Juntura P - N

Material tipo P con N_A impurezas Aceptoras

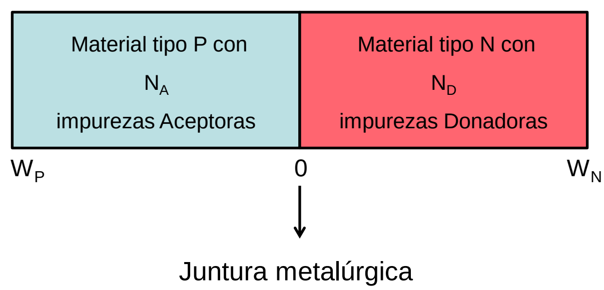
$$p_{p0} \approx N_A$$

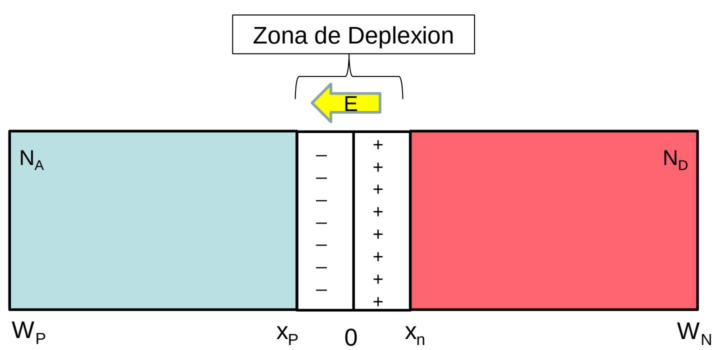
$$n_{p0} = \frac{n_i^2}{N_A}$$

Material tipo N con N_D impurezas Donadoras

$$n_{n0} \approx N_D$$

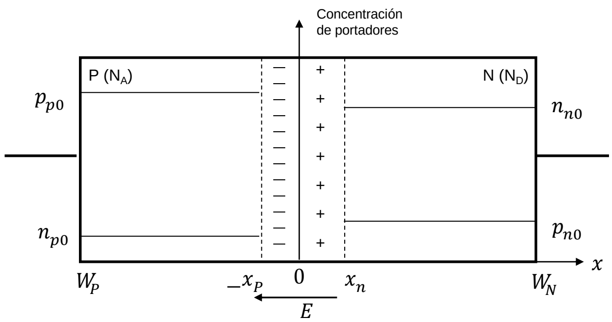
$$p_{n0} = \frac{n_i^2}{N_D}$$

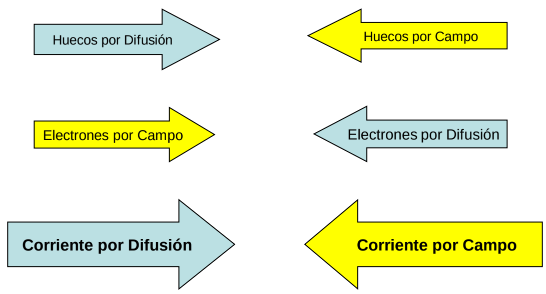




- Cada hueco que pasa del semiconductor P al N deja una carga negativa fija
- Cada electrón que pasa del semiconductor N al P deja una carga positiva fija
- Se genera una zona de carga espacial llamada “Zona de Deplexion”
- En la zona de deplexion hay campo eléctrico de magnitud E

JUNTURA P-N EN EQUILIBRIO





$$J_{Dp} = q\ D_p\ \frac{dp_n(x)}{dx} \qquad\qquad J_{\mu p} = q\ \mu_p\ p_n(x)\ E(x)$$

En equilibrio $\Rightarrow$ $\boxed{J_{Dp} = J_{\mu p}}$

$$q\ D_p\ \frac{dp_n(x)}{dx} = q\ \mu_p\ p_n(x)\ E(x)$$

$$E(x) = \frac{D_p}{\mu_p}\frac{1}{p_n(x)}\frac{dp_n(x)}{dx}$$

Campo que establece la condición de equilibrio $\Rightarrow$ $\boxed{E(x) = U_T\frac{1}{p_n(x)}\frac{dp_n(x)}{dx}}$

$$V_{j0} = -\int_{-x_p}^{x_n} E(x)dx \qquad V_{j0} = -U_T \int_{-x_p}^{x_n} \frac{dp_n(x)}{p_n(x)}$$

