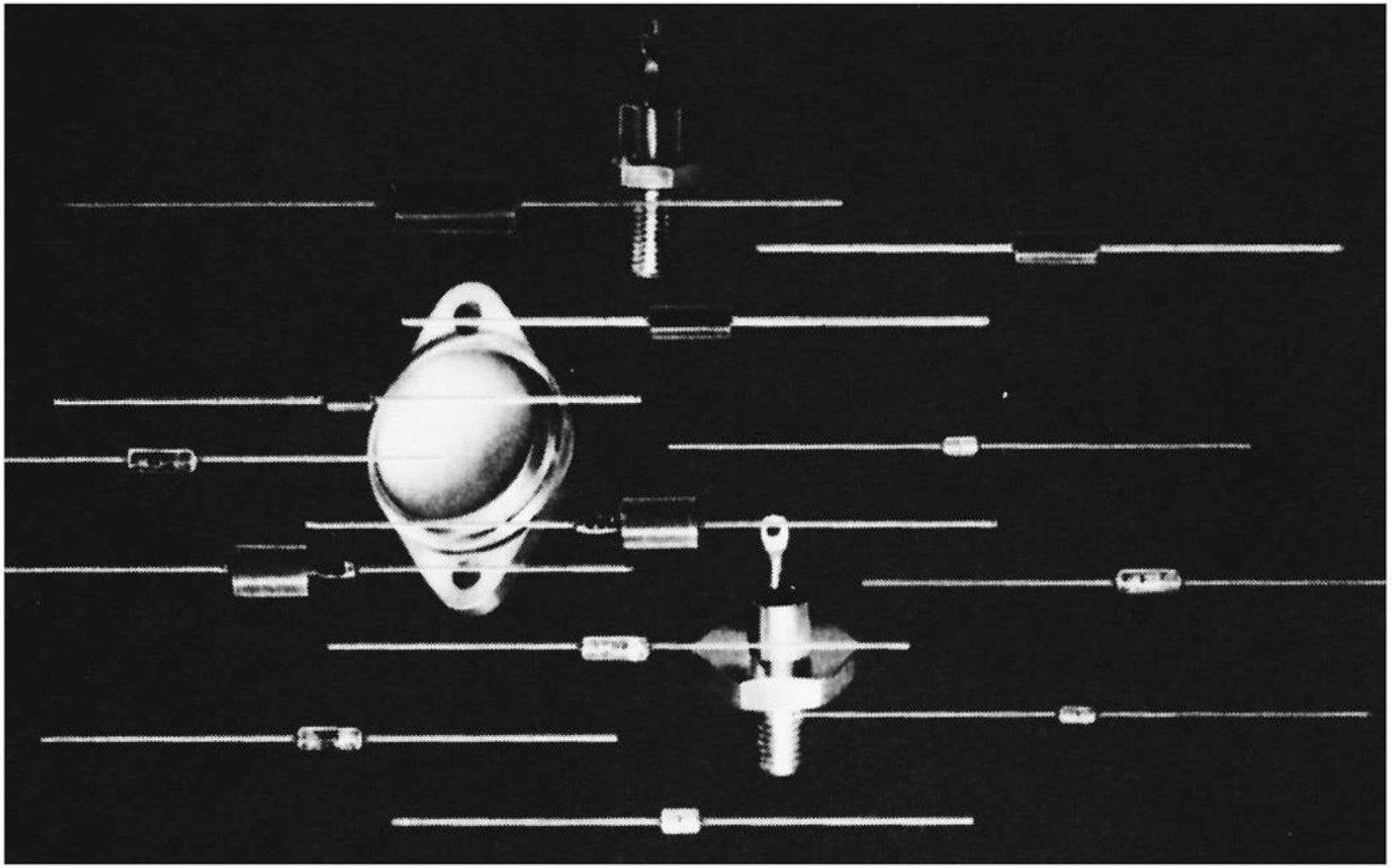
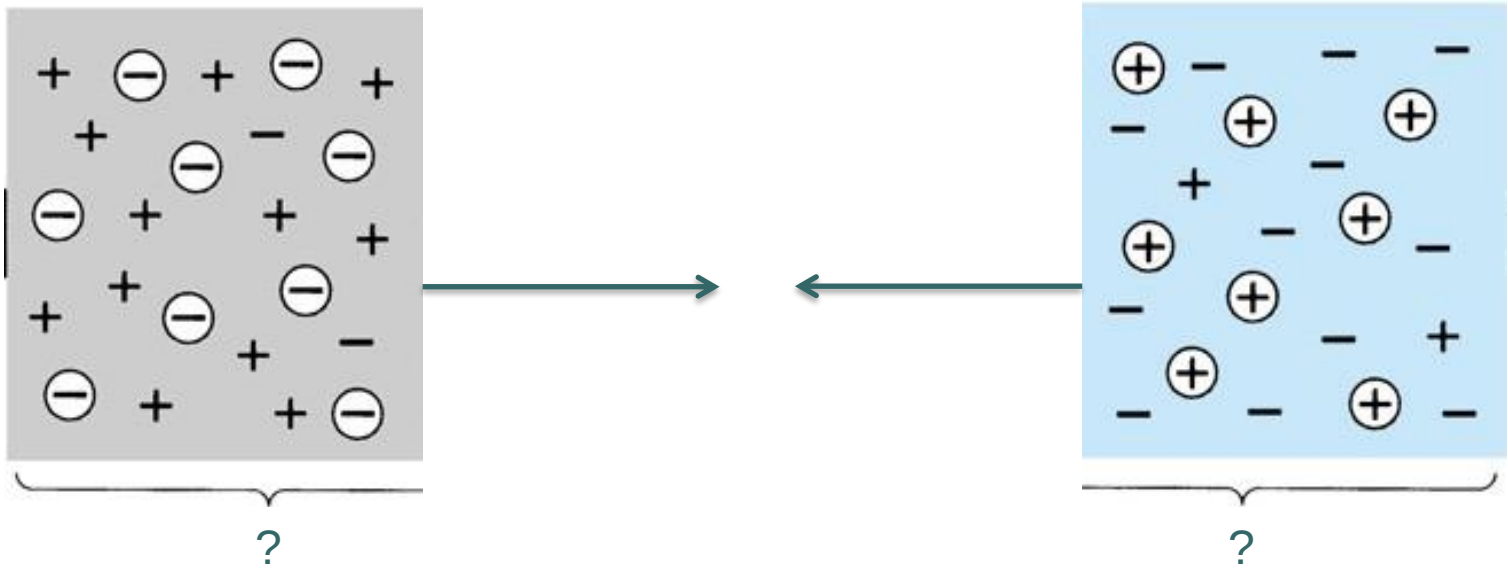
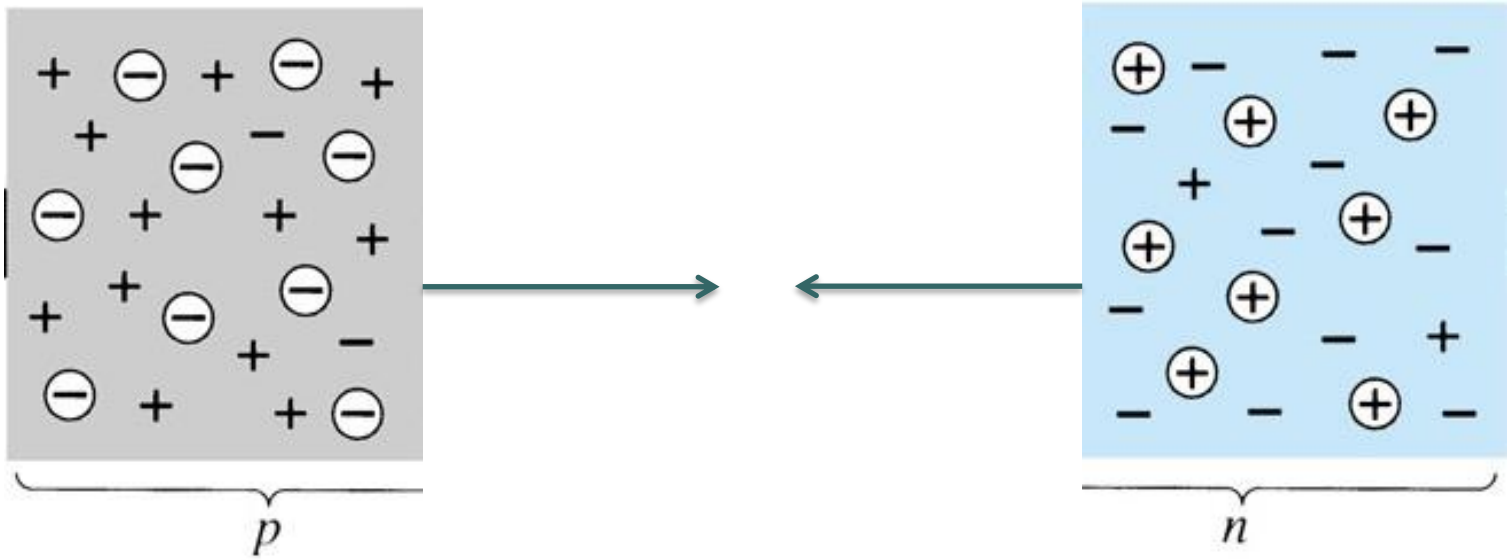
Diodos de Junção PN



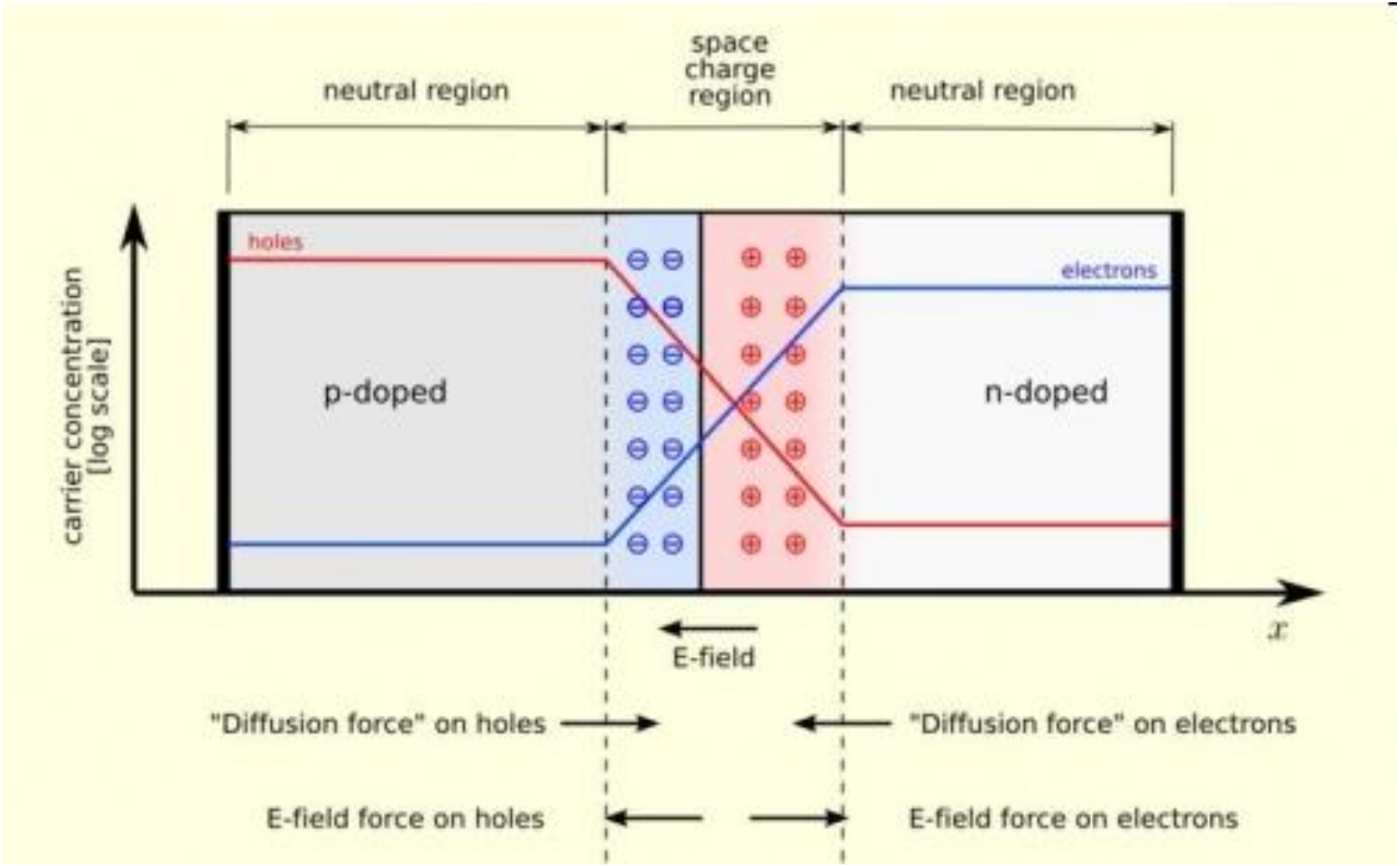
Junção PN



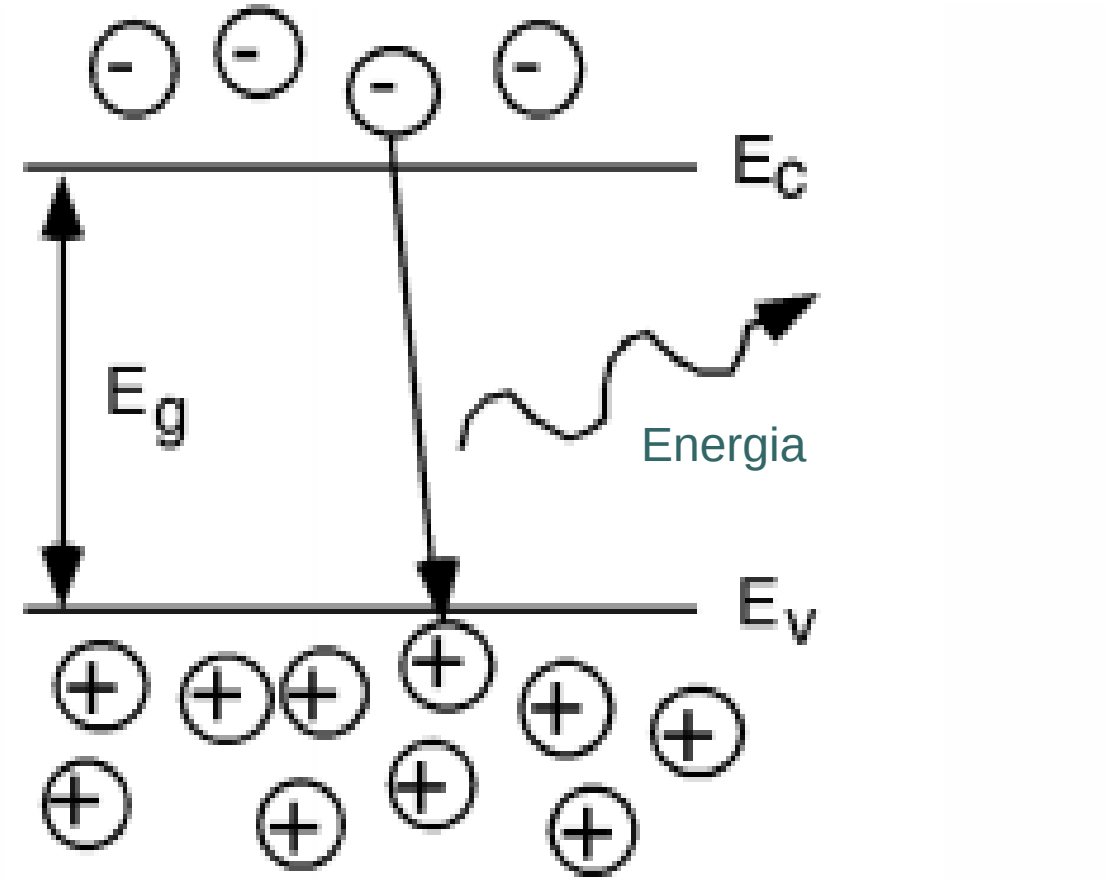
Junção PN



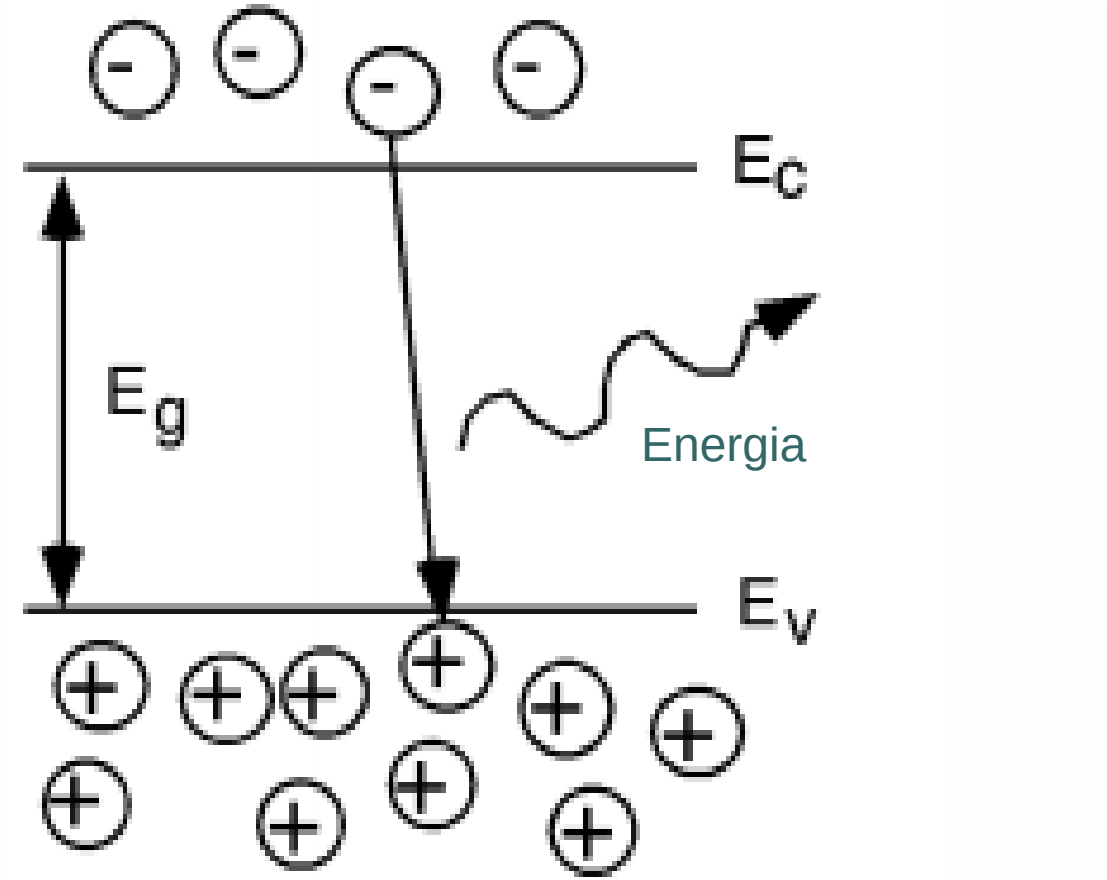
Junção PN


neutral region
space charge region
neutral region
holes
electrons
p-doped
n-doped
carrier concentration [log scale]
x
E-field
"Diffusion force" on holes
"Diffusion force" on electrons
E-field force on holes
E-field force on electrons

Recombinação elétron-lacuna



Recombinação elétron-lacuna

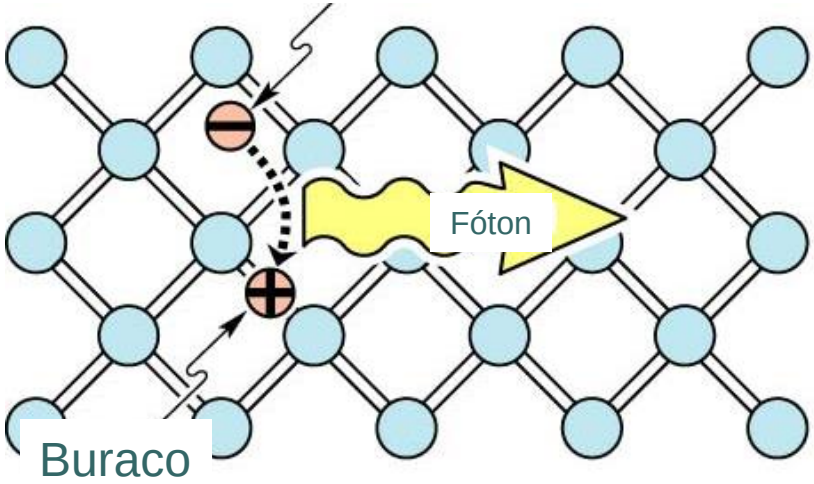


A probabilidade de recombinação é proporcional à densidade de portadores.

