# Electronic Devices

## Lecture 3
## P-N Junction

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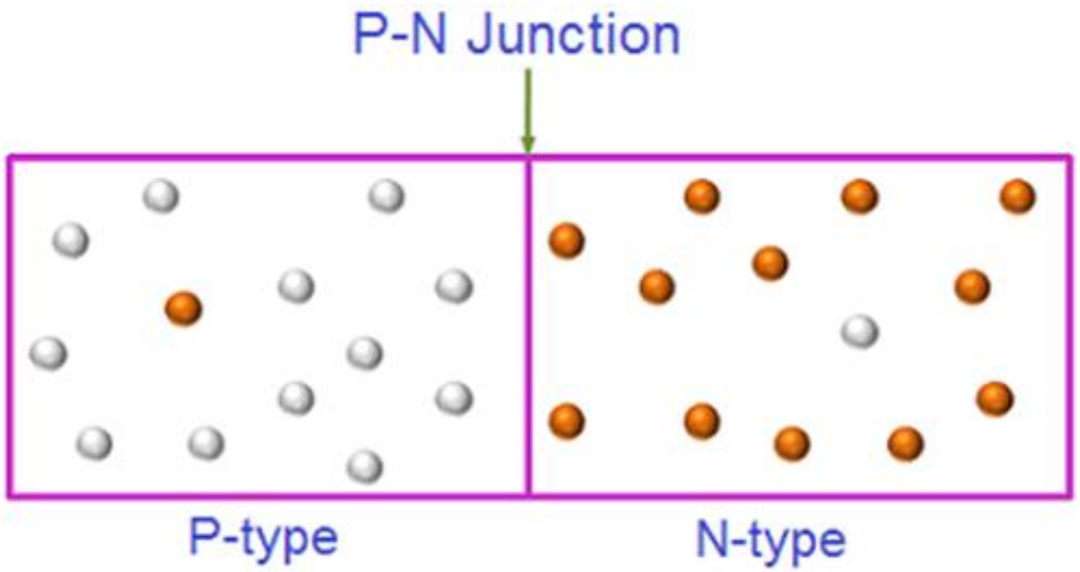
# P-N Junction Diode