$$V_{j0} = -U_T \ln p_n(x) \Big|_{-x_p}^{x_n} \qquad V_{j0} = -U_T[\ln p_n(-x_p) - \ln p_n(x_n)]$$

$$V_{j0} = U_T ln \frac{p_n(-x_p)}{p_n(x_n)} \qquad V_{j0} = U_T ln \frac{p_{p0}}{p_{n0}}$$

$$p_{p0} \approx N_A$$

$$p_{n0} = \frac{n_i^2}{N_D}$$

Tensión de juntura para equilibrio

$$\boxed{V_{j0} = U_T \; ln \frac{N_A N_D}{n_i^2}}$$

$$V_{j0} = U_T ln \frac{p_n(-x_p)}{p_n(x_n)} \qquad \frac{V_{jo}}{U_T} = ln \frac{p_n(-x_p)}{p_n(x_n)} \qquad e^{V_{j0}/U_T} = \frac{p_n(-x_p)}{p_n(x_n)}$$

$$p_n(-x_p) = p_n(x_n)e^{\left(V_{j0}/U_T\right)} \qquad p_n(x_n) = p_n(-x_p)e^{\left(-V_{j0}/U_T\right)}$$

Concentraciones de huecos de la juntura en equilibrio

$$\boxed{p_n(x_n) = p_{n0}}$$

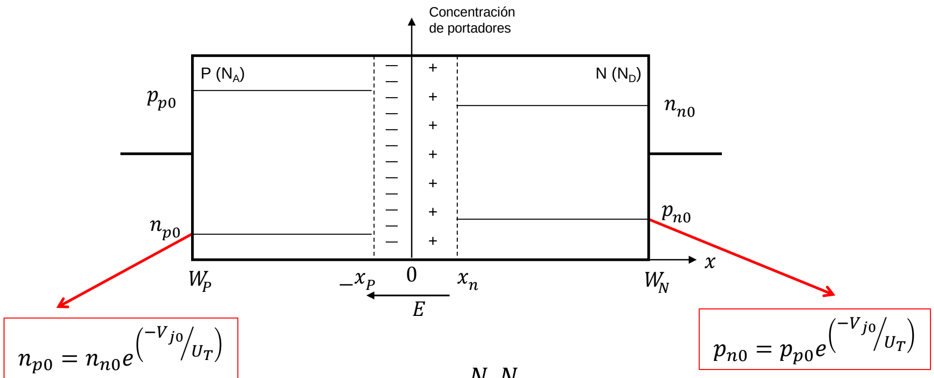
$$\boxed{p_n(-x_p) = p_{p0}}$$

Analizando la concentración de electrones

$$\boldsymbol{p_{n0} = p_{p0} \; e^{\left(-V_{j0}/U_T\right)}}$$

$$\boldsymbol{n_{p0} = n_{n0} \; e^{\left(-V_{j0}/U_T\right)}}$$

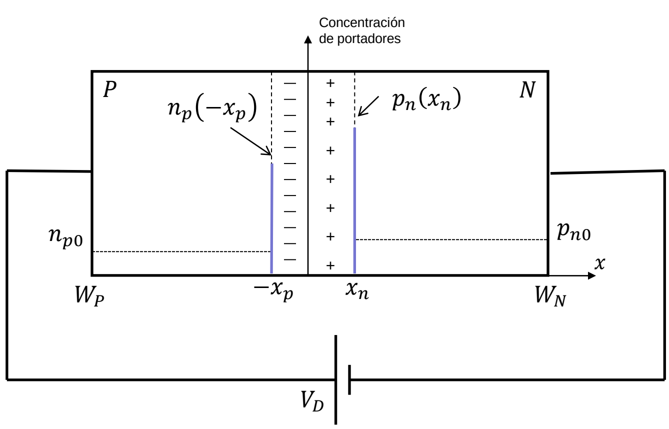
JUNTURA P-N EN EQUILIBRIO



$$V_{j0} = U_T ln \frac{N_A N_D}{n_i^2}$$

- Con la juntura en equilibrio en la zona de deplexion se establece un potencial Vj_0
- Las concentraciones de huecos y electrones en los bordes de la zona de deplexion están relacionadas por la exponencial $e^{\left(-V_{jo}/U_T\right)}$