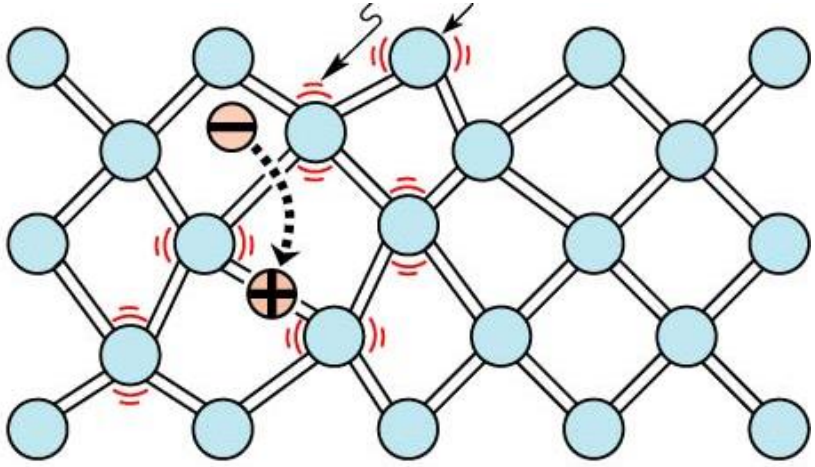
Recombinação elétron-lacuna

Duas formas:

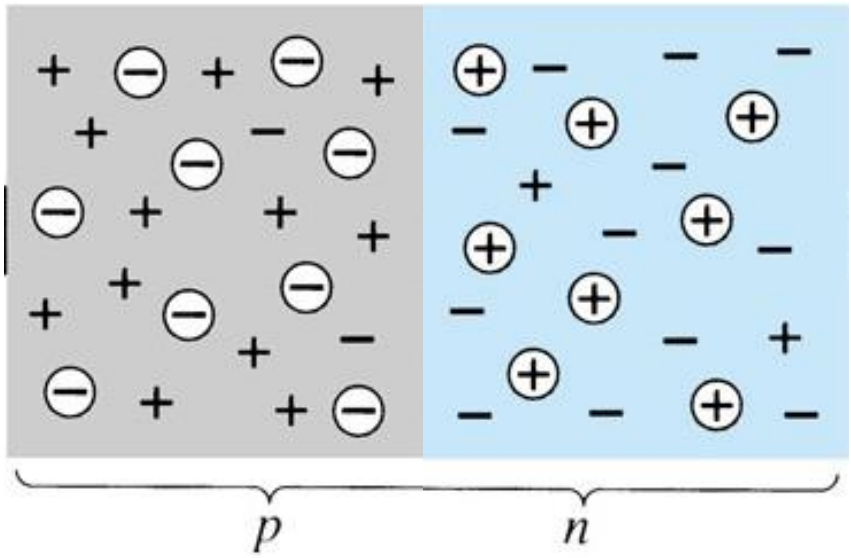
Elétron livre



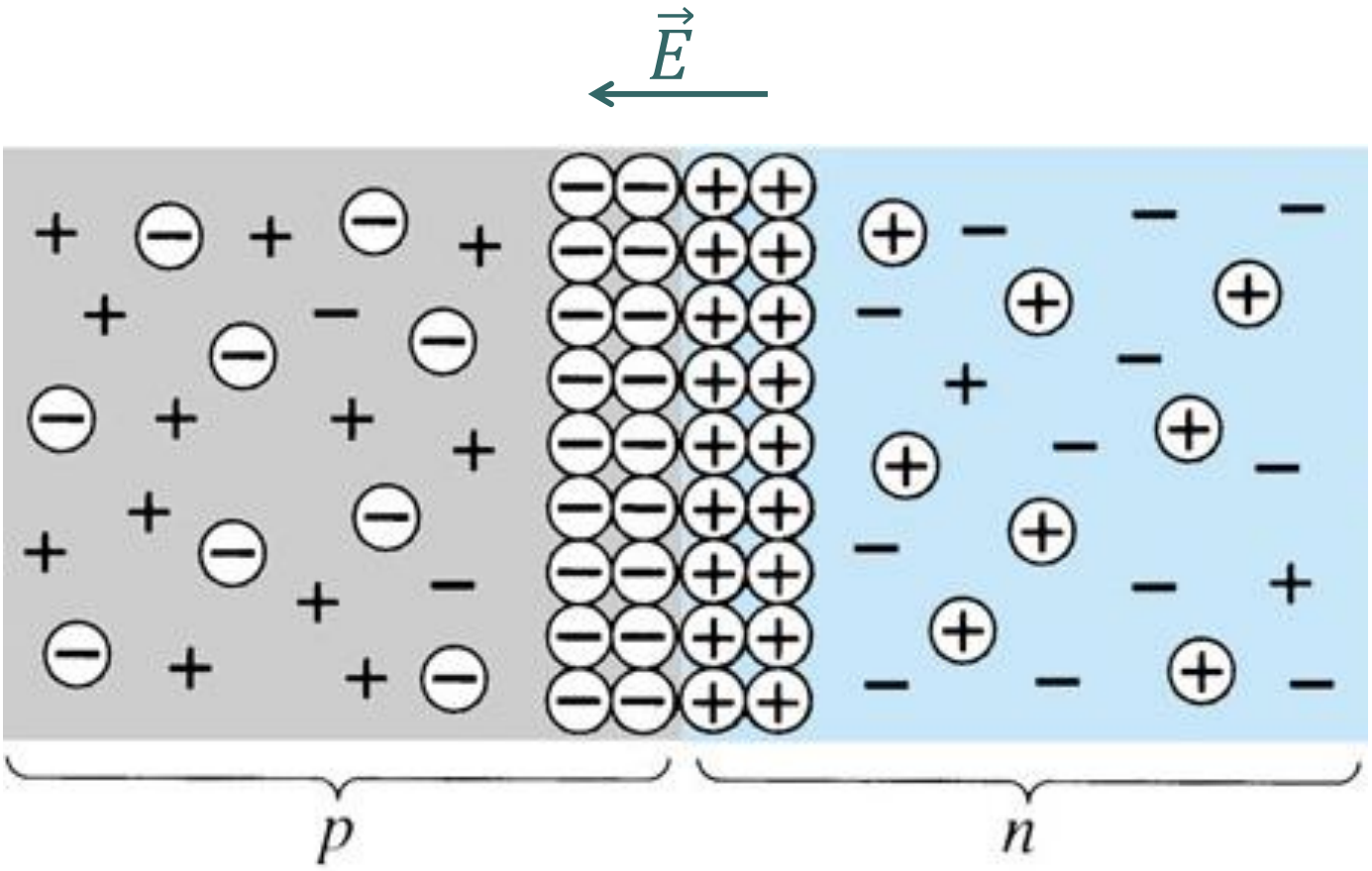
Vibração (Fónon)



