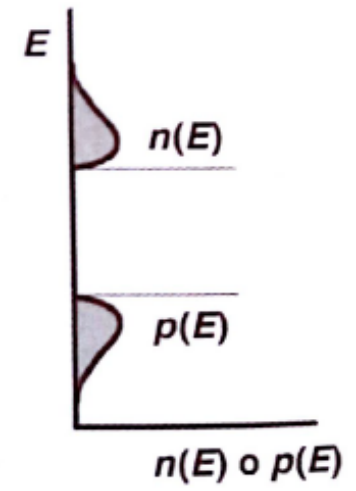
SEMICONDUCTOR



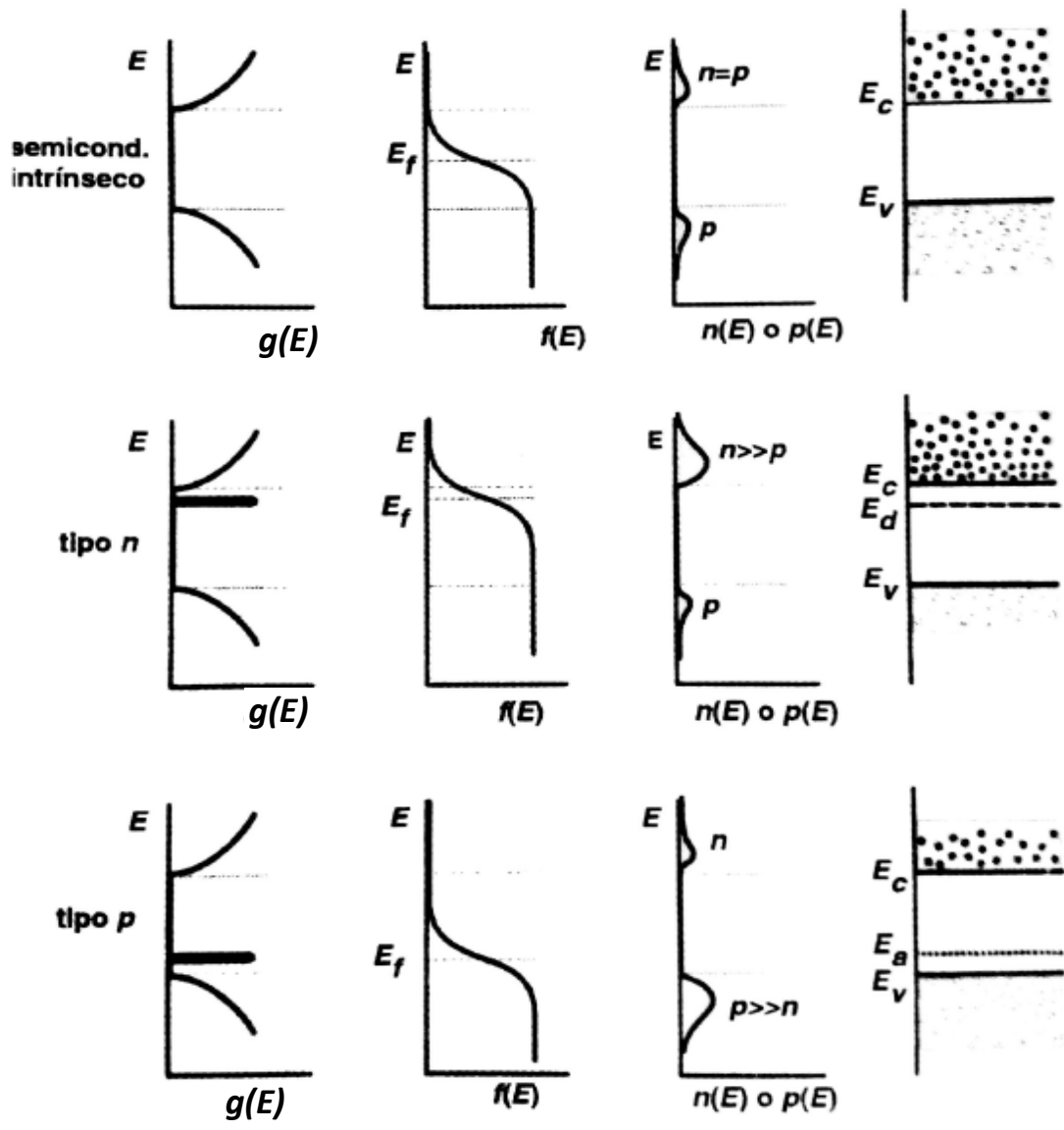
$\times$



$=$



J.M. Albella, Ed. Pearson



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