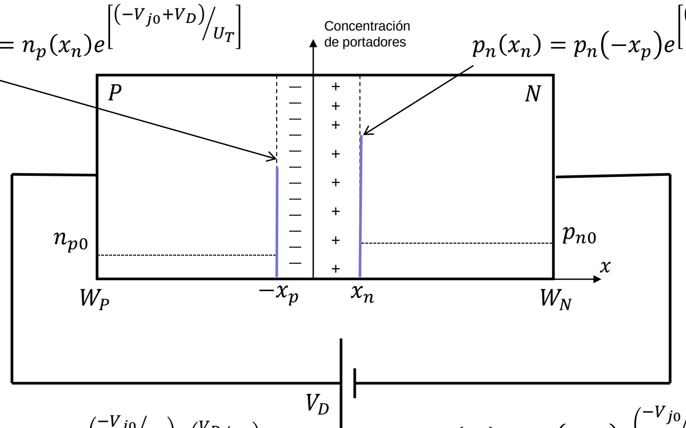
JUNTURA P-N CON POLARIZACION DIRECTA



- Aplicamos una tensión exterior V_D
- La tensión a través de la zona de deplexion es $\left(-V_{jo} + V_D\right)$
- Al cambiar la tensión las nuevas concentraciones de portadores son:

$$n_p(-x_p) = n_{n0} e^{\left[\left(-V_{j0}+V_D\right)/U_T\right]} \qquad p_n(x_n) = p_{p0} e^{\left[\left(-V_{j0}+V_D\right)/U_T\right]}$$

$$n_p(-x_p) = n_p(x_n)e^{\left[\left(-V_{j0}+V_D\right)/U_T\right]} \qquad p_n(x_n) = p_n(-x_p)e^{\left[\left(-V_{j0}+V_D\right)/U_T\right]}$$



$$n_p(-x_p) = n_p(x_n)e^{\left(-V_{j0}/U_T\right)}e^{\left(V_D/U_T\right)} \qquad p_n(x_n) = p_n(-x_p)e^{\left(-V_{j0}/U_T\right)}e^{\left(V_D/U_T\right)}$$

$$n_p(x_n) = n_{n0} \qquad n_{n0}e^{\left(-V_{j0}/U_T\right)} = n_{p0} \qquad p_n(-x_p) = p_{p0} \qquad p_{p0}e^{\left(-V_{j0}/U_T\right)} = p_{n0}$$

$$n_p(-x_p) = n_{n0}\, e^{\left(-V_{j0}/U_T\right)}e^{\left(V_D/U_T\right)} \qquad p_n(x_n) = p_{p0}\, e^{\left(-V_{j0}/U_T\right)}e^{\left(V_D/U_T\right)}$$

$$n_p(-x_p) = n_{p0}e^{\left(V_D/U_T\right)} \qquad p_n(x_n) = p_{n0}e^{\left(V_D/U_T\right)}$$

- Como consecuencia de la tensión V_D se produce:
    - Una inyección de huecos [$p_n(x_n)$] de la zona P a la N
    - Una inyección de electrones [$n_p(-x_p)$] de la zona N a la P

LEY DE LA JUNTURA

$$\boxed{n_p(-x_p) = n_{p0}e^{\left(V_D/U_T\right)}} \qquad \boxed{p_n(x_n) = p_{n0}e^{\left(V_D/U_T\right)}}$$

- Podemos calcular como se distribuyen los electrones y huecos inyectados aplicando la ecuación de continuidad en la zona N y P
- Las condiciones iniciales para aplicar la ecuación de continuidad son

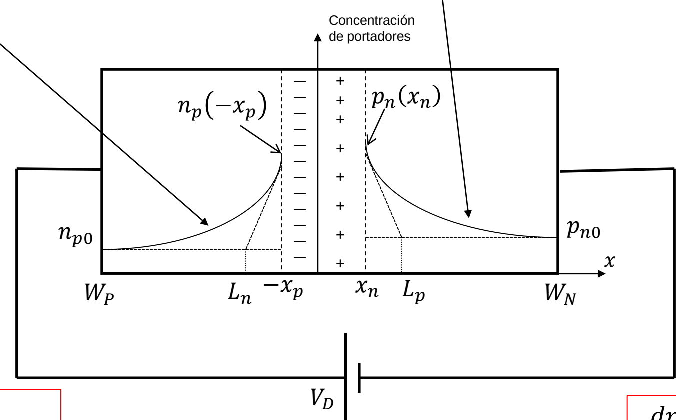
$$\boxed{E = 0} \qquad \boxed{\frac{dp_n}{dt} = \frac{dn_p}{dt} = 0} \qquad \boxed{p_n(x_n) = p_{n0}e^{\left(V_D/U_T\right)}} \qquad \boxed{n_p(-x_p) = n_{p0}e^{\left(V_D/U_T\right)}}$$