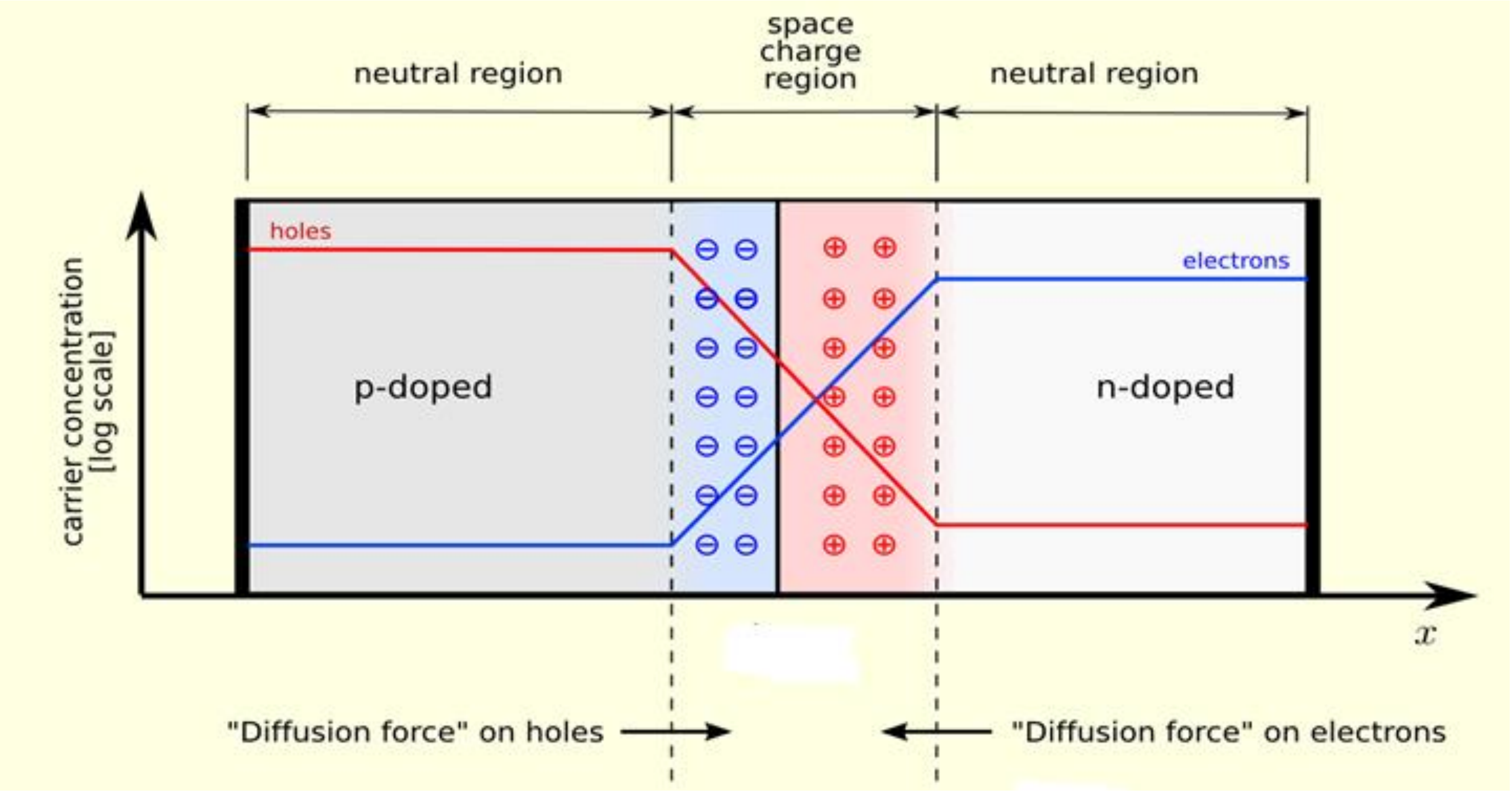
# P-N Junction Diode

- P-N junction is formed when a single crystal of semiconductor is doped with acceptors on one side and donors on the other side.