Diodo de Junção PN

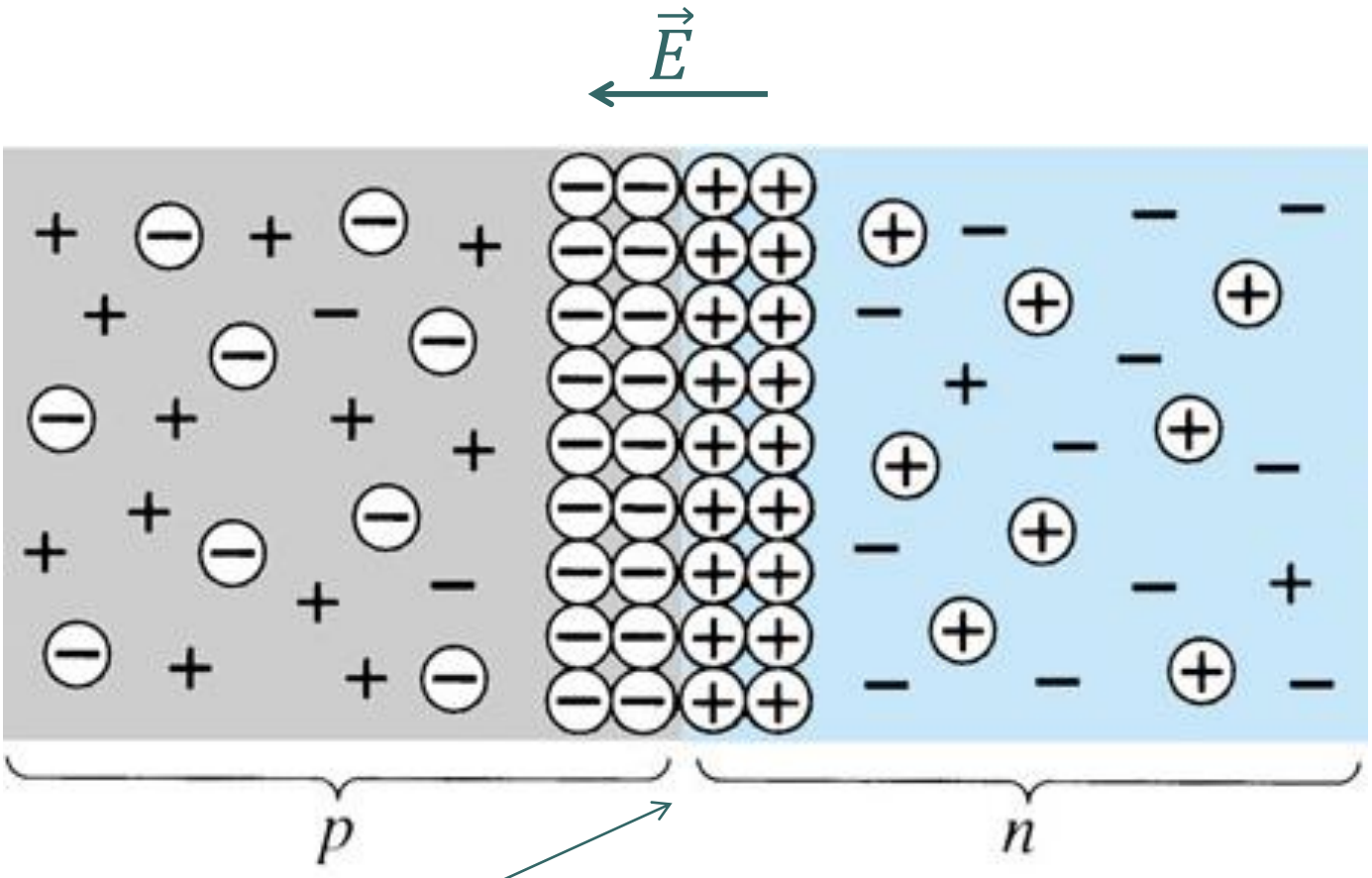


Diodo de Junção PN



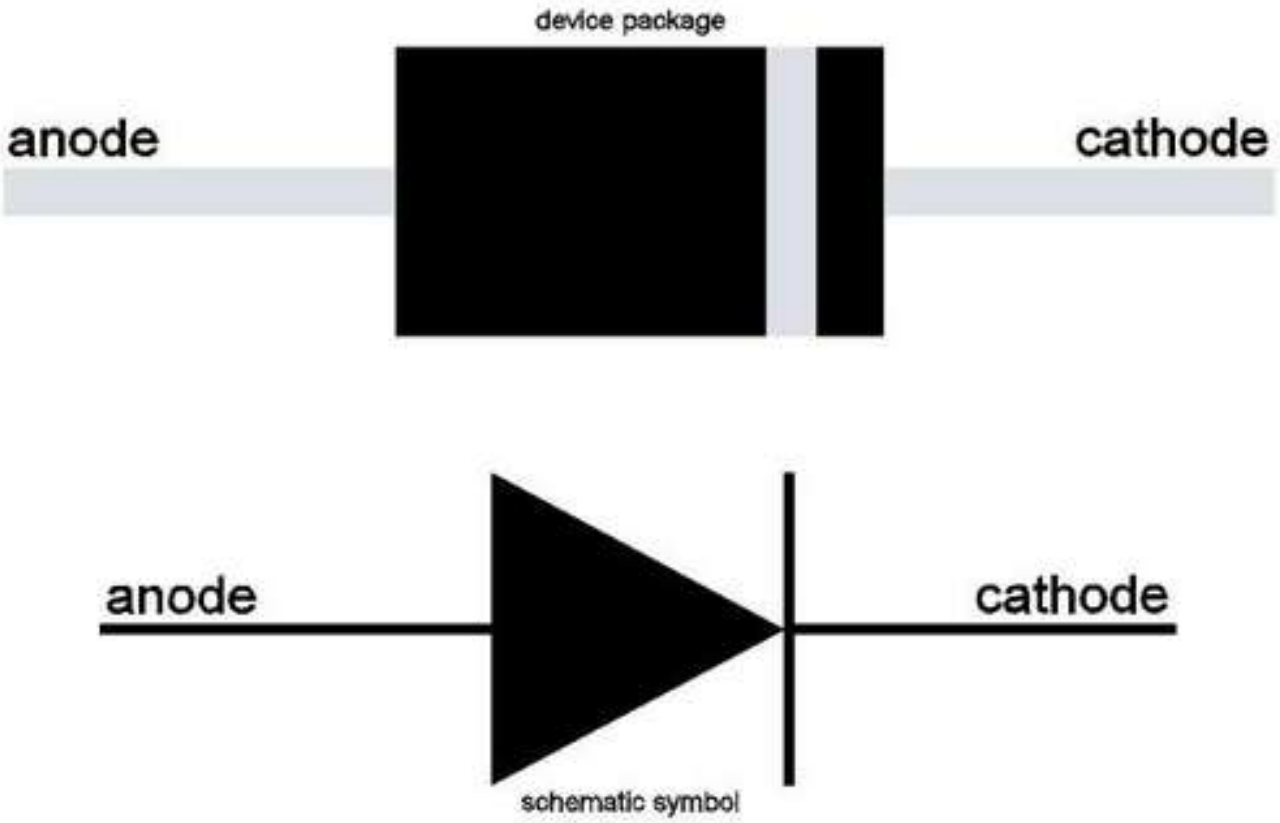
$$\vec{E} = \frac{dV}{dx}\hat{\imath}$$

Diodo de Junção PN

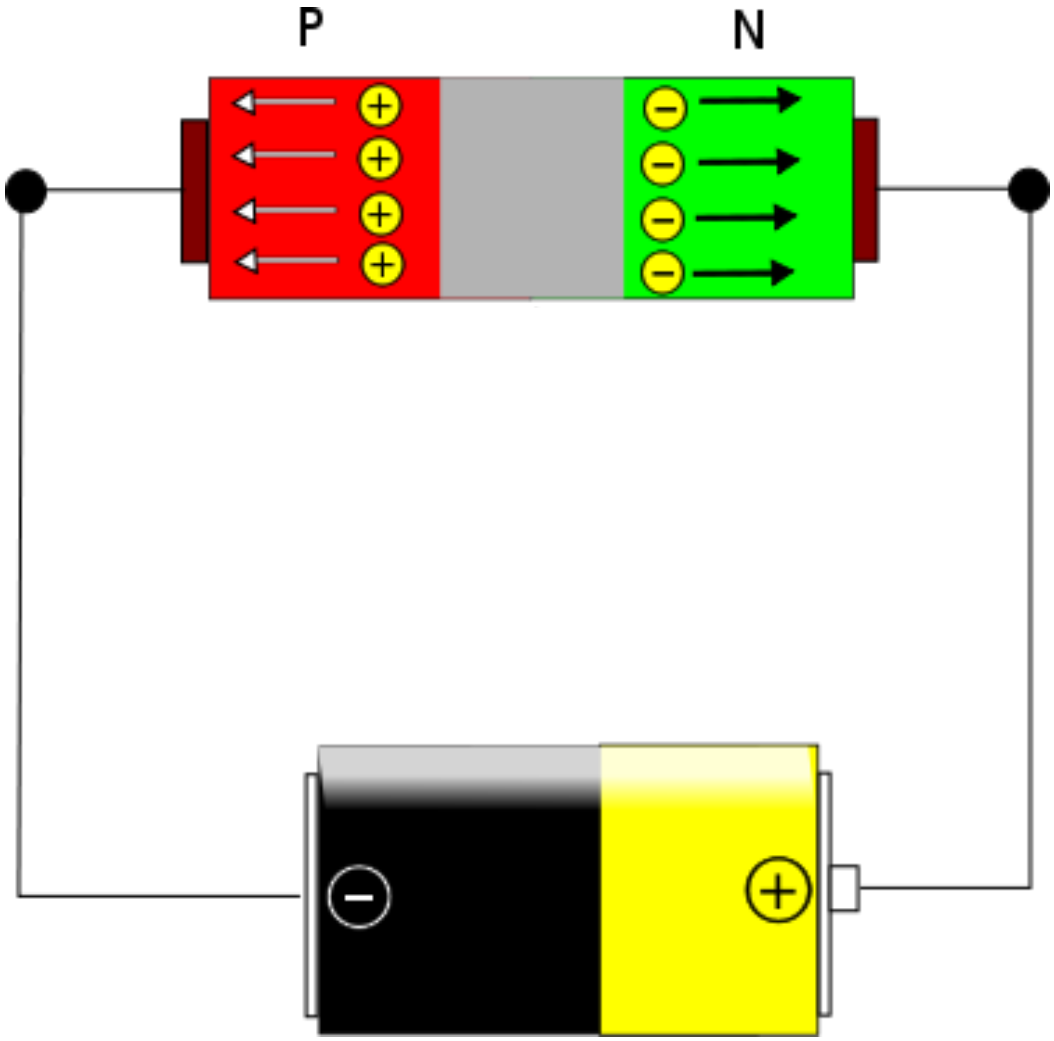


$$\vec{E} = \frac{dV}{dx}\hat{\imath}$$

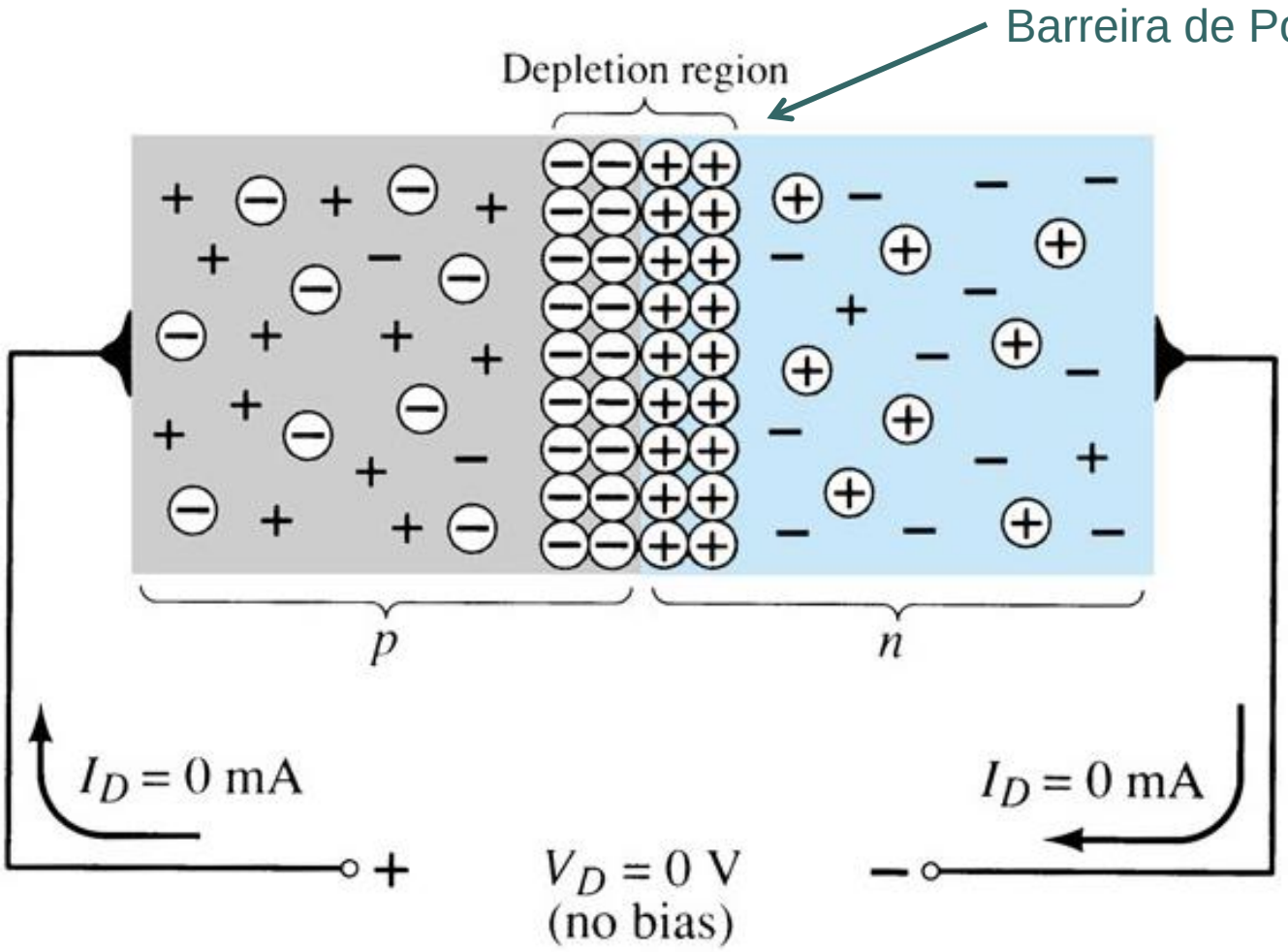
Símbolo


device package
anode
cathode
anode
cathode
schematic symbol

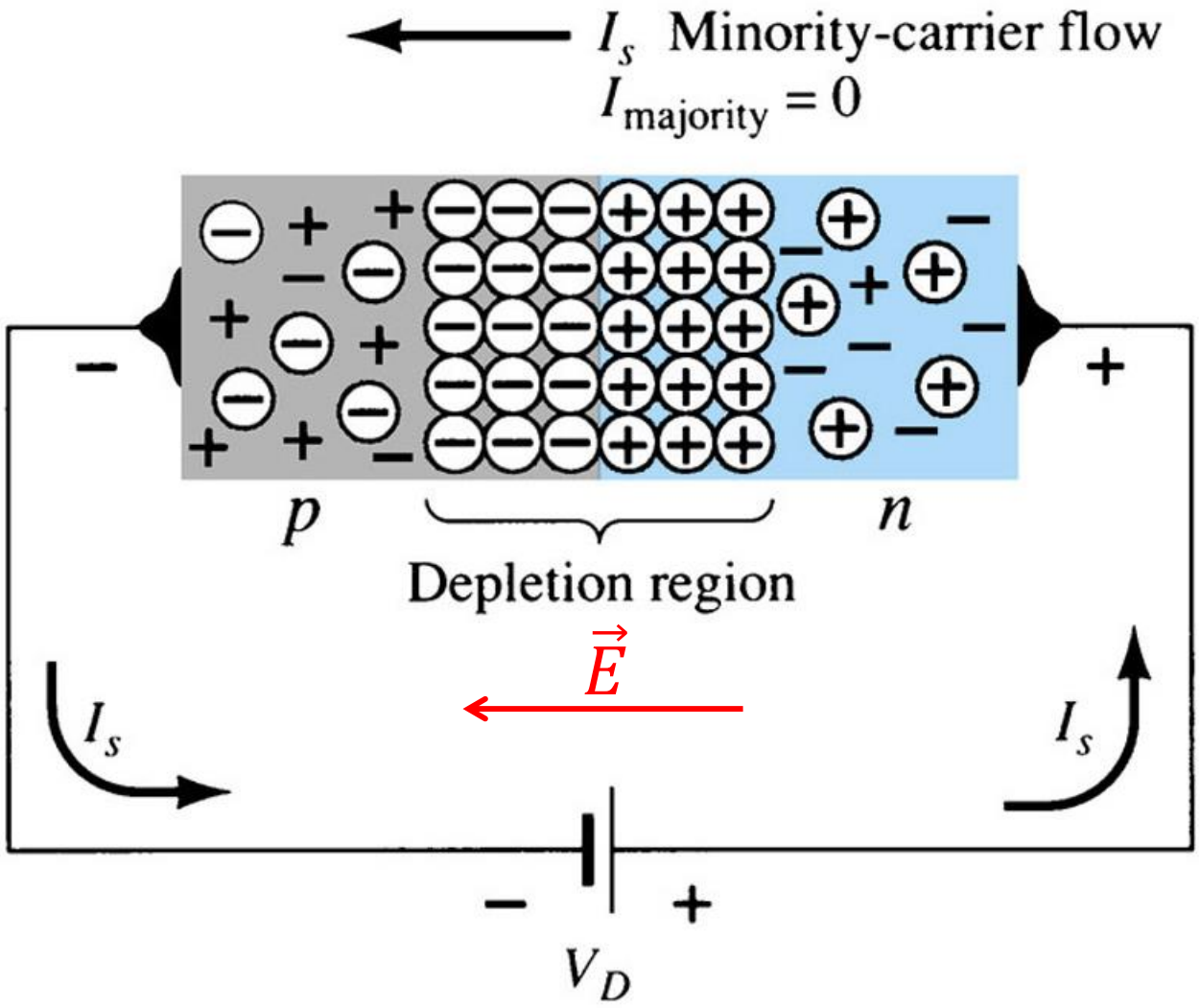
Polarização do Diodo

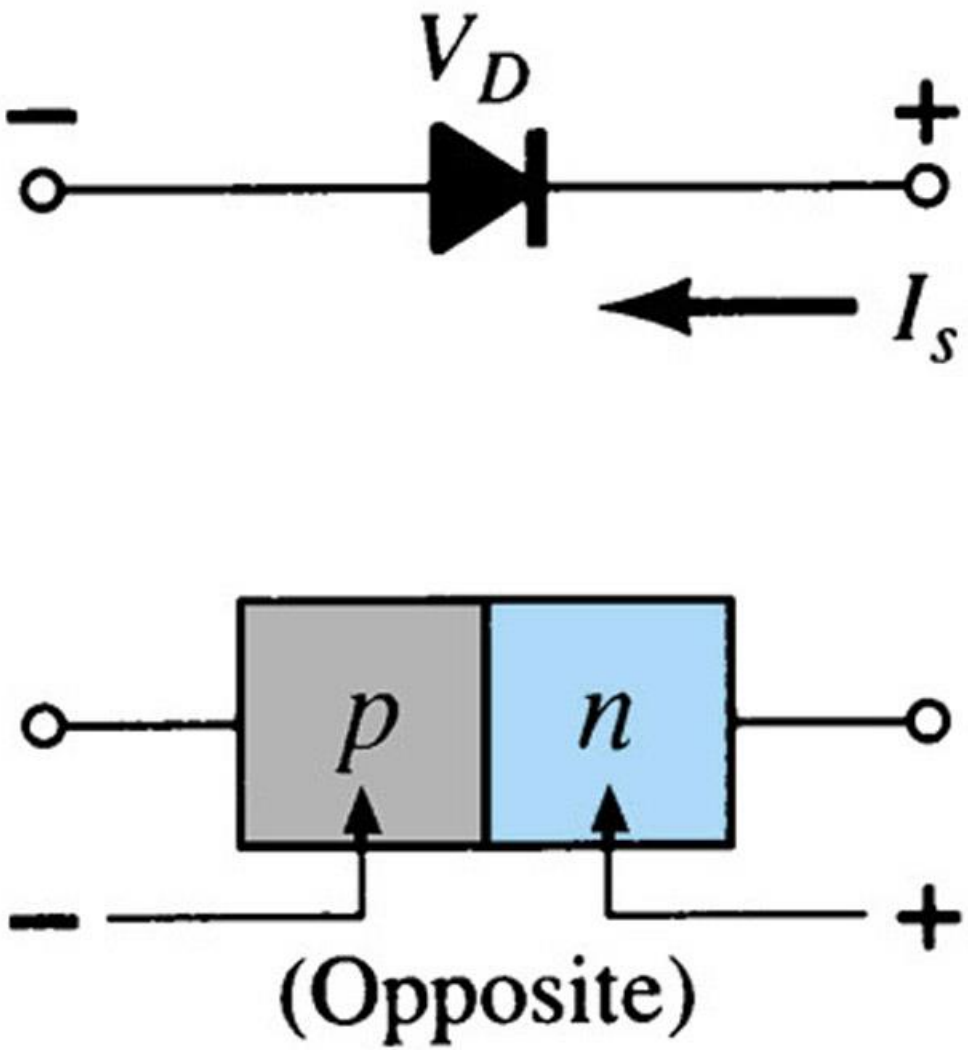


Diodo de Junção PN

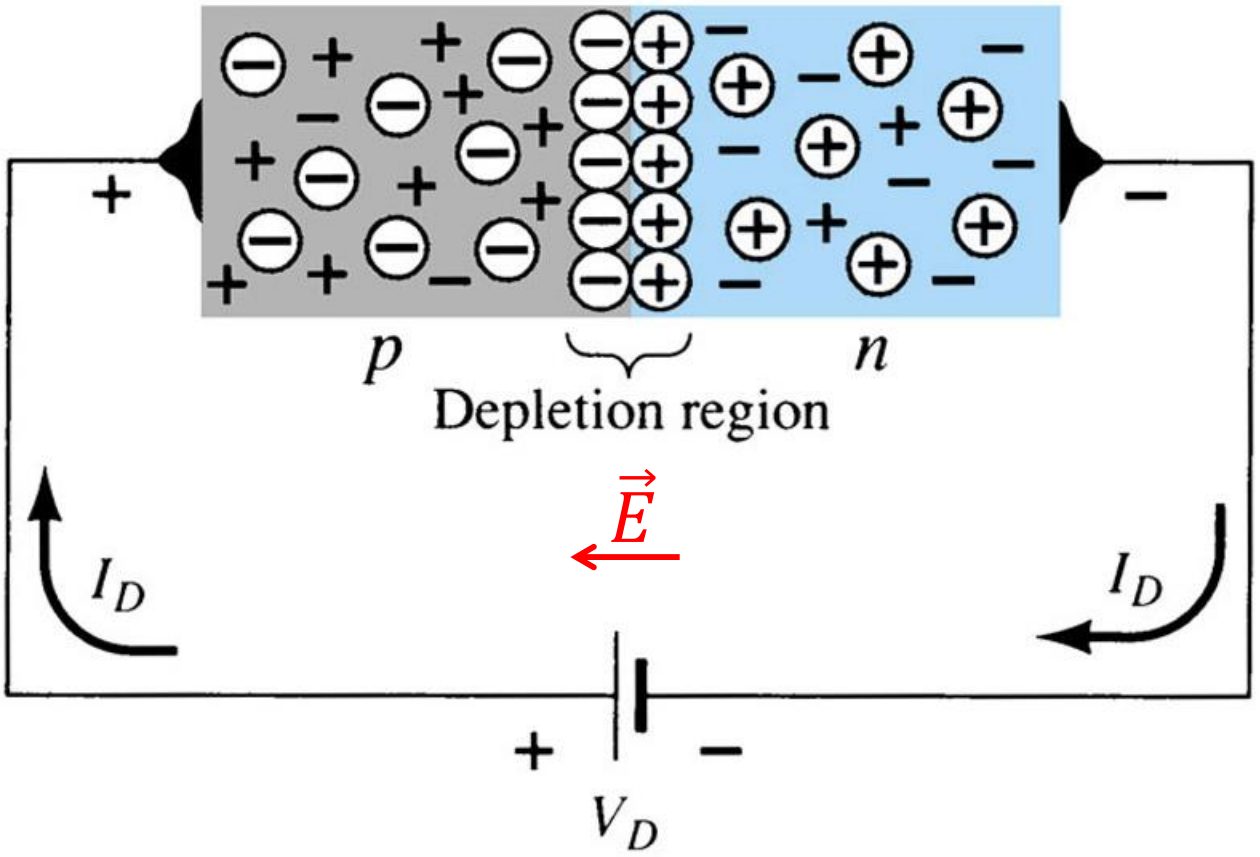


Polarização Reversa

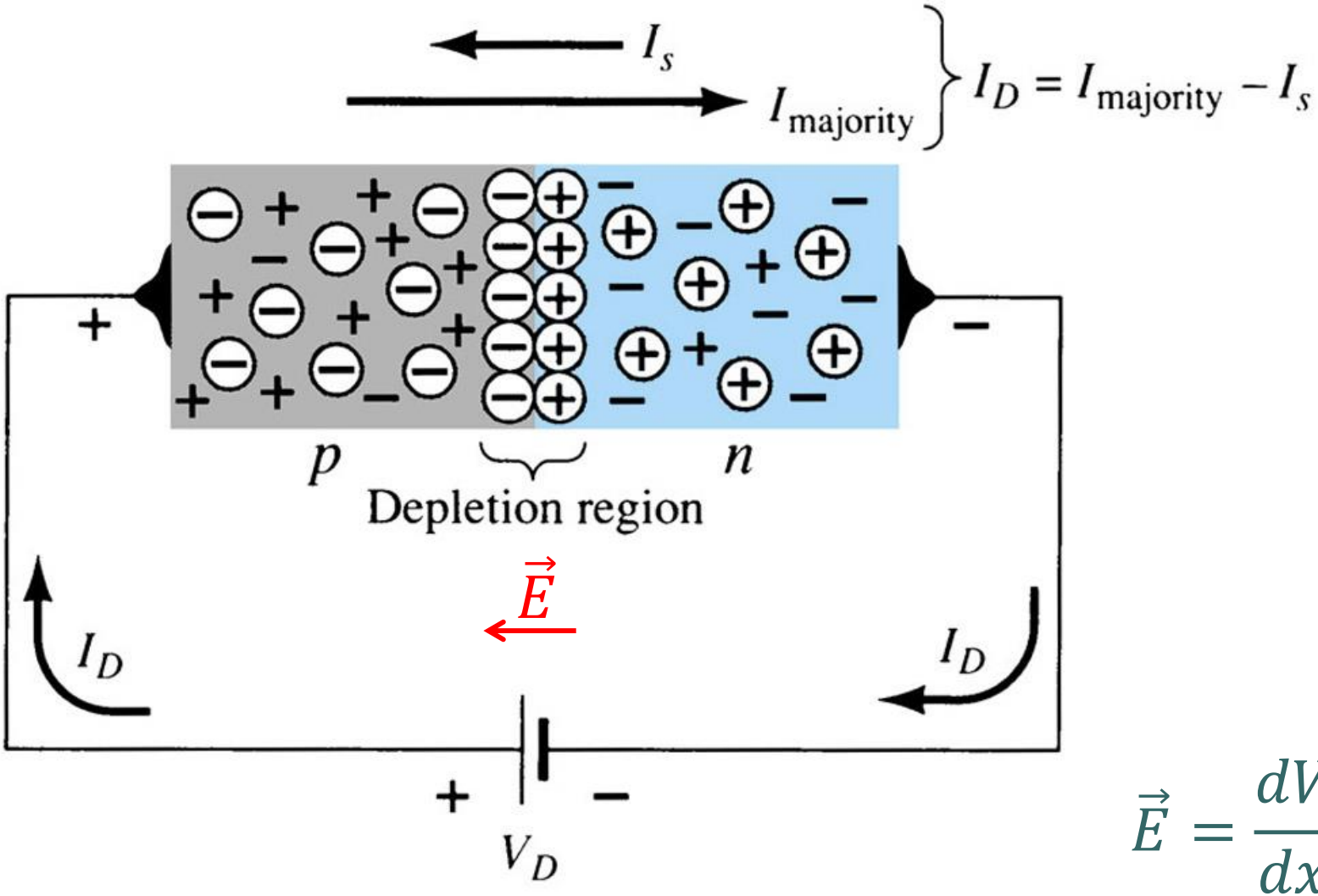



V_D
−
+
I_s
p
n
−
+
(Opposite)

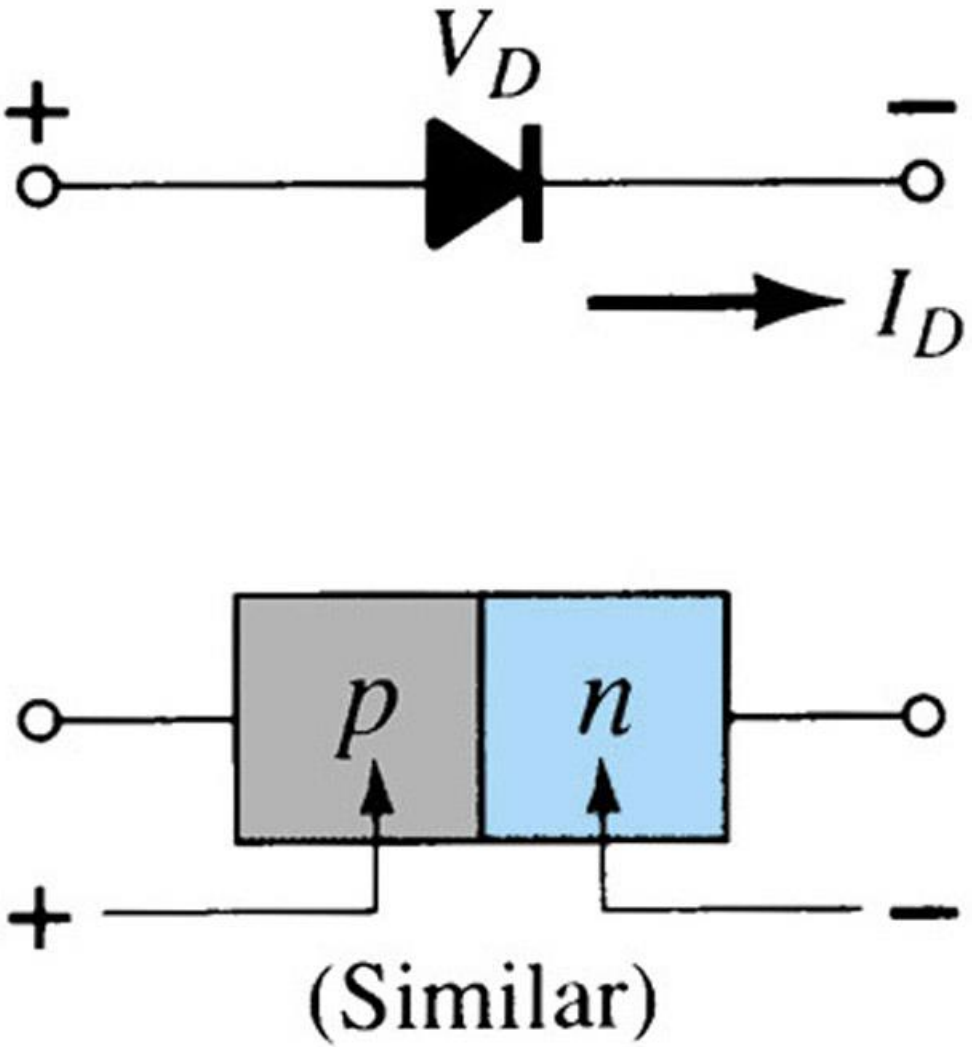
Polarização Direta



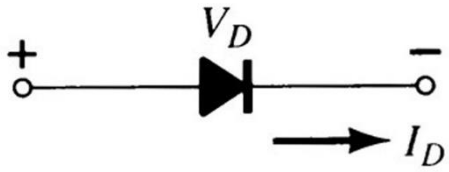
Polarização Direta

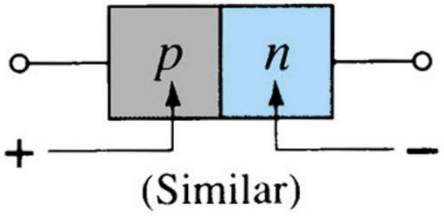


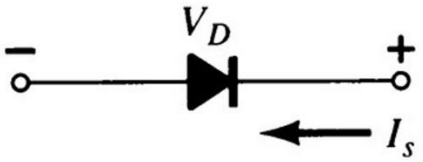
$$\vec{E} = \frac{dV}{dx}\hat{\imath}$$

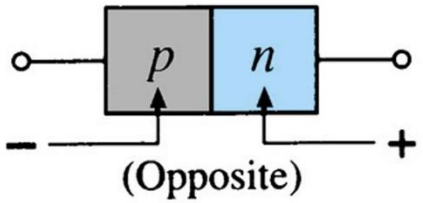

V_D
+
−
I_D
p
n
+
−
(Similar)

Diodos polarizados!









