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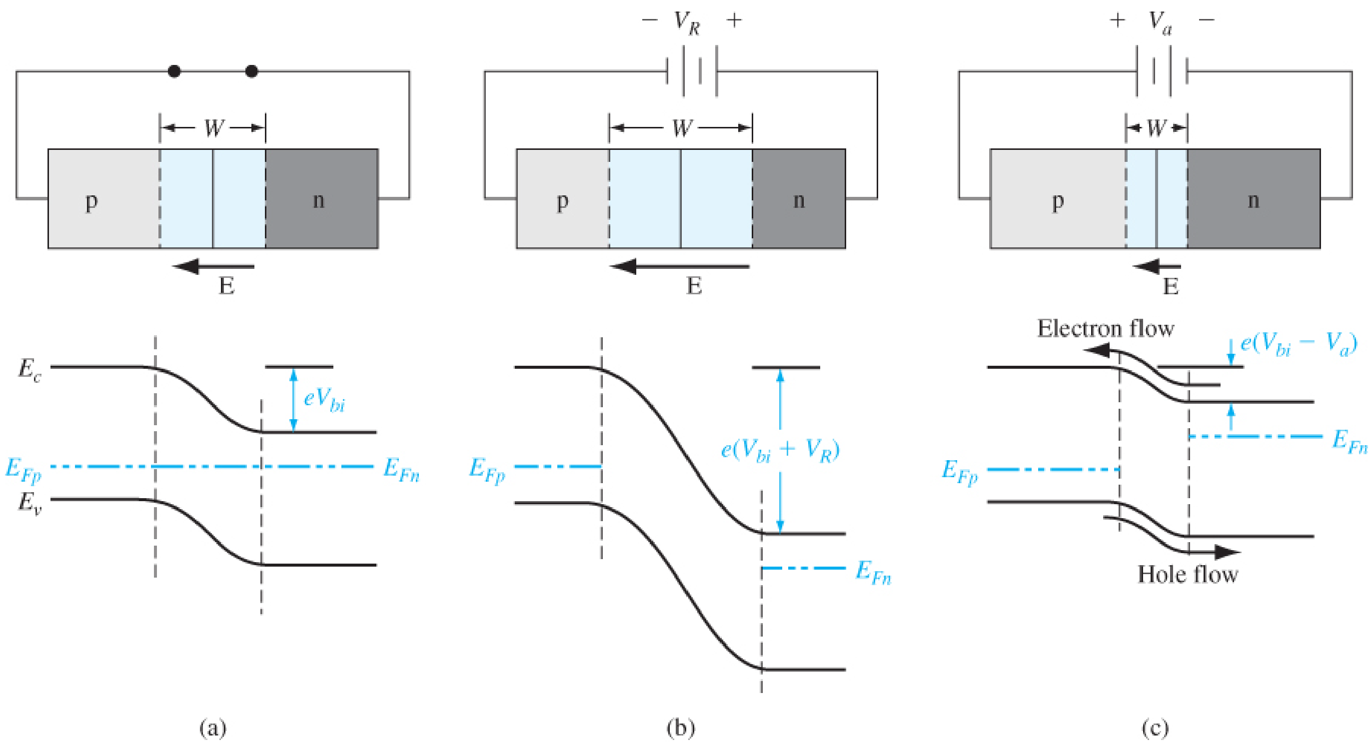

Figure 8.1 | A pn junction and its associated energy-band diagram for (a) zero bias, (b) reverse bias, and (c) forward bias.

No external bias (a)/left- There is a built-in potential V_{bi} and potential energy barrier eV_{bi} keeping electrons/holes from flowing (no current) and a space region width W and electric field E.

Reverse bias (b)/middle- There is a total potential of $V_R + V_{bi}$ and potential energy barrier $e(V_R + V_{bi})$ keeping electrons/holes from flowing (~no current until breakdown). Space region width W and electric field E increases.

Forward bias (c)/right- There is a total potential of $V_{bi} – V_a$ and potential energy barrier $e(V_{bi} – V_a)$ allowing electrons/holes to flow (current flows from left to right). Space region width W and electric field E decreases.

Key assumptions to find Ideal *I-V* Relationship

- Abrupt Junction – Clear dividing line between p-type material and n-type material.
- Abrupt Space Charge Region – The edges of the space charge region are well defined and abrupt.
- Boltzmann Approximation applies – The doping concentrations used in both materials are low enough that $E_F > 3k_BT$ away from the conduction and valence band edges.
- Low-Level Injection – The quantity of minority holes and electrons injected across the pn junction are small enough to be "low-level".
- Total current through the pn structure is constant – We do not violate Kirchoff's Current Law; the amount of current that flows into one terminal is that same amount of current that flows out the other terminal and all points in between.
- Each electron and hole current component is continuous – No black holes or antimatter allowed!
- The electron and hole currents are constant in the depletion region – No recombination in the depletion region.

Definitions (all with typical units of #/cm^3)

N_a	Acceptor concentration in p region of the pn junction
N_d	Donor concentration in n region of the pn junction
$n_{n0} = N_d$	Thermal-equilibrium majority carrier electrons in n region
$p_{p0} = N_a$	Thermal-equilibrium majority carrier holes in p region
$n_{p0} = n_i^2/N_a$	Thermal-equilibrium minority carrier electrons in p region
$p_{n0} = n_i^2/N_d$	Thermal-equilibrium minority carrier holes in n region
n_p	Total minority carrier electron concentration in p region
p_n	Total minority carrier hole concentration in n region
$n_p(-x_p)$	Minority carrier electrons in p region at space charge edge
$p_n(x_n)$	Minority carrier holes in n region at space charge edge
$\delta n_p = n_p - n_{p0}$	Excess minority carrier electron concentration in p region
$\delta p_n = p_n - p_{n0}$	Excess minority carrier hole concentration in n region