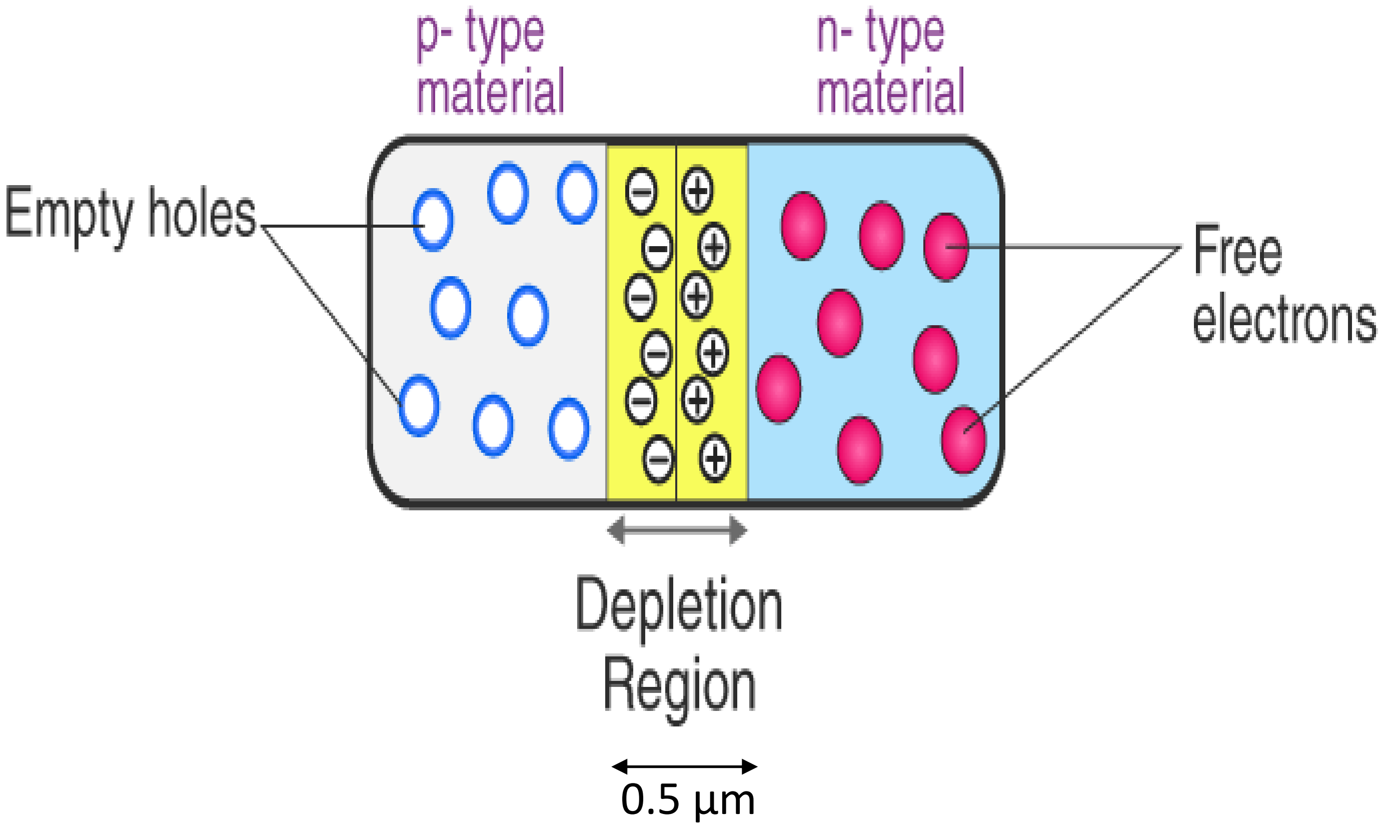


# Equilibrium P-N junction :

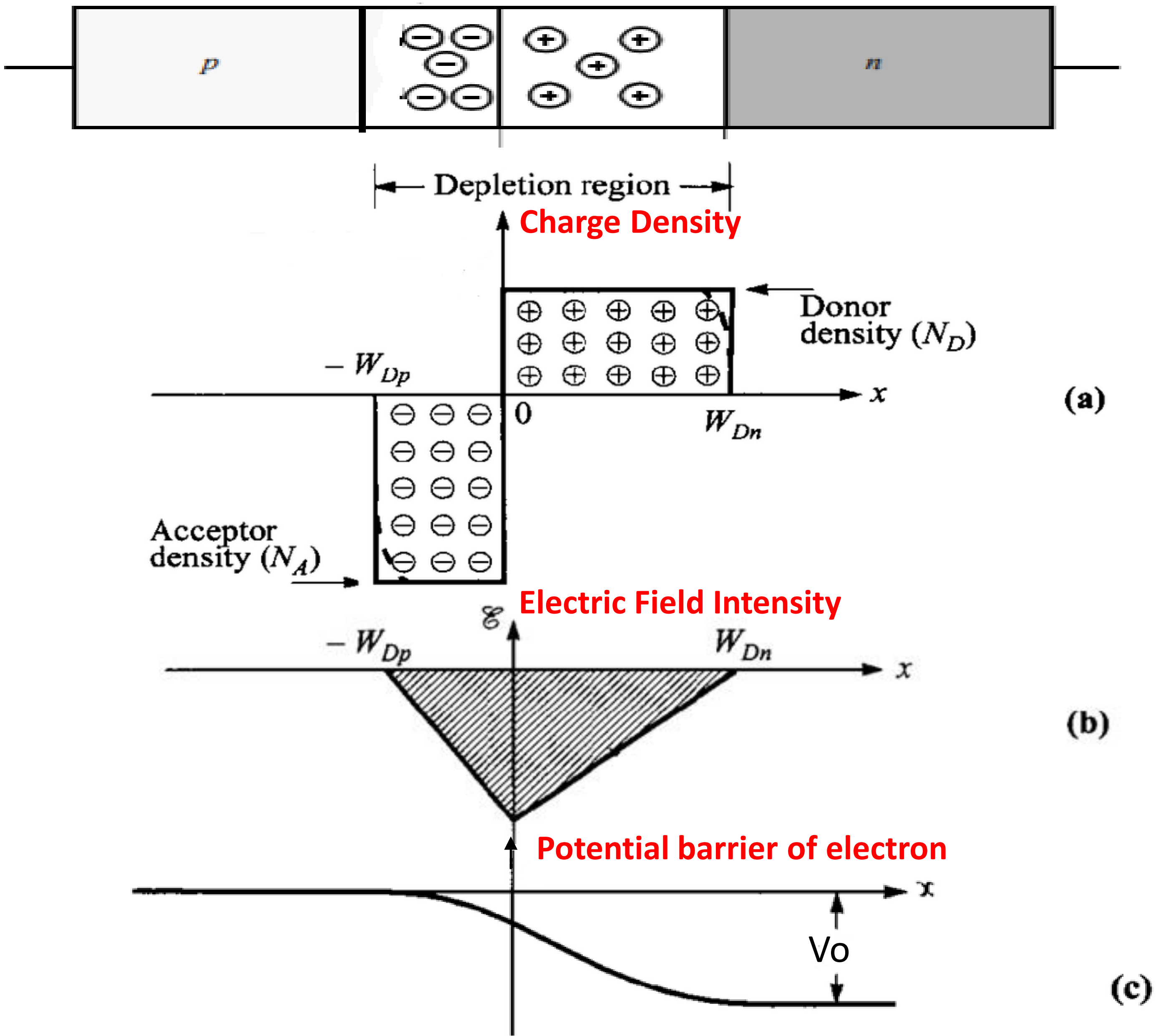
- Uniform doping in each region
- Thermal equilibrium



- A diffusion of free carriers due to the non-uniform concentration of charges between the two regions.



# Open Circuit P-N Junction



$$V_o = \frac{KT}{q} \ln\left(\frac{N_A N_D}{ni^2}\right) = V_T \ln\left(\frac{N_A N_D}{ni^2}\right)$$

$V_T$= 26 mv at room temperature (300 K)