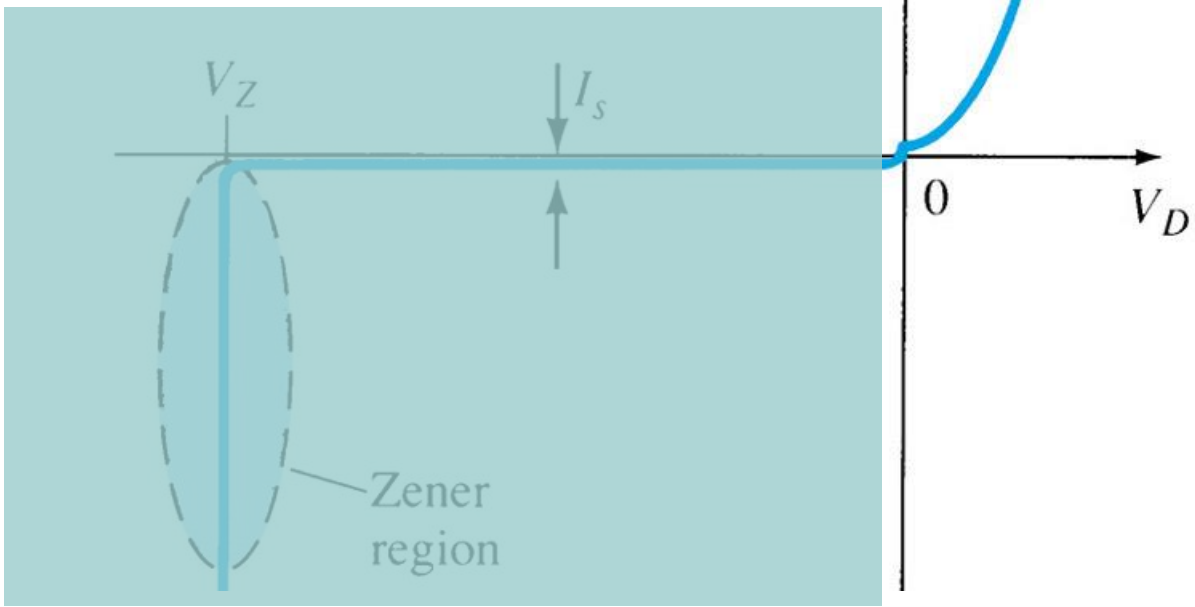
Análise Quantitativa

$V_D > 0\ V$

$$I_D = I_S\left(e^{qV_D/KT} - 1\right)$$

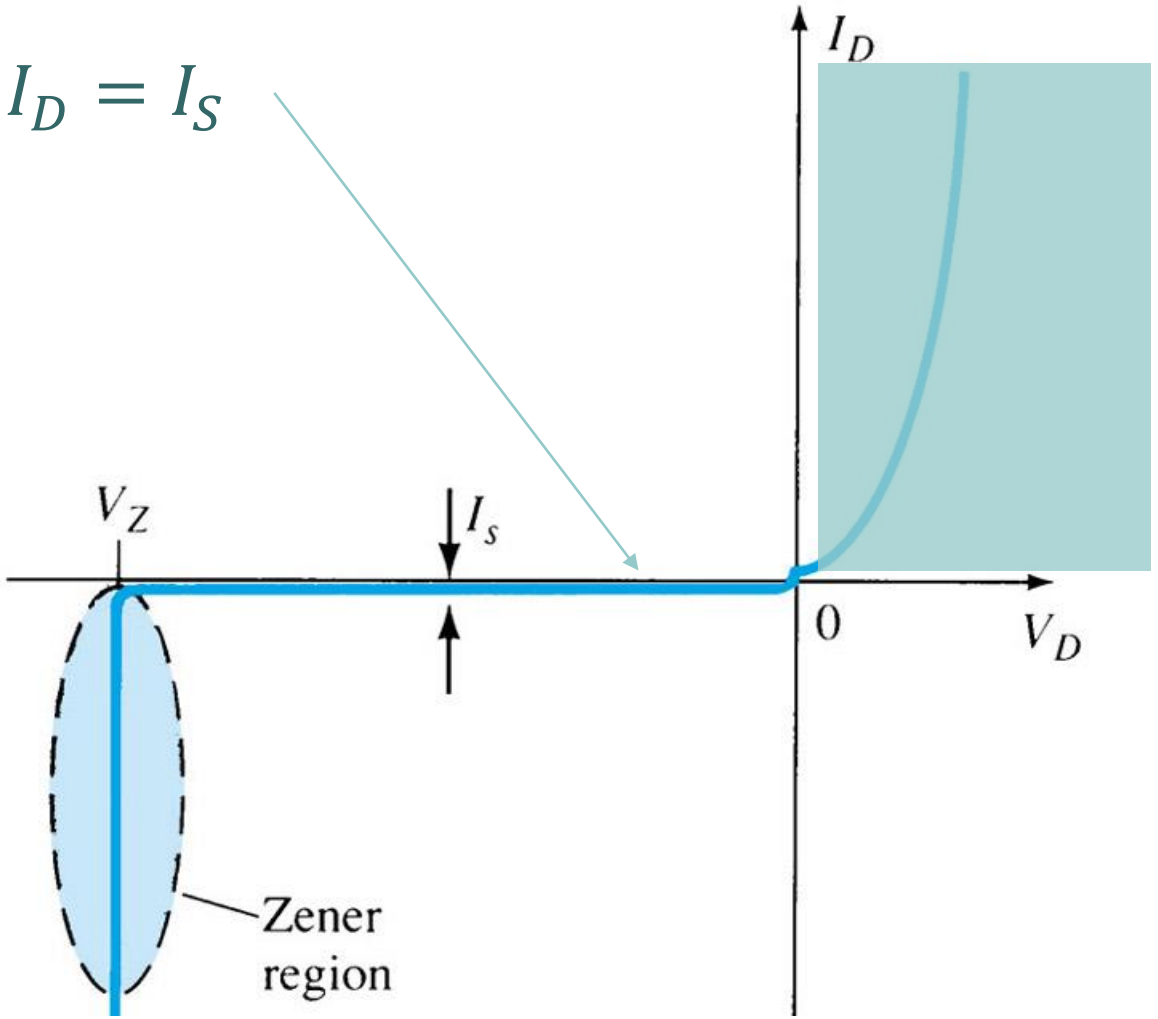
$K \rightarrow$ Constante de Boltzmann

$$K = 1.38 \text{ x } 10^{-23}\ \text{J/K}$$
$$q = 1.602 \text{ x } 10^{-19}\ \text{C}$$

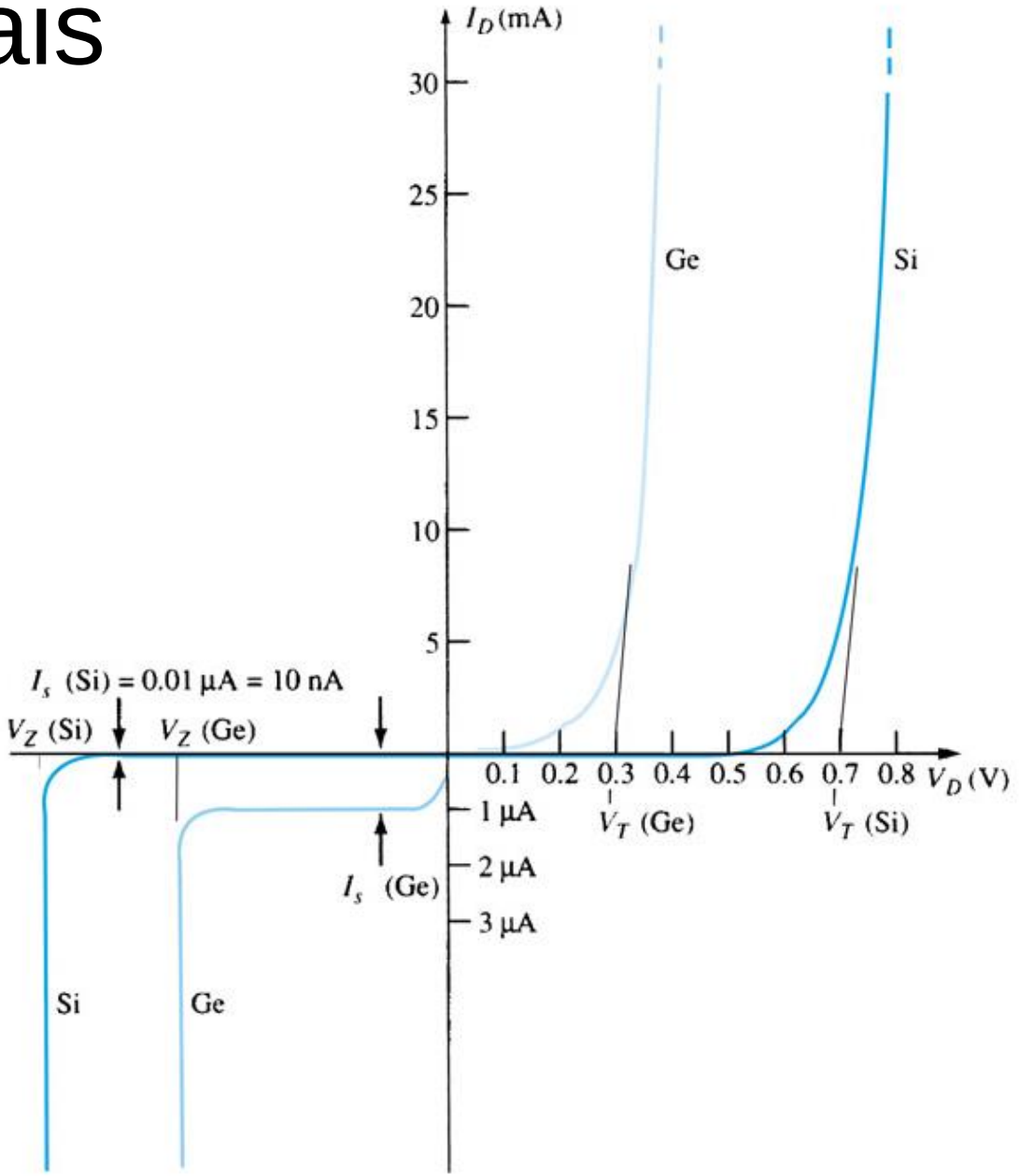


Análise Quantitativa

$V_D < 0\ V$

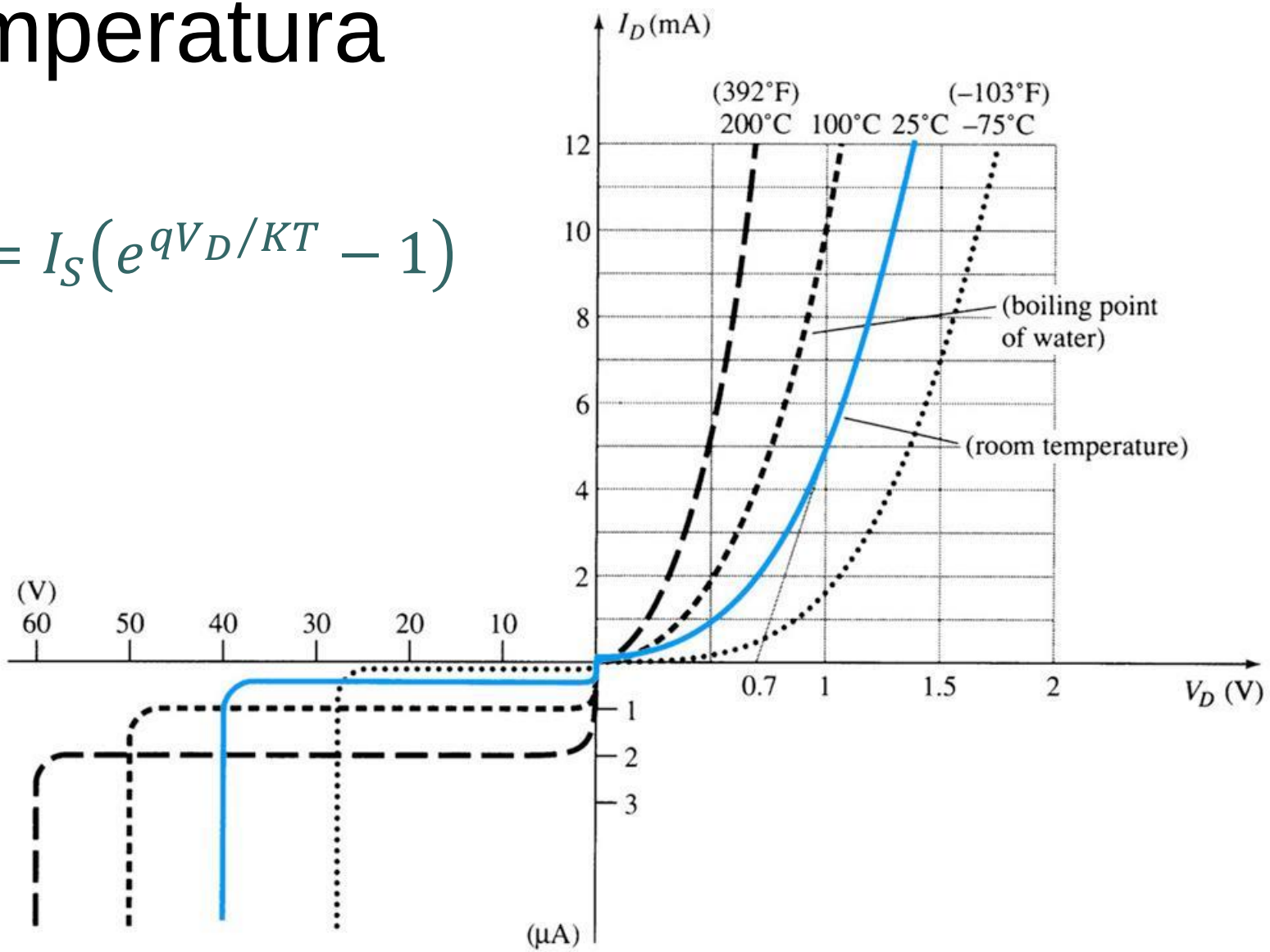


Exemplos reais



Influência da Temperatura

$$I_D = I_S\left(e^{qV_D/KT} - 1\right)$$



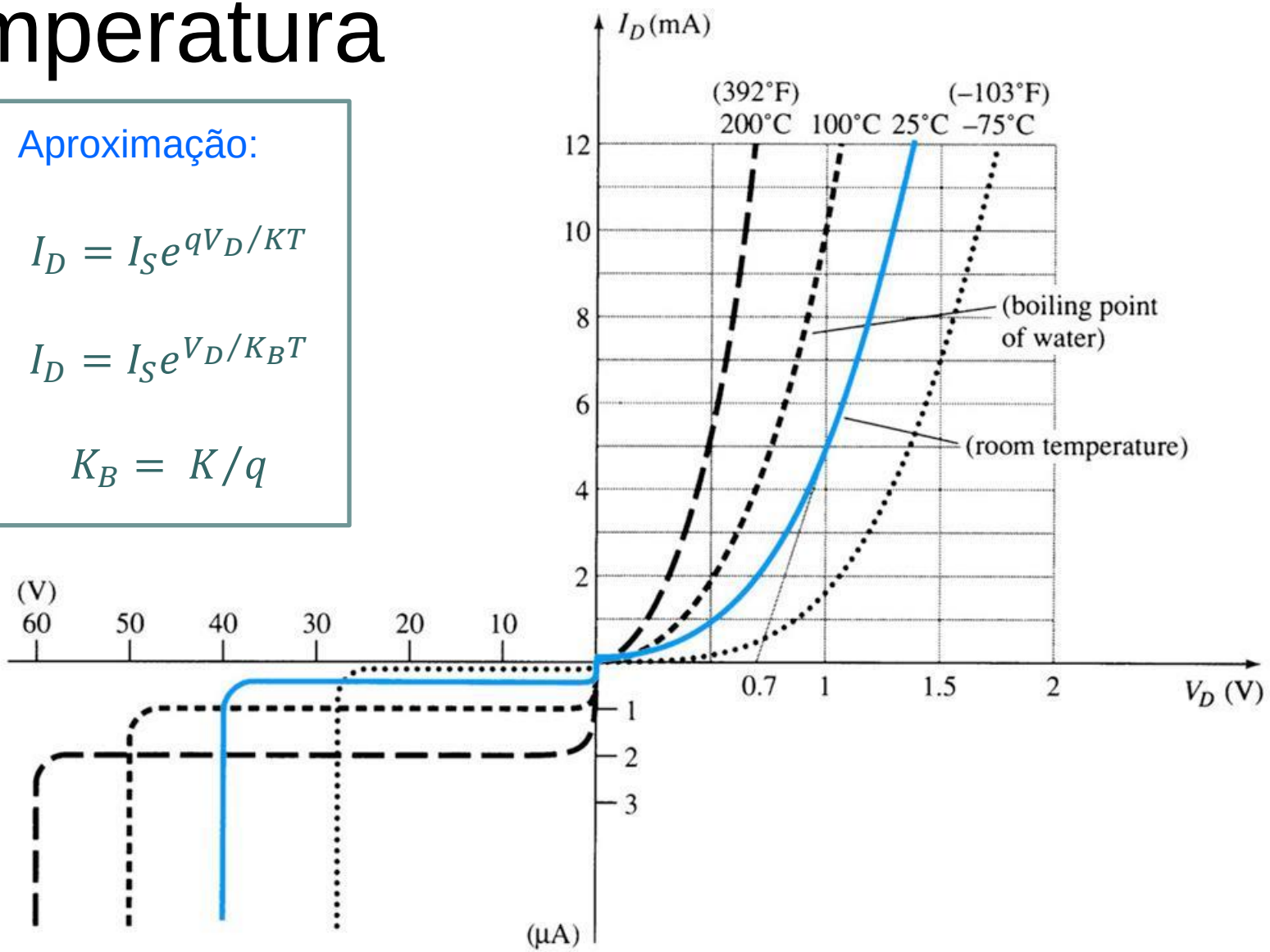
Influência da Temperatura

Aproximação:

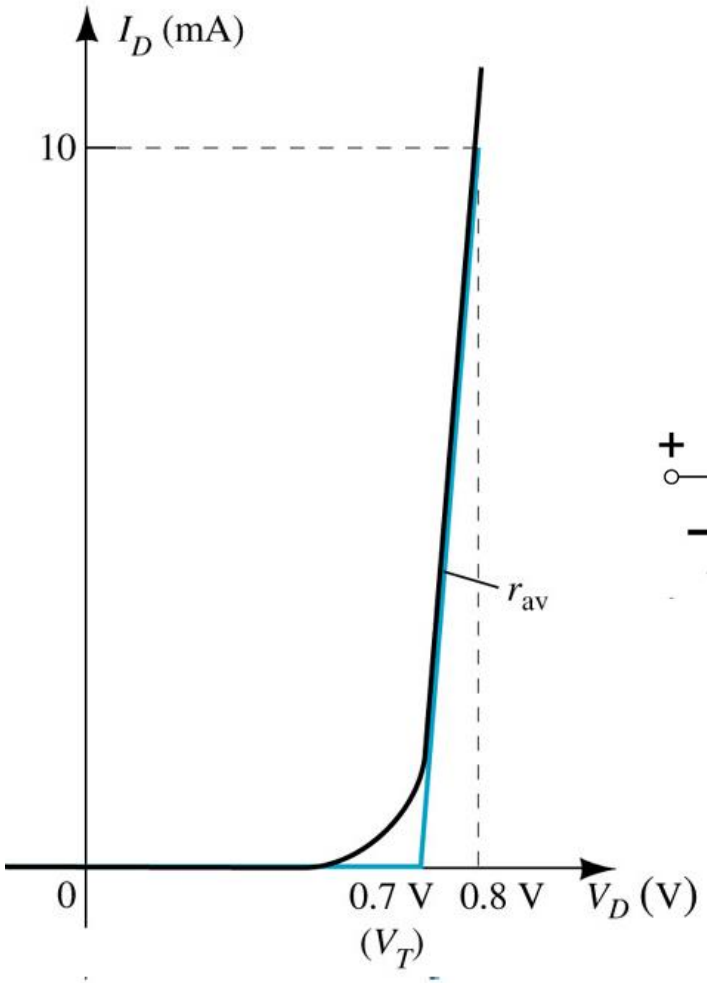
$$I_D = I_S e^{qV_D/KT}$$

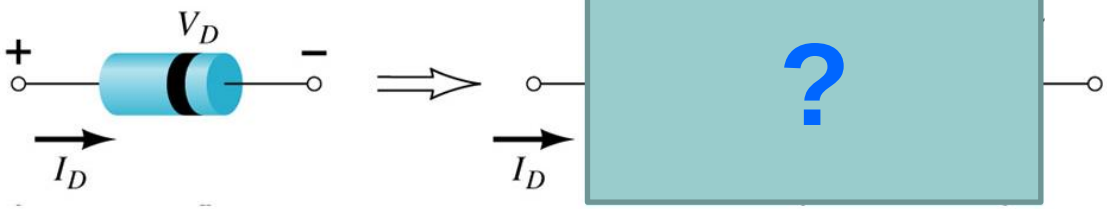
$$I_D = I_S e^{V_D/K_B T}$$

$$K_B = K/q$$

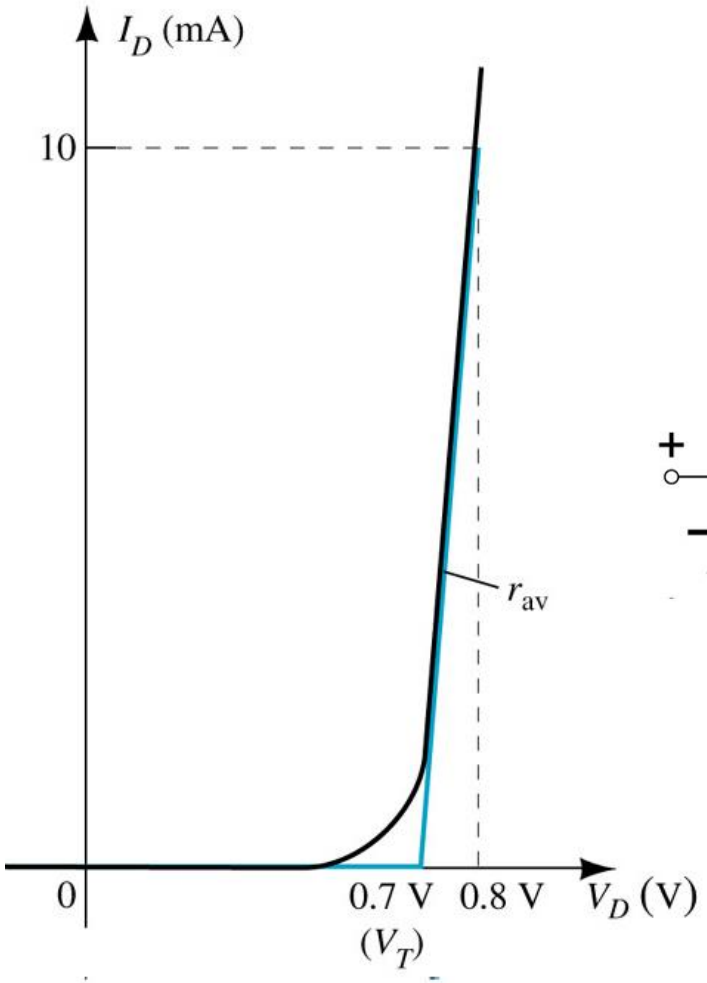


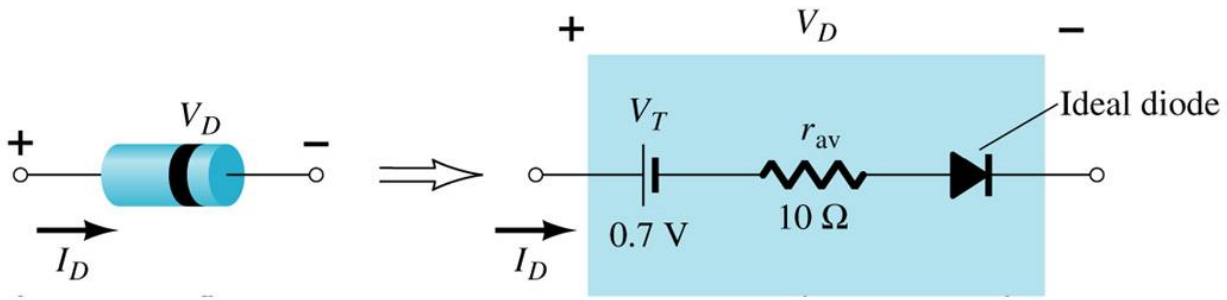
Circuito equivalente do Diodo I



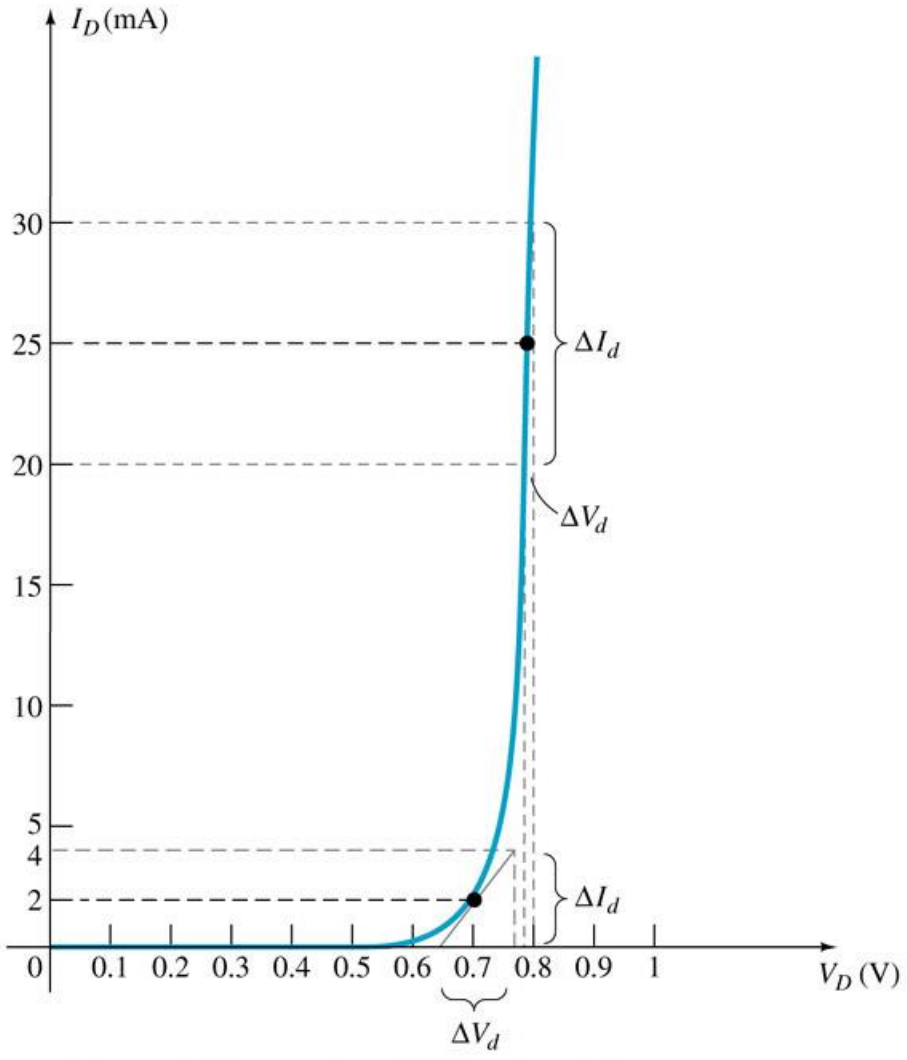


Circuito equivalente do Diodo I



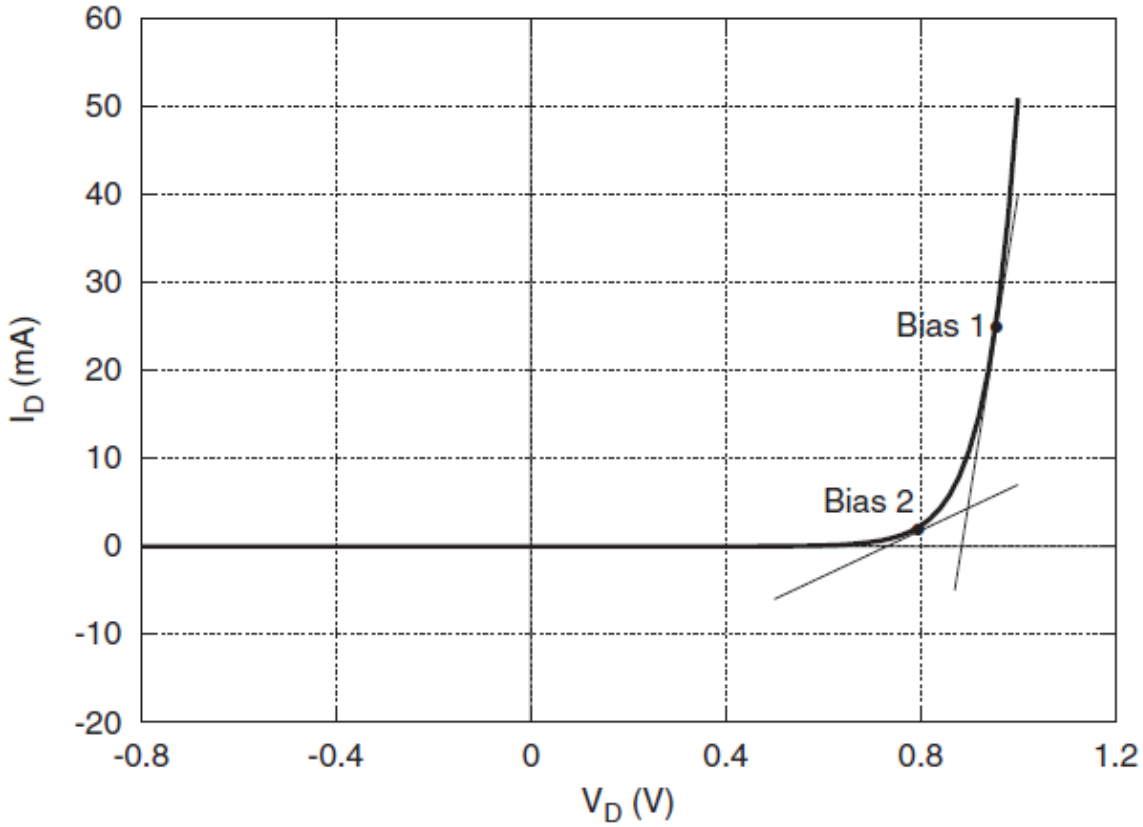


Resistência do Diodo



Resistência do Diodo

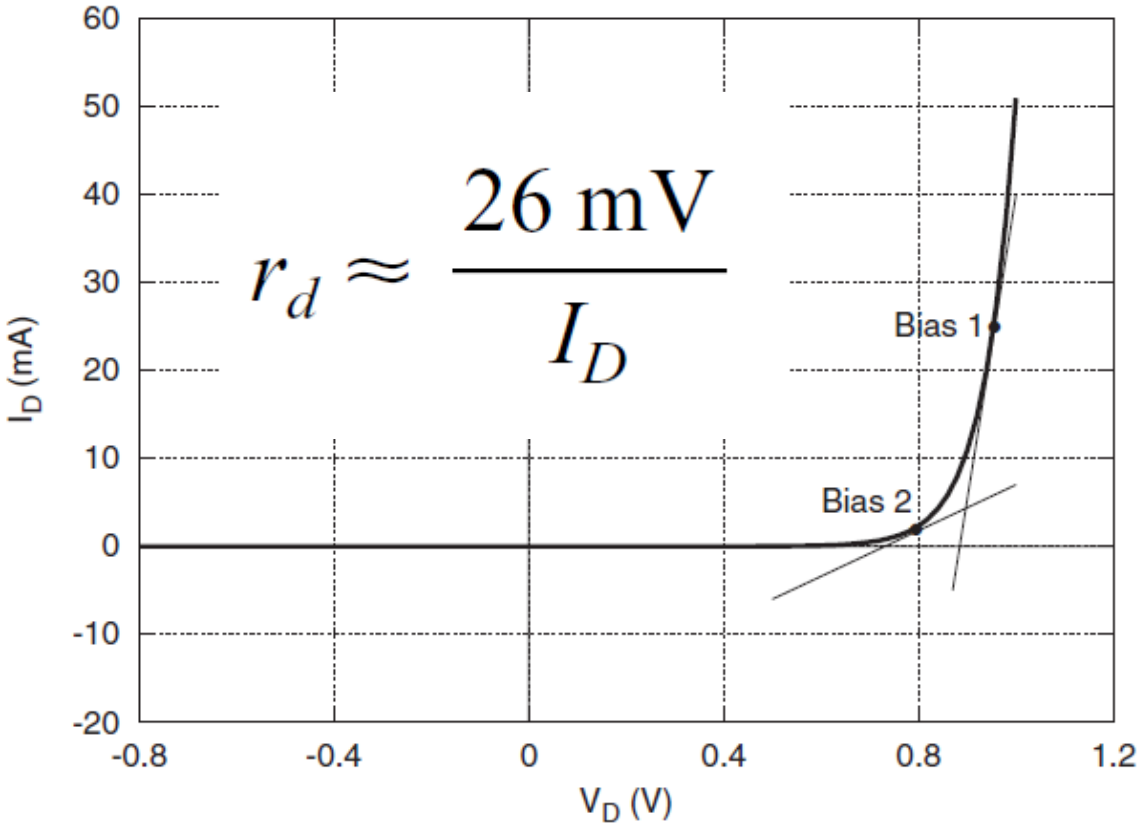
$$\frac{1}{r_d} = \frac{dI_D}{dV_D} = \frac{d[I_S e^{qV_D/kT}]}{dV_D} = \frac{qI_S e^{qV_D/kT}}{kT} = \frac{qI_D}{kT}$$



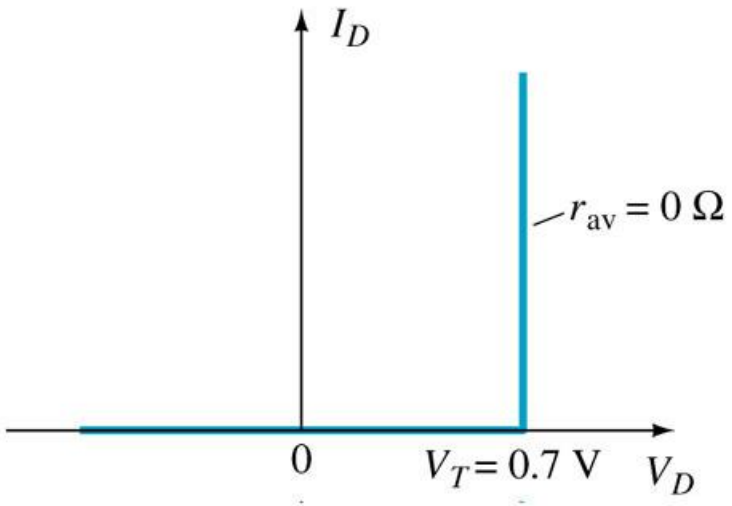
Resistência do Diodo

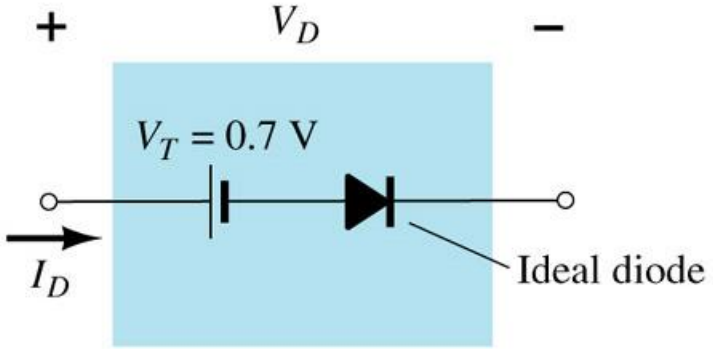
$$\frac{1}{r_d} = \frac{dI_D}{dV_D} = \frac{d[I_S e^{qV_D/kT}]}{dV_D} = \frac{qI_S e^{qV_D/kT}}{kT} = \frac{qI_D}{kT}$$

T = 25 °C

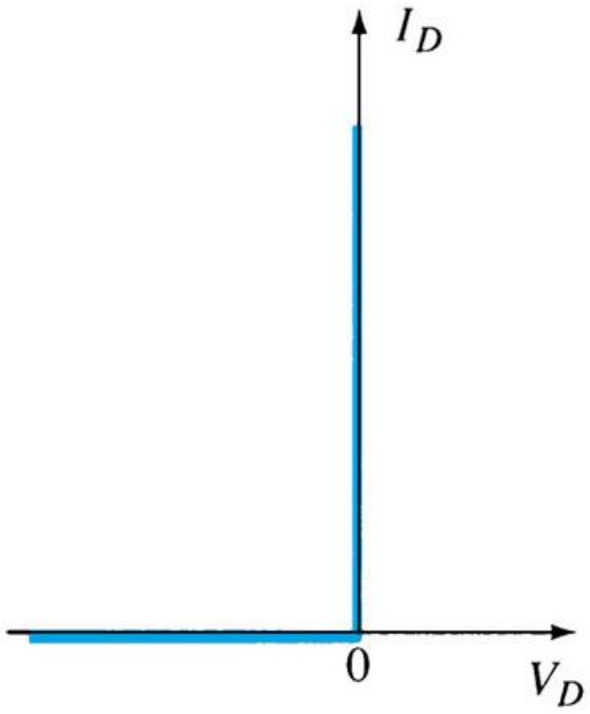


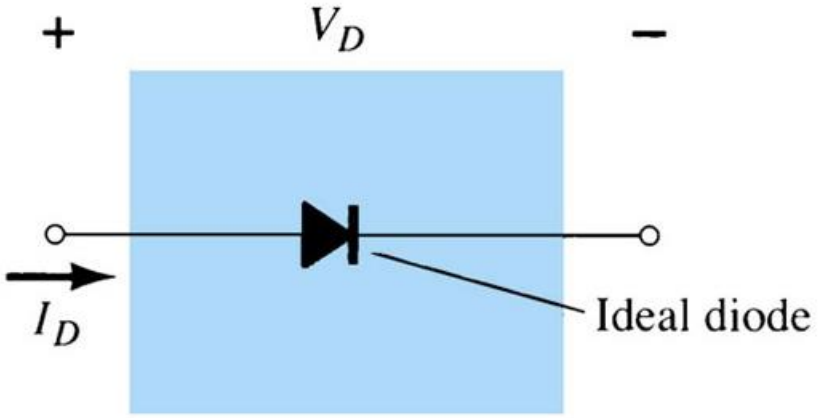
Circuito equivalente do Diodo II



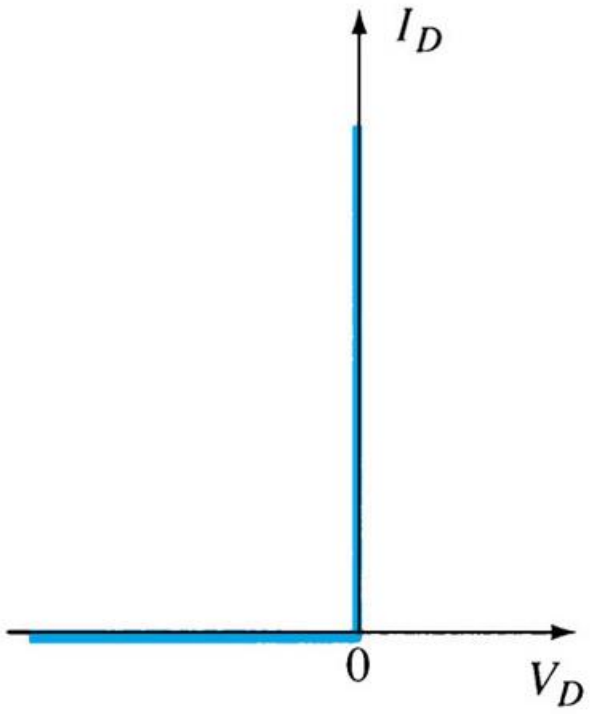


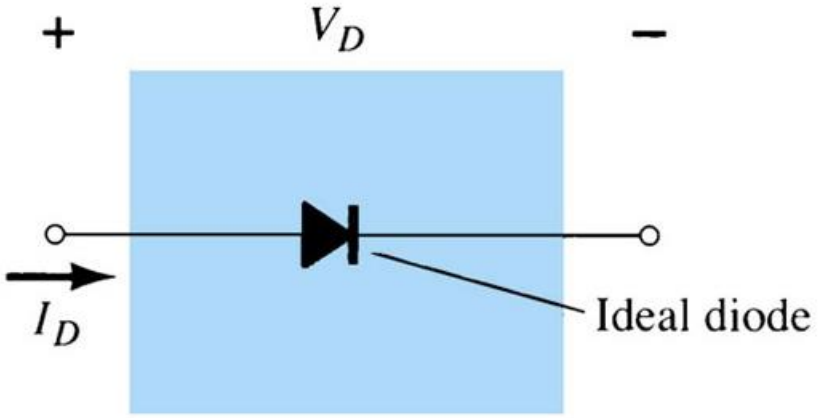
Circuito equivalente do Diodo III





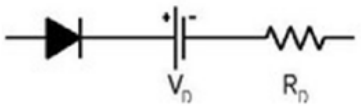
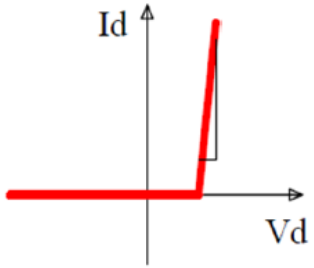
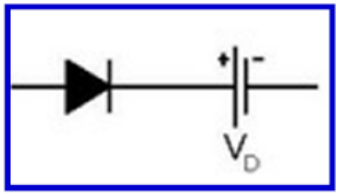
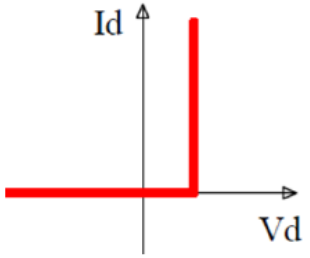
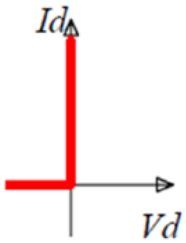
Circuito equivalente do Diodo III