- La solución de la ecuación de continuidad nos dará

$$\boxed{p_n(x)} \qquad \boxed{n_p(x)}$$

$$n_p(x) = [n_p(-x_p) - n_{p0}]\, e^{\frac{(x+x_p)}{L_n}} + n_{p0}$$

$$p_n(x) = [p_n(x_n) - p_{n0}]\, e^{\frac{(-x+x_n)}{L_p}} + p_{n0}$$



$$\frac{dn_p(x)}{dx} \neq 0$$

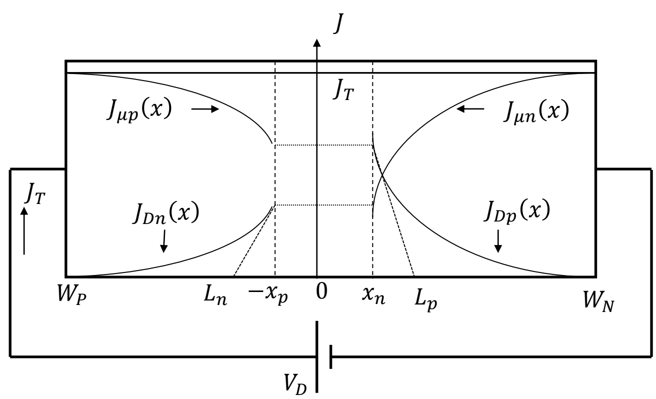
$$\frac{dp_n(x)}{dx} \neq 0$$

Tendremos corrientes por difusión de huecos en la zona N y electrones en la zona P

$$J_n(x) = q\, D_n \frac{dn(x)}{dx}$$

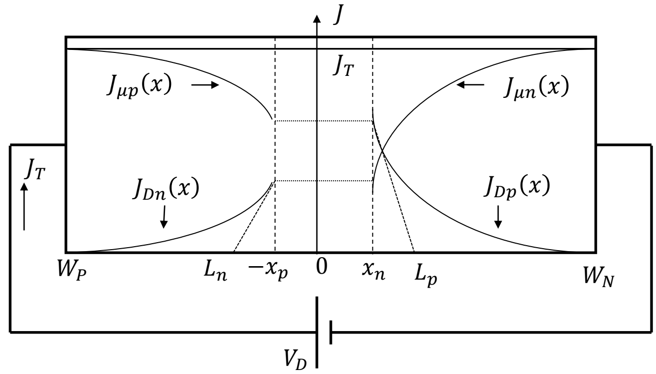
$$J_p(x) = -q\, D_p \frac{dp(x)}{dx}$$

CORRIENTES EN LA JUNTURA P-N POLARIZADA DIRECTA



$$J_{Dn}(x) = \frac{qD_n[n_p(-x_p) - n_{p0}]}{L_n}\, e^{\left(\frac{x+x_p}{L_n}\right)} \longrightarrow para\ x \leq -x_p$$

$$J_{Dp}(x) = \frac{qD_p[p_n(x_n) - p_{n0}]}{L_p}\, e^{\left(\frac{-x+x_n}{L_p}\right)} \longrightarrow para\ x \geq x_n$$



$$J_T = cte.$$

$$J_T = J_{Dn}(x) + J_{\mu p}(x) \longrightarrow para\ x \leq -x_p$$

$$J_T = J_{Dp}(x) + J_{\mu n}(x) \longrightarrow para\ x \geq x_n$$

$$J_T = J_{\mu n}(W_N) = J_{\mu p}(-W_P)$$

$$J_T = J_{Dp}(x_n) + J_{Dn}(-x_p)$$

ECUACION DE LA JUNTURA P-N

$$J_T = J_{Dp}(x_n) + J_{Dn}(-x_p)$$

$$\boxed{J_{Dp}(x) = \frac{qD_p[p_n(x_n) - p_{n0}]}{L_p}\ e^{\left(\frac{-x+x_n}{L_p}\right)}} \longrightarrow \boxed{J_{Dp}(x_n) = \frac{qD_p[p_n(x_n) - p_{n0}]}{L_p}}$$

$$p_n(x_n) = p_{n0}e^{\left(V_D/U_T\right)}$$

$$\boxed{J_{Dp}(x_n) = \frac{qD_p p_{n0}}{L_p}\left[e^{\left(V_D/U_T\right)} - 1\right]}$$