K: Boltzman Constant

$N_A$: Acceptor Concentration

$N_D$: Donor Concentration

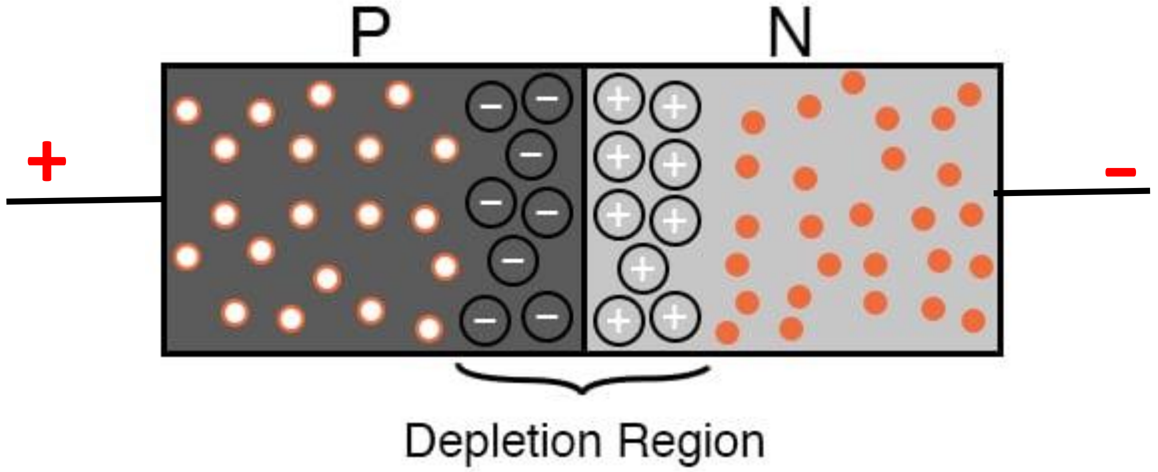
$ni$: Intrinsic Concentration

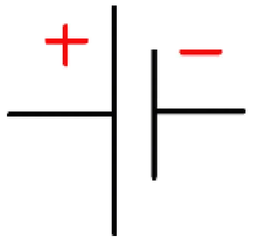
$\frac{K\,T}{q}$ ≈ 0.026 V = VT

# Biased P-N Junction

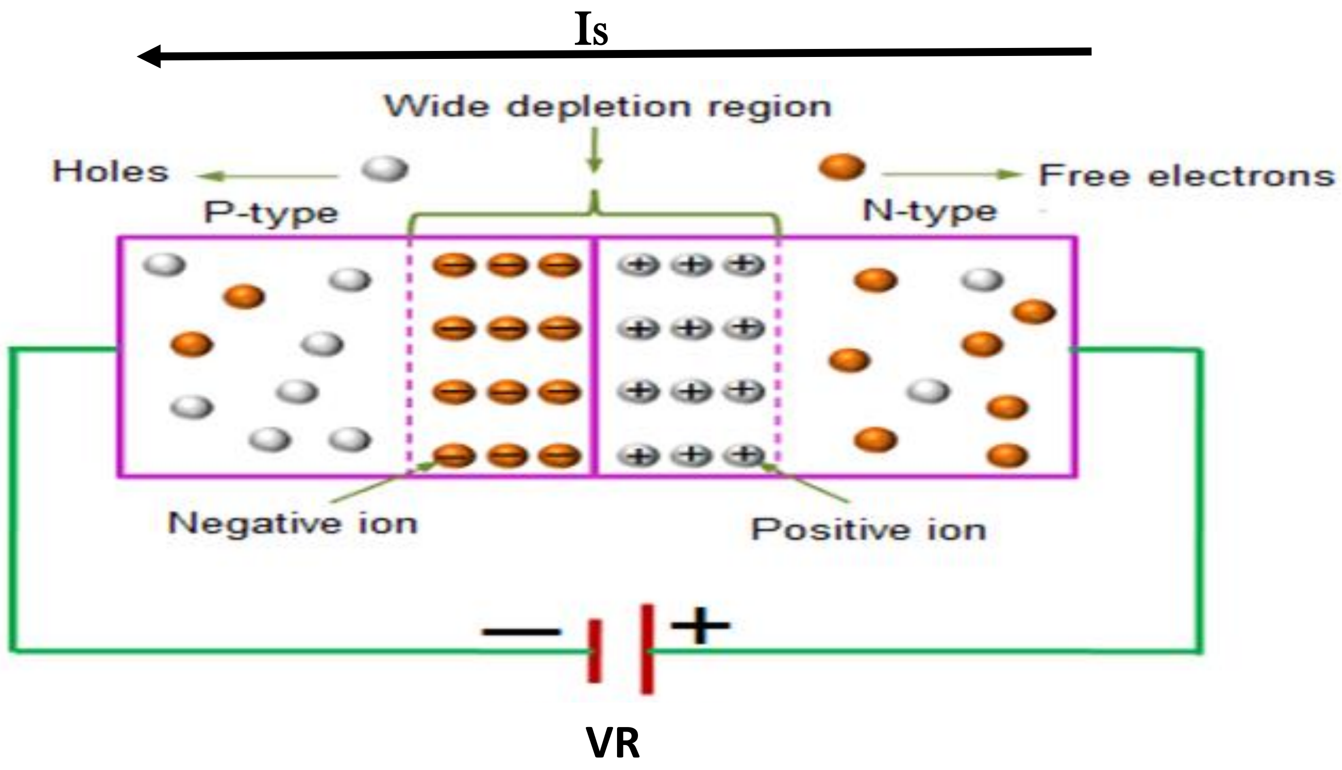
- Reverse Biased P-N junction (التوصيل المعكوس)