Diodo IDEAL

Circuitos equivalentes do Diodo

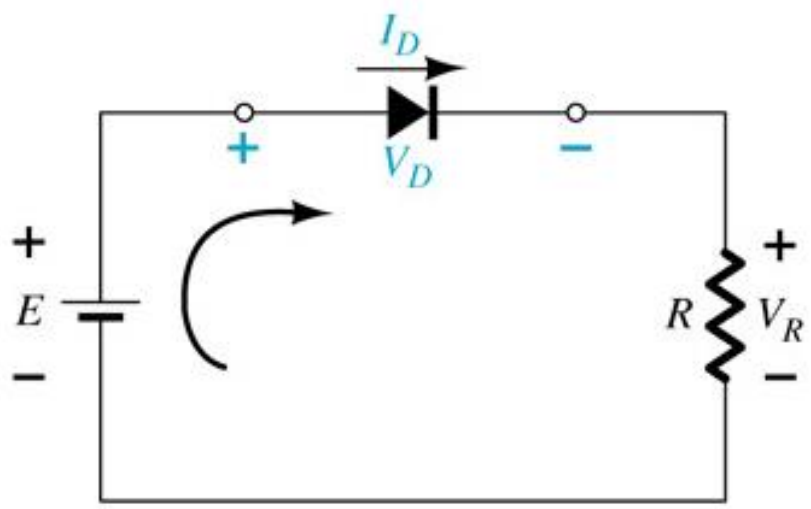
Modelo	Condições	Circuito equivalente	Curva característica (polarização direta)
Modelo linear por partes	--		
Modelo Simplificado	$R_{circuito} >> r_{av}$ Onde, r_{av} = resistência interna CA média		
Modelo Ideal	$R_{circuito} >> r_{av}$ $E_{circuito} >> V_T$ Onde, V_T = tensão de limiar		

Ponto de Operação (Q) do Diodo

Q → Quiescente = “Repouso”

$V_D = ?$

$I_D = ?$

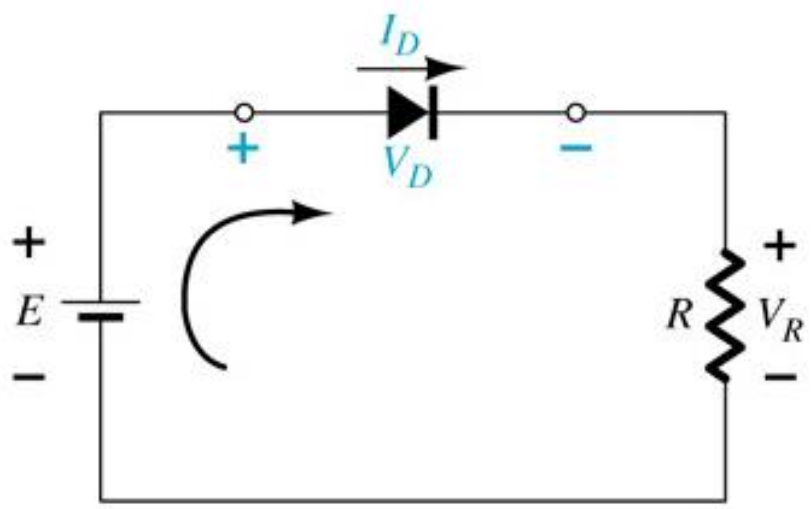


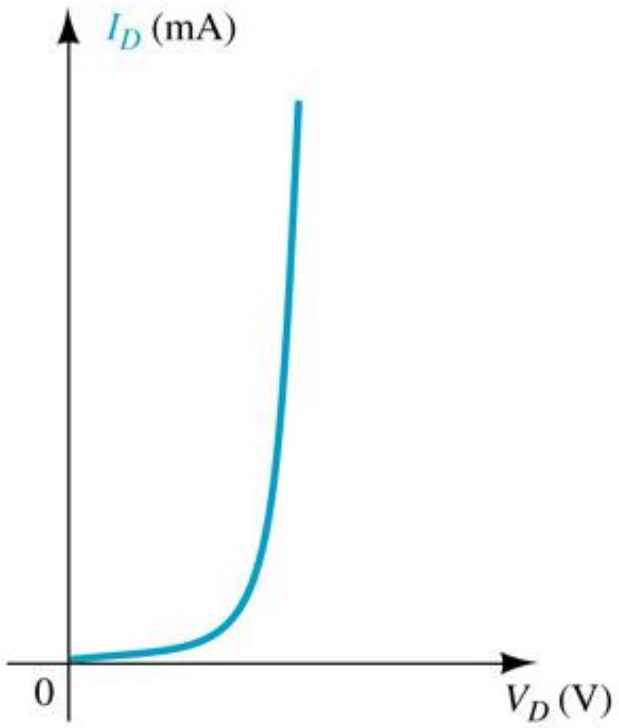
$$E = V_D + I_D R$$

Modelo NÃO aproximado

Q → Quiescente = “Repouso”

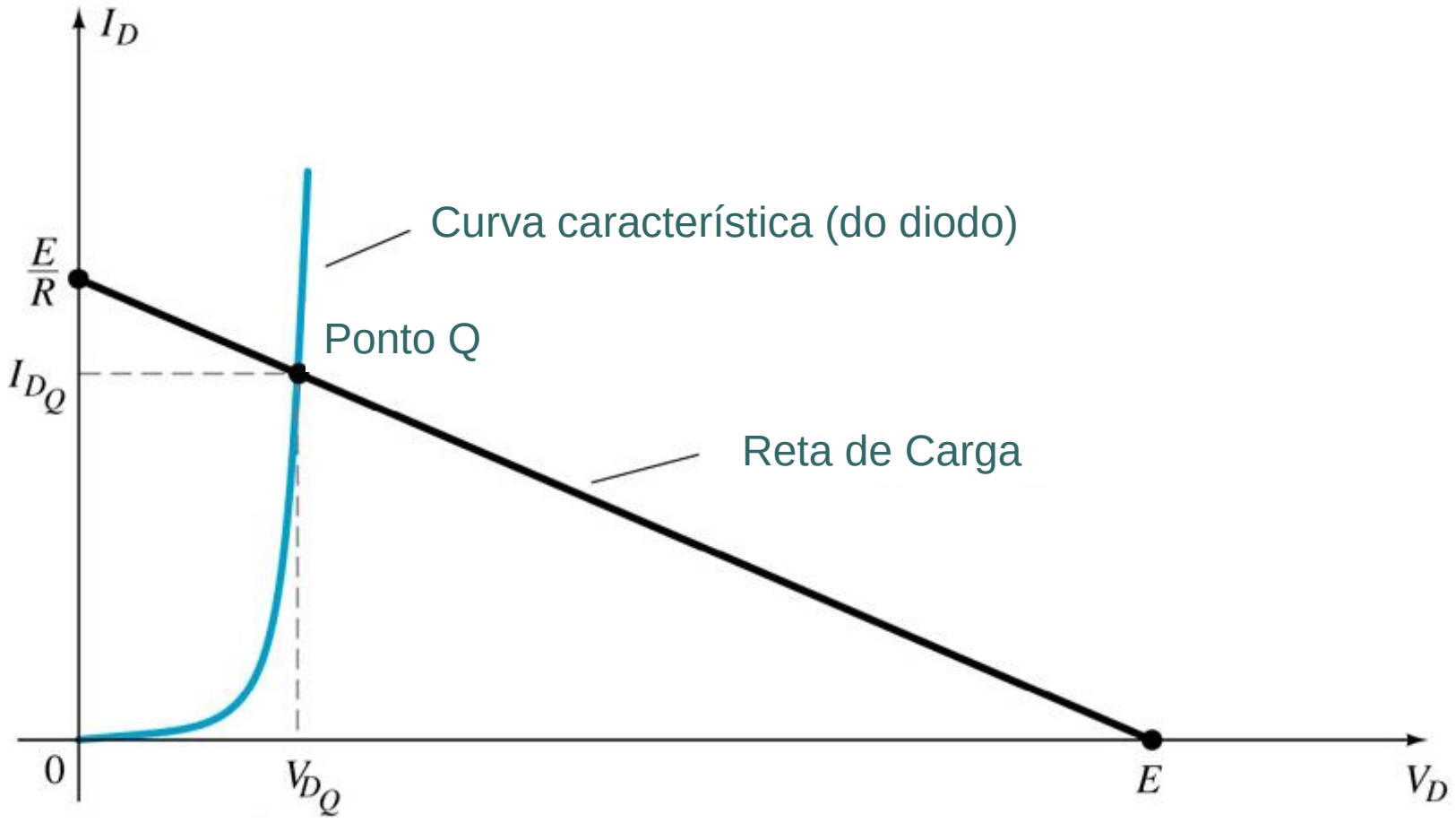
$$I_D = I_S\left(e^{V_D/K_BT} - 1\right)$$



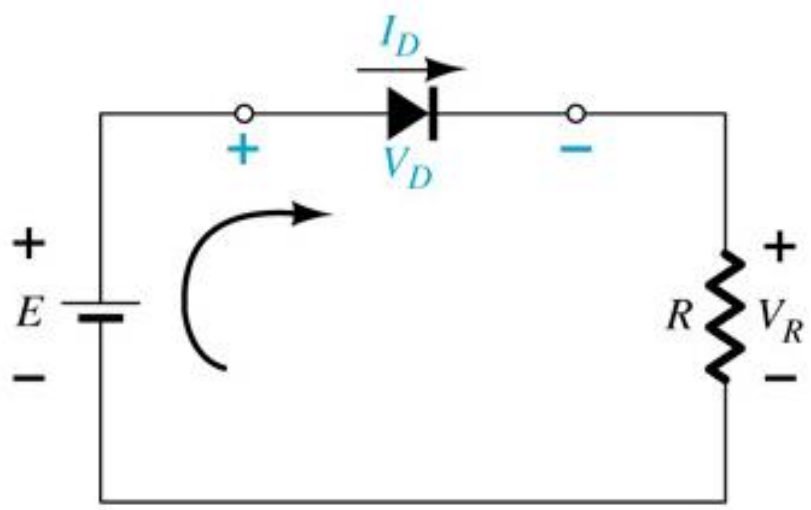


$$E = V_D + I_D R$$

Ponto de Operação (Q) do Diodo



Ponto de Operação (Q) do Diodo (Modelos Aproximados)



Aprox. I

$$E = 0.7 + I_D(R + R_D)$$

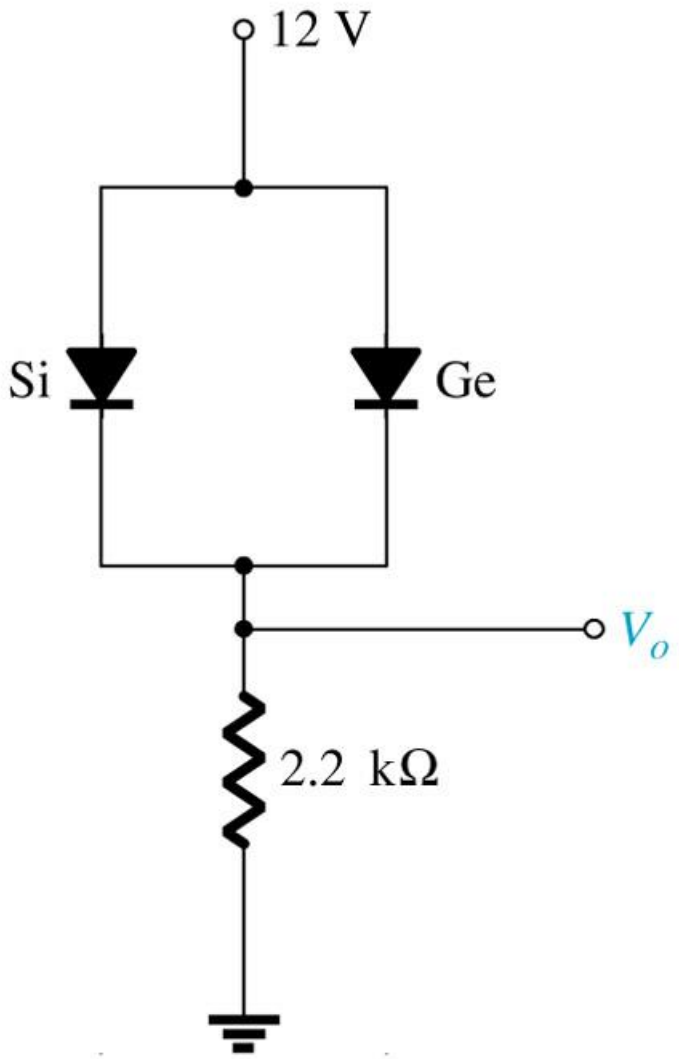
Aprox. II

$$E = 0.7 + I_D R$$

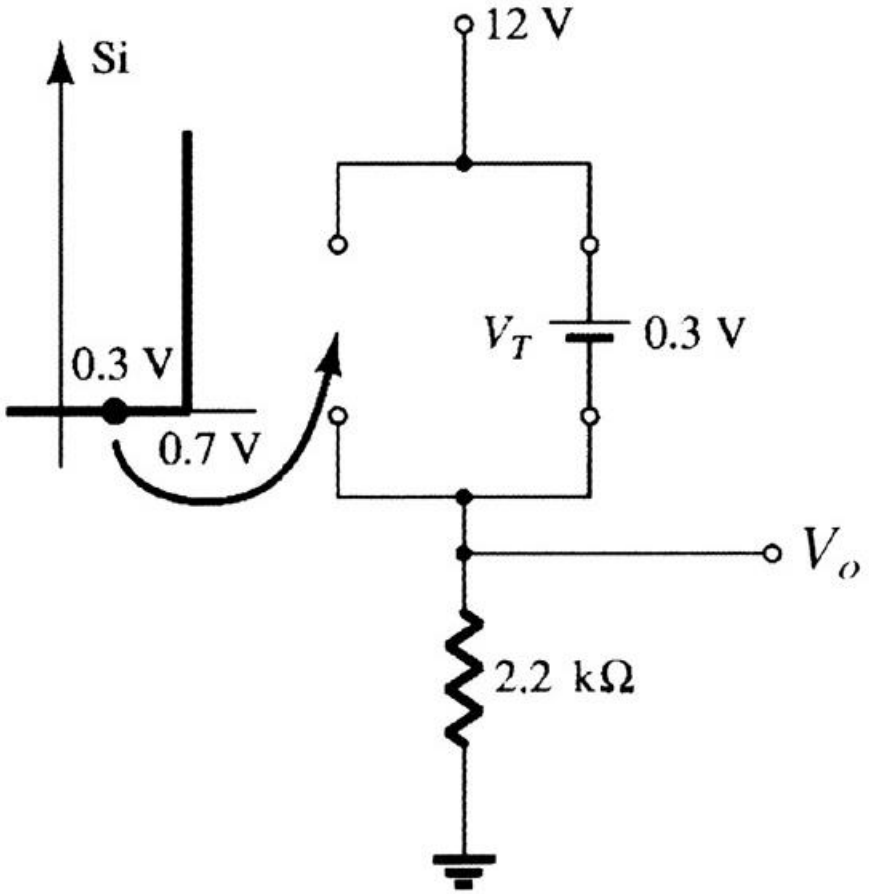
Aprox. III

$$E = I_D R$$

Diodos - Exemplo

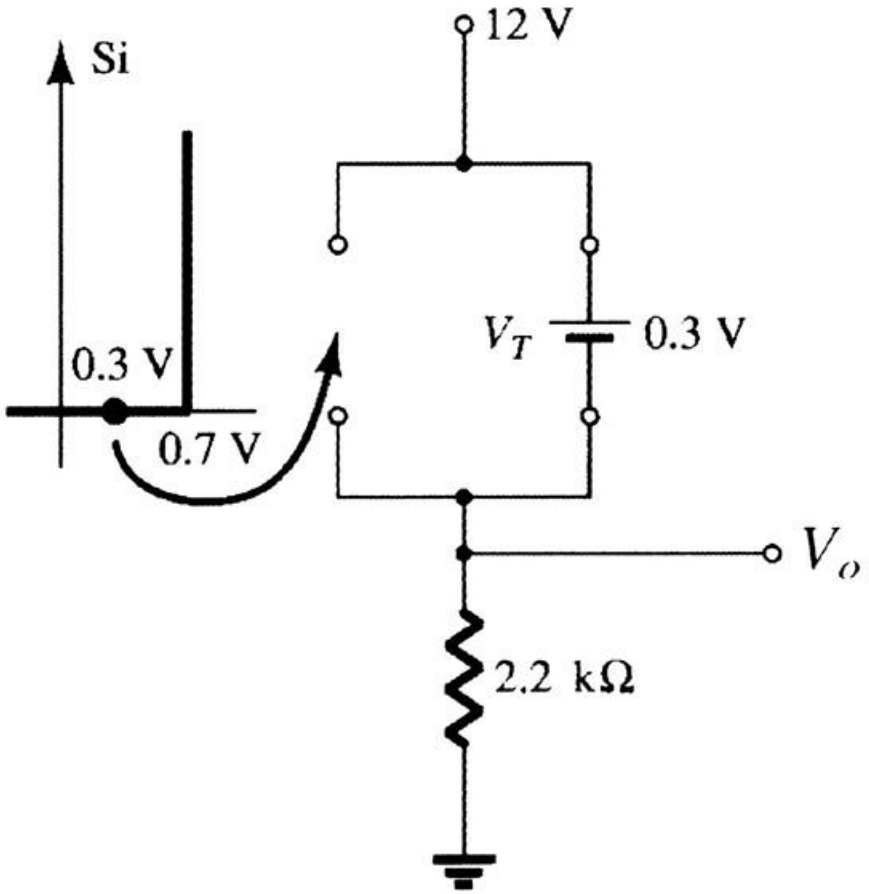


Solução



Solução

$$V_o = 12\ \text{V} - 0.3\ \text{V} = \mathbf{11.7\ V}$$



Folha de Dados

A — • BV . . . 125 V (MIN) @ 100 µA (BAY73)