$$\boxed{J_{Dn}(x) = \frac{qD_n[n_p(-x_p) - n_{p0}]}{L_n}\ e^{\left(\frac{x+x_p}{L_n}\right)}} \longrightarrow \boxed{J_{Dn}(-x_p) = \frac{qD_n[n_p(-x_p) - n_{p0}]}{L_n}}$$

$$n_p(-x_p) = n_{p0}e^{\left(V_D/U_T\right)}$$

$$\boxed{J_{Dn}(-x_p) = \frac{qD_n n_{p0}}{L_n}\left[e^{\left(V_D/U_T\right)} - 1\right]}$$

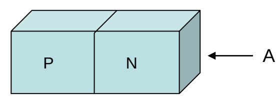
$$\boxed{J_T = \left[\frac{qD_p p_{n0}}{L_p} + \frac{qD_n n_{p0}}{L_n}\right]\left[e^{\left(V_D/U_T\right)} - 1\right]}$$

$$J_T = J_s \left[e^{\left(V_D/U_T \right)} - 1 \right]$$

$$J_s = \left[\frac{qD_p p_{n0}}{L_p} + \frac{qD_n n_{p0}}{L_n} \right]$$

$$n_{p0} = \frac{n_i^2}{N_A} \qquad\qquad p_{n0} = \frac{n_i^2}{N_D}$$

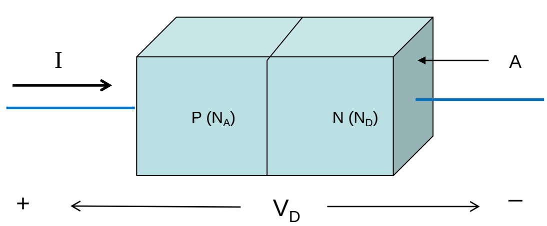
$$J_s = qn_i^2 \left[\frac{qD_p}{L_p N_D} + \frac{qD_n}{L_n N_A} \right]$$



$$I_s = J_s \times A \longrightarrow \boxed{J_s = qn_i^2 A \left[\frac{D_p}{L_p N_D} + \frac{D_n}{L_n N_A} \right]}$$

$$I = J \times A \longrightarrow \boxed{I = I_s \left[e^{\left(V_D/U_T \right)} - 1 \right]}$$

Ecuación de la Juntura P - N

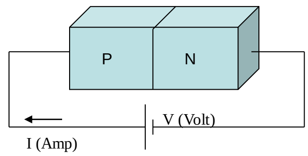


Depende de la polarización $\boxed{I = I_s \left[e^{\left(V_D/U_T \right)} - 1 \right]}$

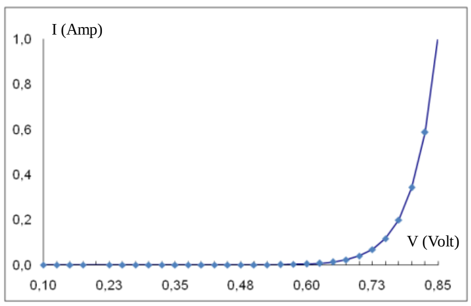
Depende de la fabricación $\boxed{I_s = qn_i^2 A \left[\frac{D_p}{L_p N_D} + \frac{D_n}{L_n N_A} \right]}$

CARACTERISTICA V- I JUNTURA P-N

$I_s = 1{,}1 \times 10^{-8}$



$$I = I_s \left[\exp (V_D/U_T) - 1 \right]$$



V	I
0,1	8,39E-08
0,125	1,52E-07
0,15	2,68E-07
0,175	4,68E-07
0,2	8,09E-07
0,225	1,40E-06
0,25	2,40E-06
0,275	4,13E-06
0,3	7,08E-06
0,325	1,22E-05
0,35	2,08E-05
0,375	3,58E-05
0,4	6,13E-05
0,425	1,05E-04
0,45	1,80E-04
0,475	3,09E-04
0,5	5,30E-04
0,525	9,09E-04
0,55	1,56E-03
0,575	2,67E-03
0,6	4,58E-03
0,625	7,86E-03
0,65	1,35E-02
0,675	2,31E-02
0,7	3,96E-02
0,725	6,79E-02
0,75	1,17E-01
0,775	2,00E-01
0,8	3,43E-01
0,825	5,87E-01
0,85	1,01E+00