- Forward Biased P-N junction (التوصيل الامامي)



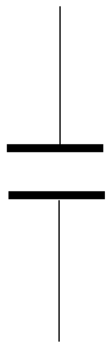
# Reverse Biased P-N Junction



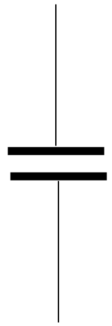

Reverse bias

# Capacitor:

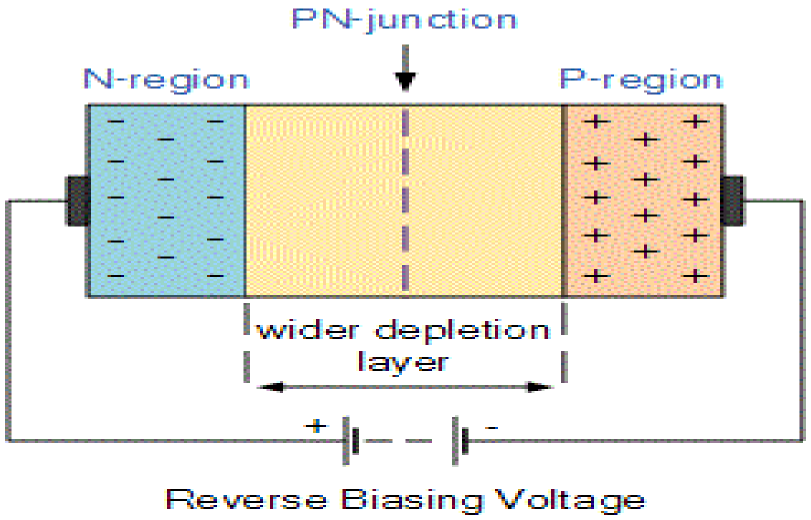
- Used to store energy electrostatically.
- Contains 2 electrical conductors separated by dielectric.
- $C = \dfrac{Q}{V}$
- $V = \mathcal{E}\,L$
- $C = \dfrac{Q}{\mathcal{E}\,L}$



**More Space**
**Less Capacitance**



**Less Space**
**More Capacitance**



# Reverse Biased P-N Junction

- The P-N junction operates as a capacitor.
- The junction Capacitance can be written as :
- $C_j = C_{jo} \left(1 + \frac{V_R}{V_o}\right)^{-\frac{1}{2}}$