ABSOLUTE MAXIMUM RATINGS (Note 1)

Temperatures

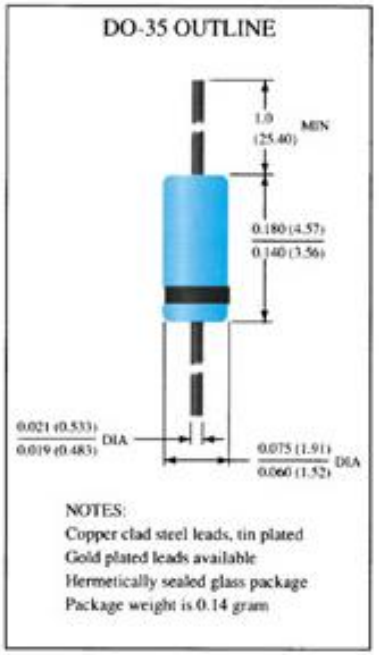
Storage Temperature Range	–65°C to +200°C
B — Maximum Junction Operating Temperature	+175°C
Lead Temperature	+260°C

Power Dissipation (Note 2)

C — Maximum Total Power Dissipation at 25°C Ambient	500 mW
Linear Power Derating Factor (from 25°C)	3.33 mW/°C

Maximum Voltage and Currents

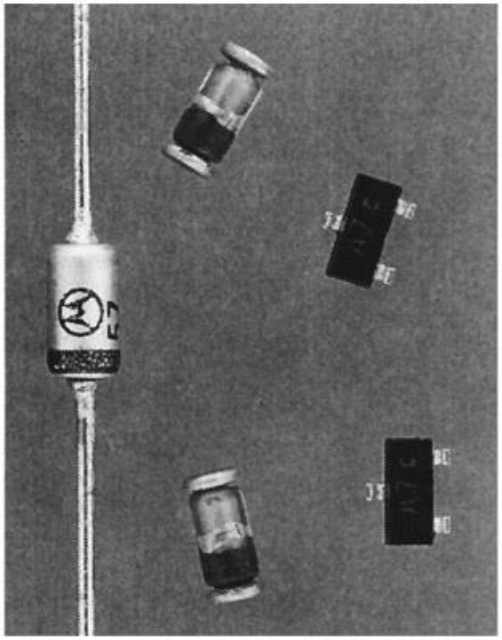
WIV	Working Inverse Voltage	BAY73	100 V
I_O	Average Rectified Current		200 mA
D — I_F	Continuous Forward Current		500 mA
i_f	Peak Repetitive Forward Current		600 mA
$i_{f(surge)}$	Peak Forward Surge Current		
	Pulse Width = 1 s		1.0 A
	Pulse Width = 1 µs		4.0 A



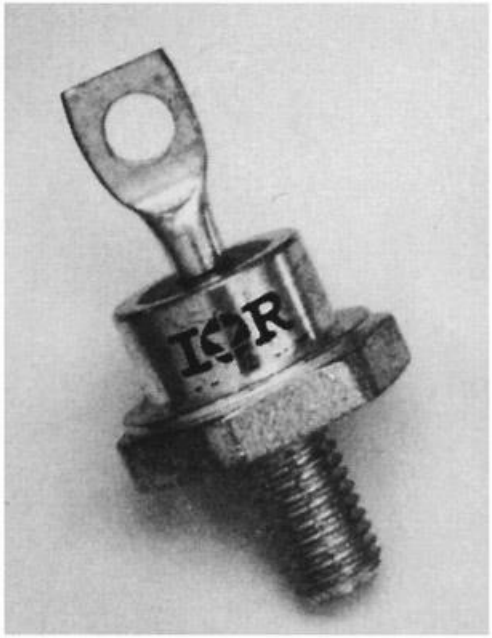
ELECTRICAL CHARACTERISTICS (25°C Ambient Temperature unless otherwise noted)

	SYMBOL	CHARACTERISTIC	BAY73 MIN	BAY73 MAX	UNITS	TEST CONDITIONS
E	V_F	Forward Voltage	0.85	1.00	V	I_F = 200 mA
			0.81	0.94	V	I_F = 100 mA
			0.78	0.88	V	I_F = 50 mA
			0.69	0.80	V	I_F = 10 mA
			0.67	0.75	V	I_F = 5.0 mA
F			0.60	0.68	V	I_F = 1.0 mA
					V	I_F = 0.1 mA
G	I_R	Reverse Current		500	nA	V_R = 20 V, T_A = 125°C
				5.0	nA	V_R = 100 V
				1.0	µA	V_R = 100 V, T_A = 125°C
					nA	V_R = 180 V
					µA	V_R = 180 V, T_A = 100°C
	BV	Breakdown Voltage	125		V	I_R = 100 µA
H	C	Capacitance		8.0	pF	V_R = 0, f = 1.0 MHz
I	t_{rr}	Reverse Recovery Time		3.0	µs	I_F = 10 mA, V_R = 35 V R_L = 1.0 to 100 kΩ C_L = 10 pF, JAN 256

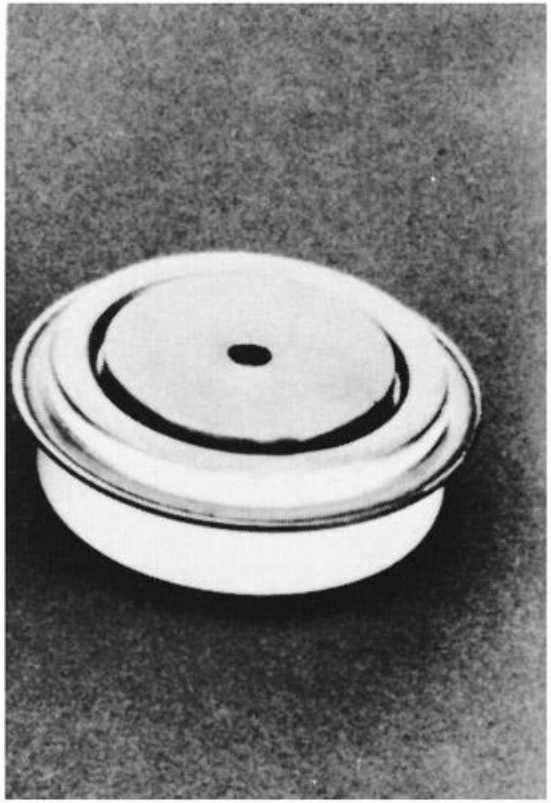
Tipos de Diodos



(a)

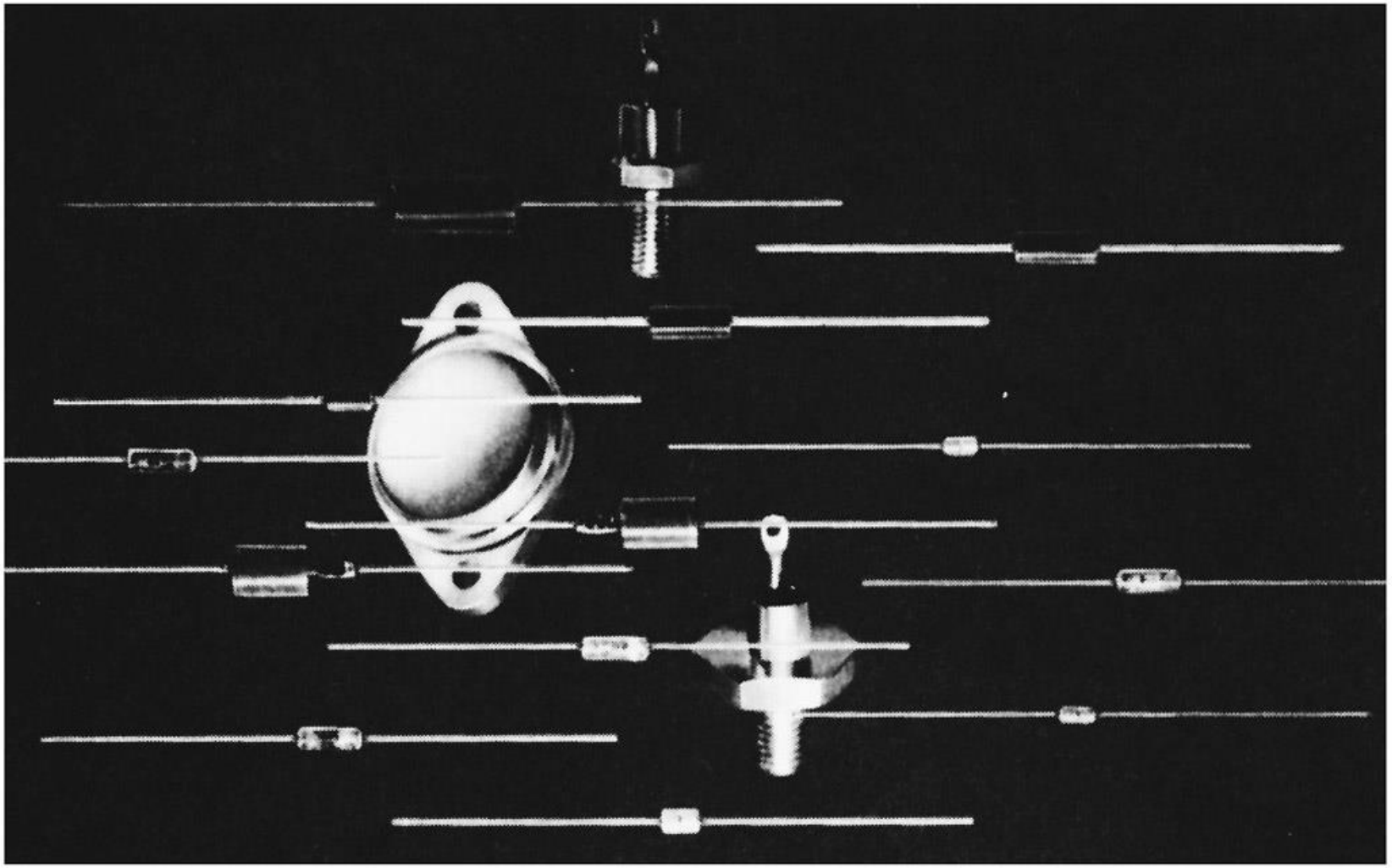


(b)

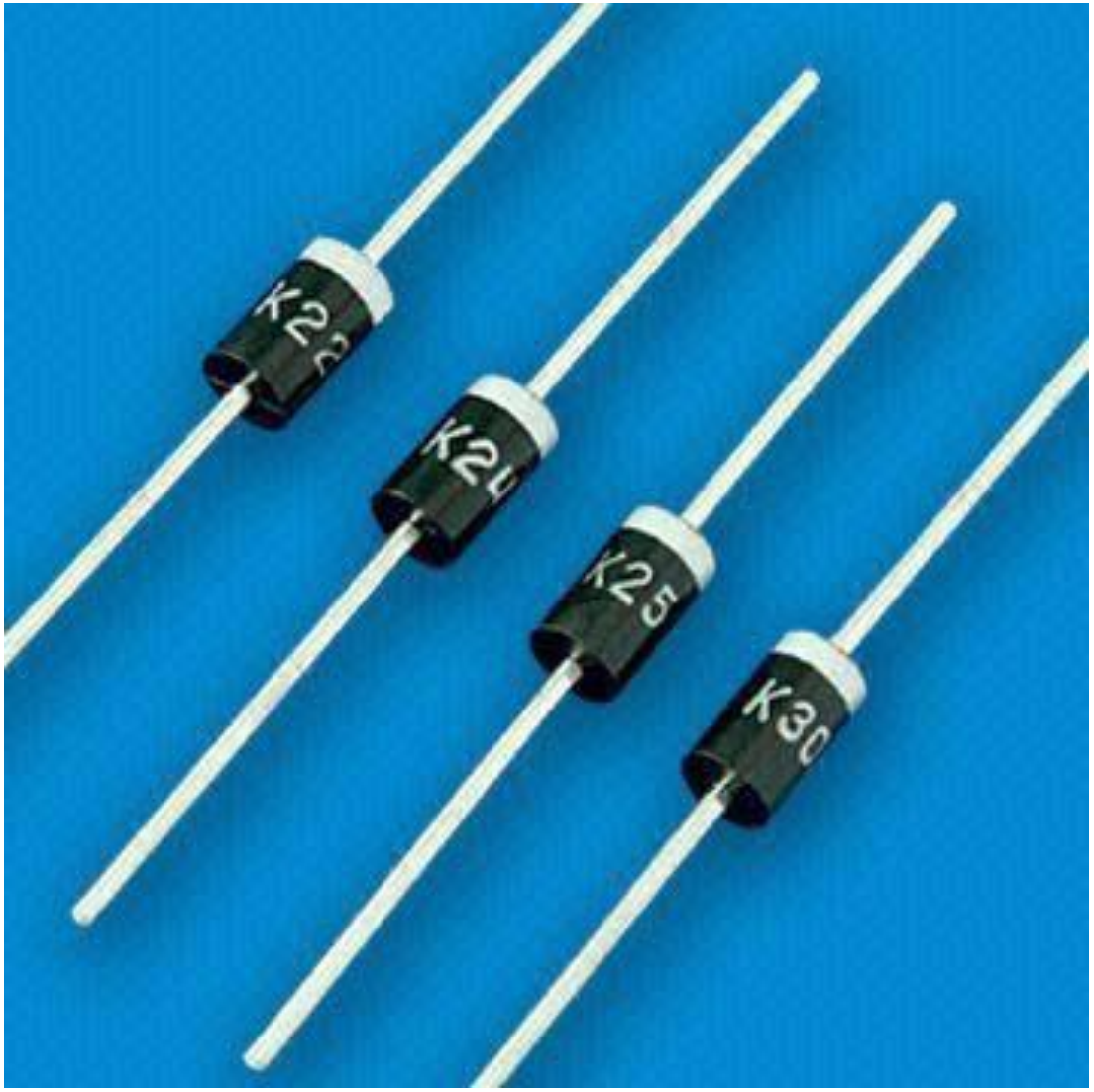


(c)