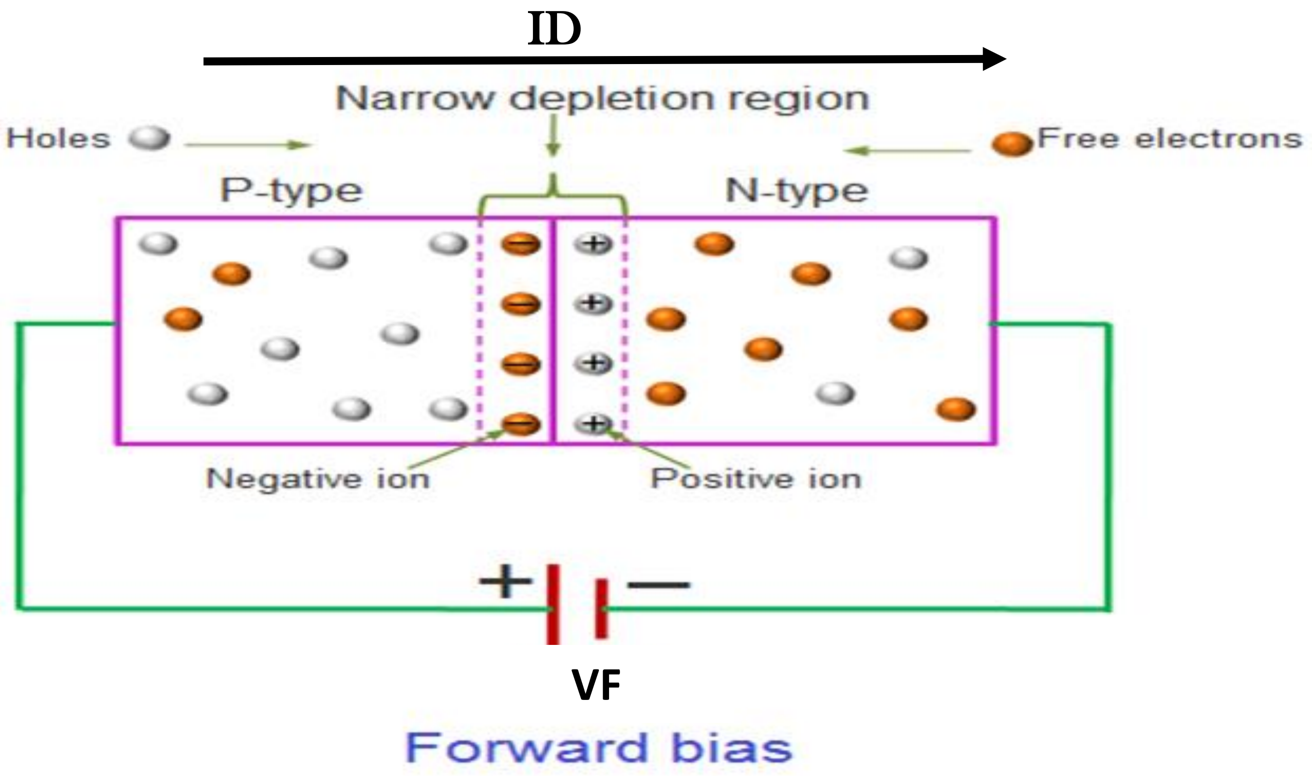
$C_{jo}$ : *the junction capacitance at zero applied voltage.*

$V_R$ : *the reverse battery voltage.*

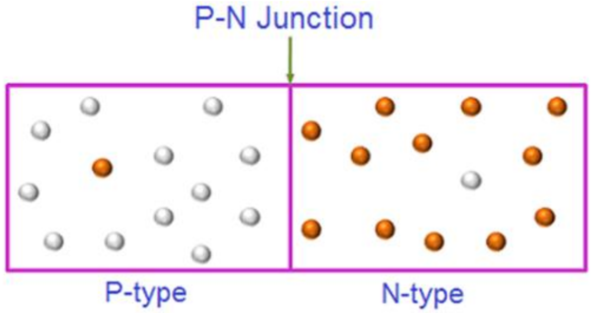
$V_o$ : *the potential barrier.*

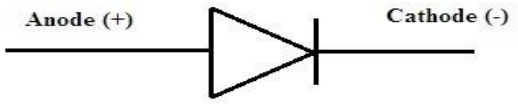
# Forward Biased P-N Junction

- Steady State minority Carrier Concentrations in a P-N junction under forward bias.
- The gradients in the minority carrier concentrations generate diffusion currents in the device.



# Diode symbol




- Diode current voltage Relation :

$$I_D = I_s \left( e^{\frac{V_D}{\eta V_T}} - 1 \right)$$

$V_D$ : *Voltage across diode*
$I_D$ : *Diode current*
$I_s$ : *Reverse sturation current*
$V_T$: *Thermal voltage*
$\eta$: *Ideality Factor Constant ( Si $\eta$=2, Ge $\eta$=1)*