Tipos de Diodos



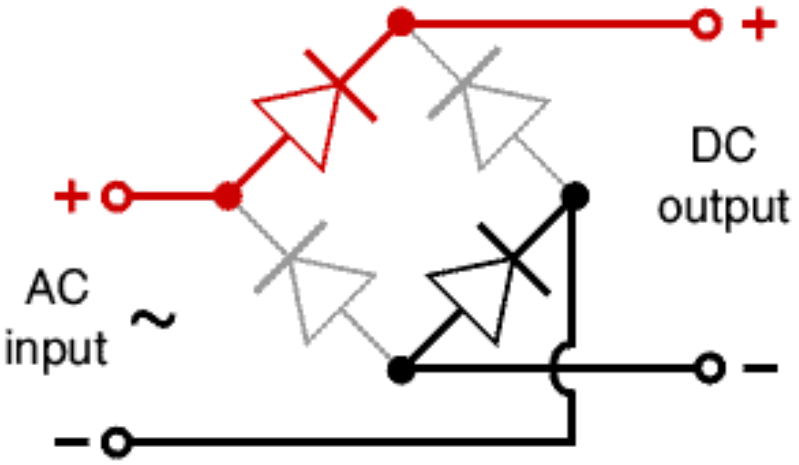
Tipos de Diodos

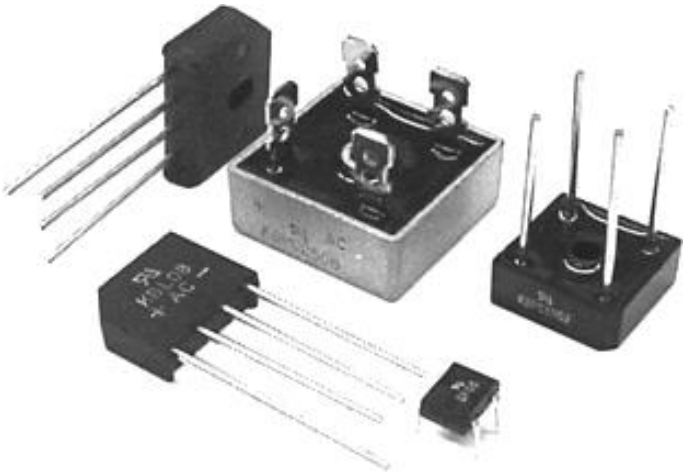


Tipos de Diodos

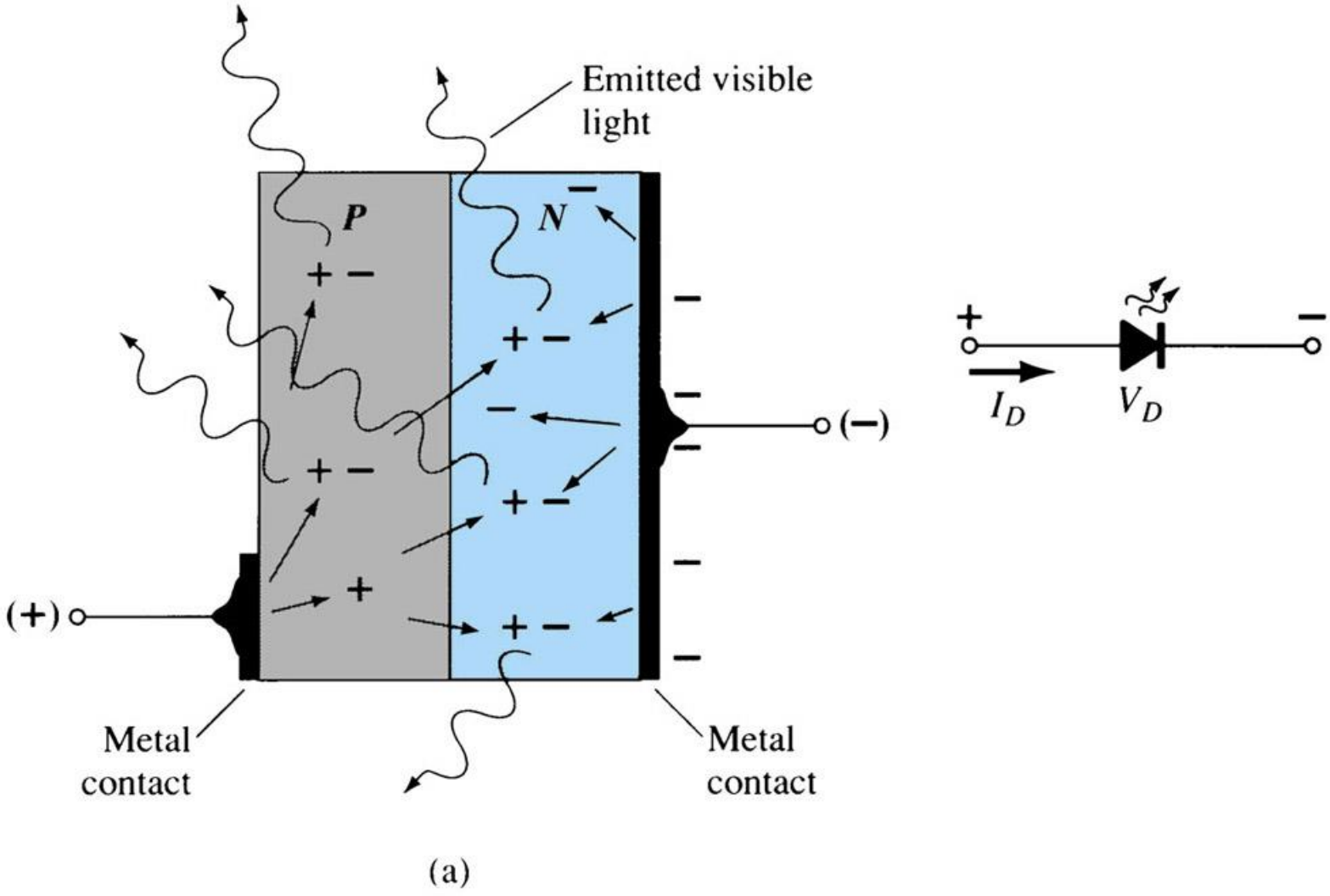
Tipos de Diodos

Ponte retificadora:
Utilizado no circuito de retificação em fontes de tensão

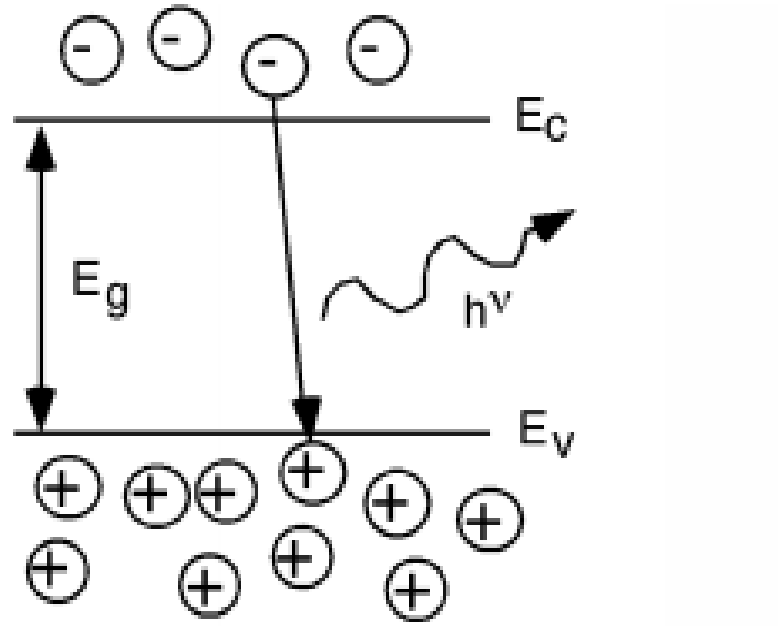


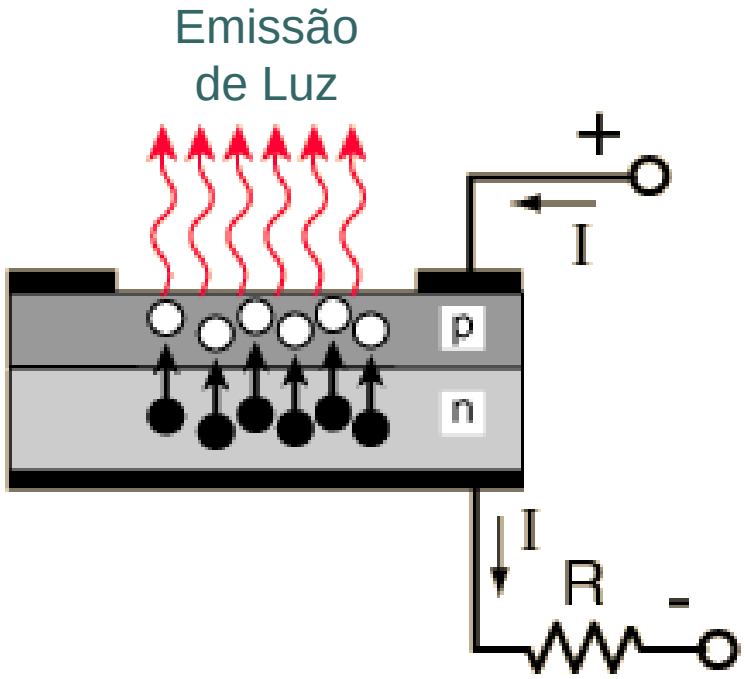


Diodos Especiais - LED



Recombinação elétron-lacuna

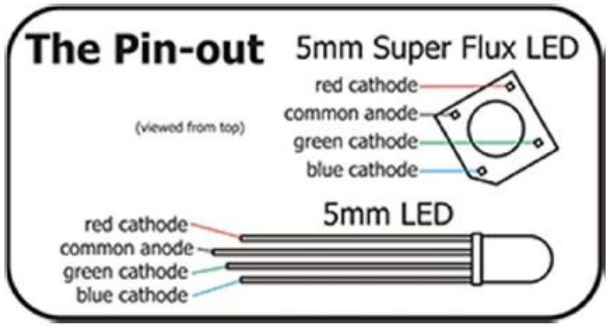


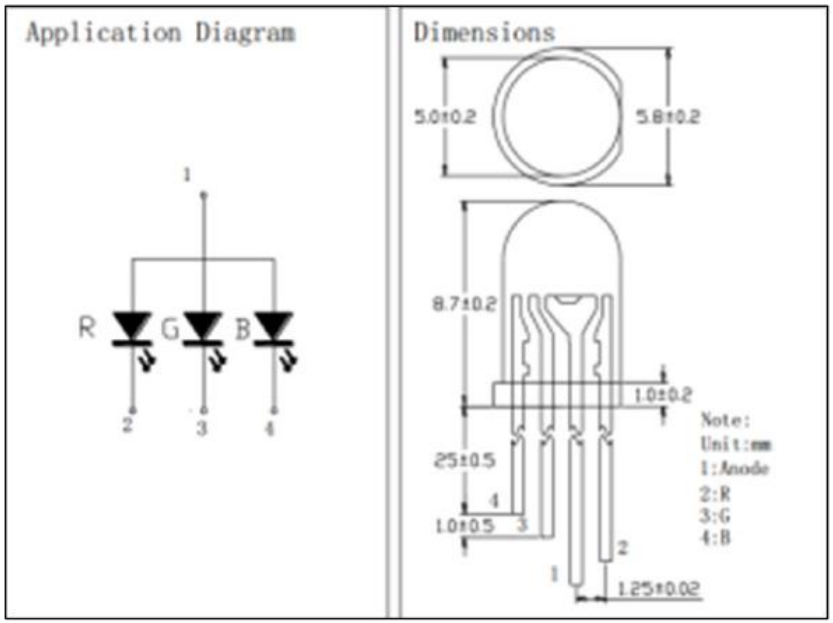


$h = 6{,}62606957 \times 10^{-34}\ m^2\ kg / s$

LEDs

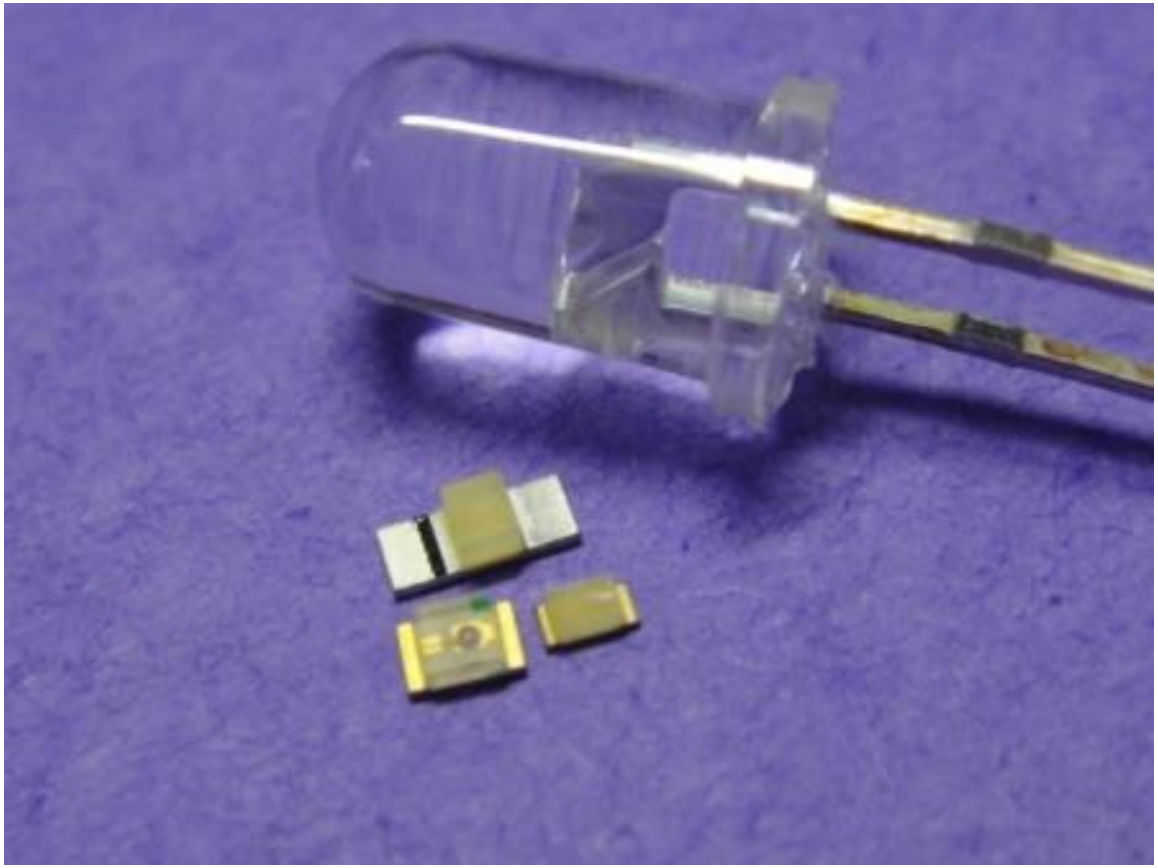
LED RGB



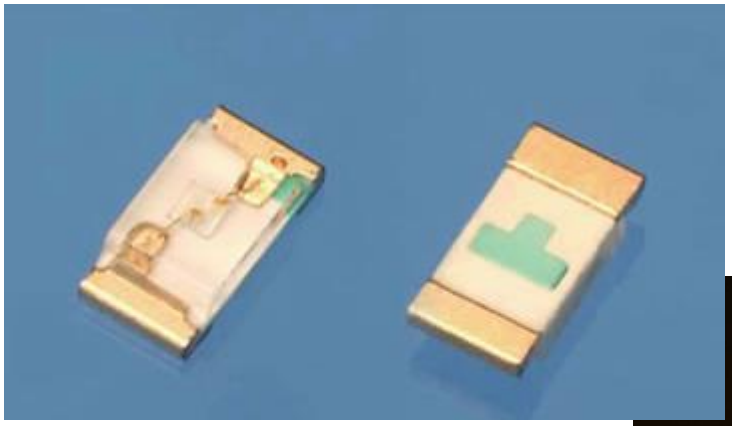


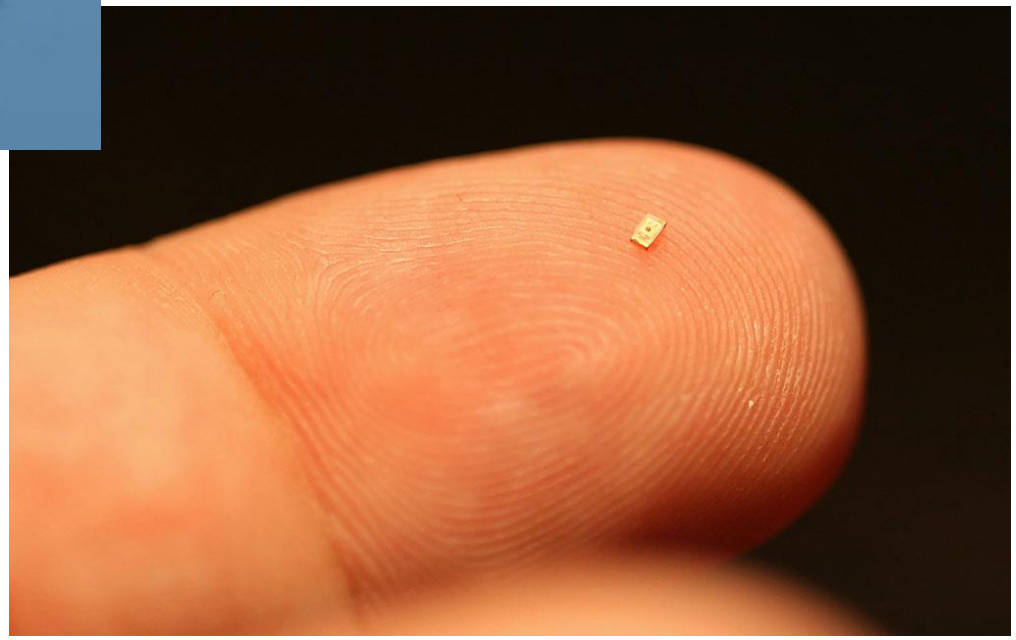
Tipo anodo comum

LEDs



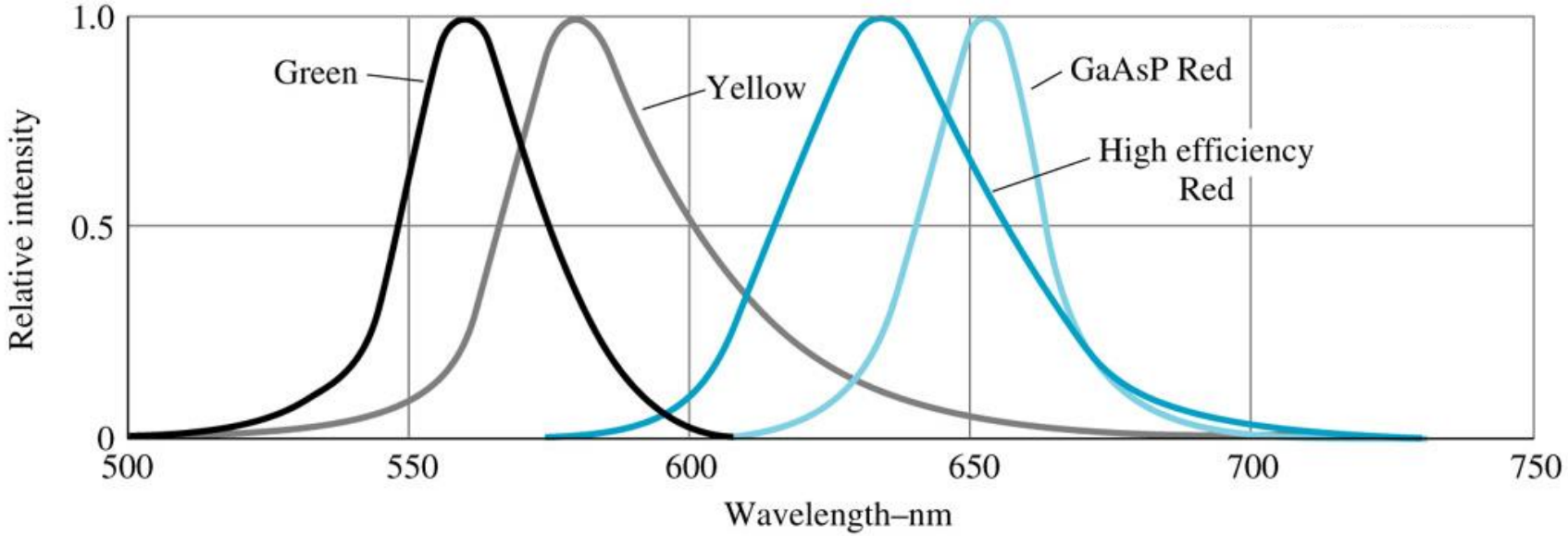
LEDs - SMD





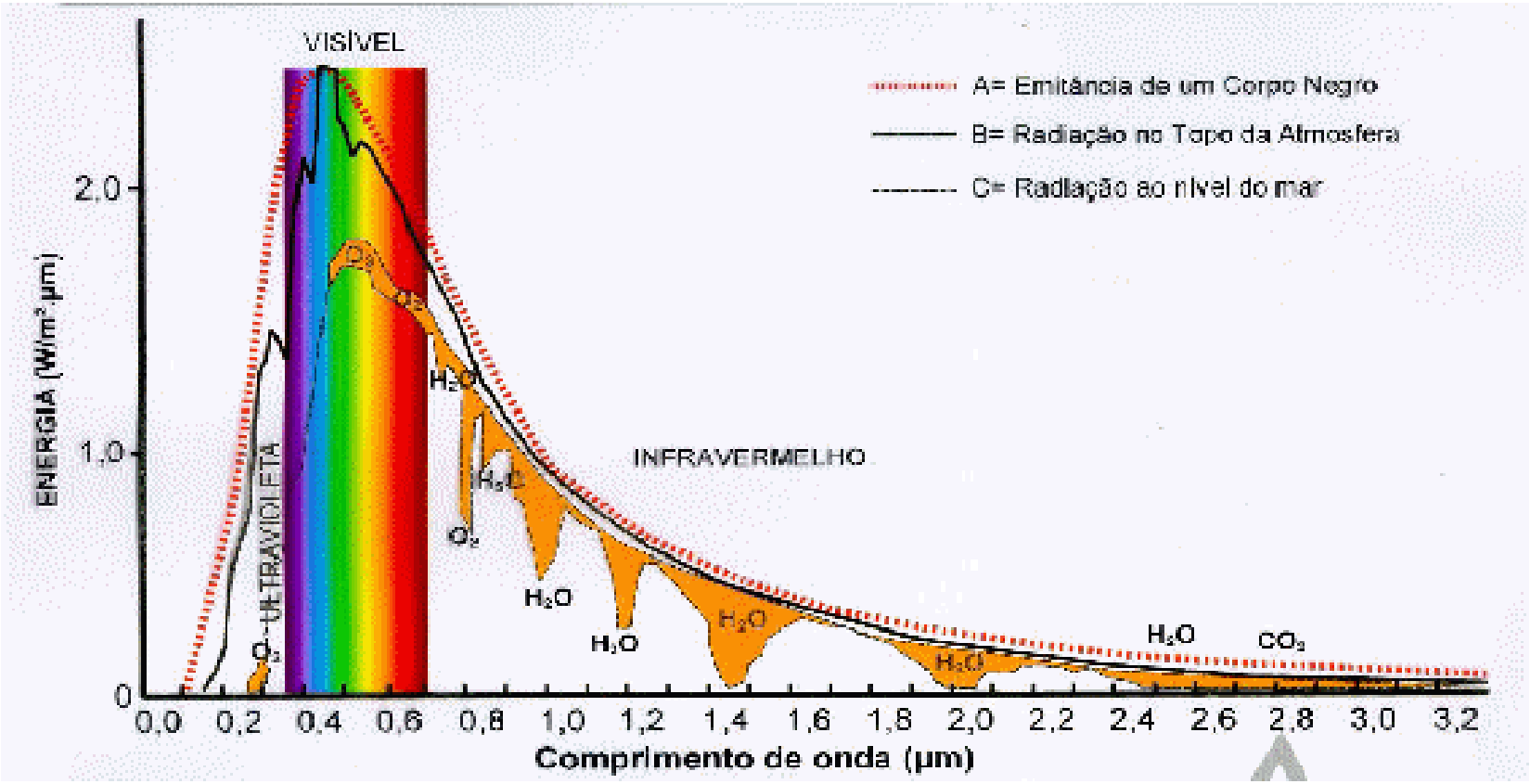
SMD – Surface Mounted Device

Espectro de emissão



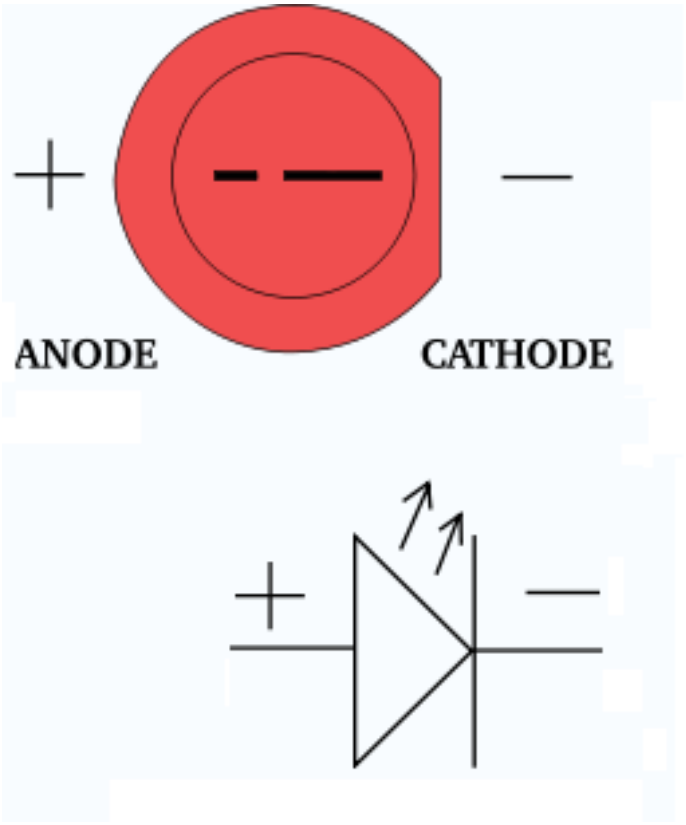
$$\nu = \frac{c}{\lambda}$$

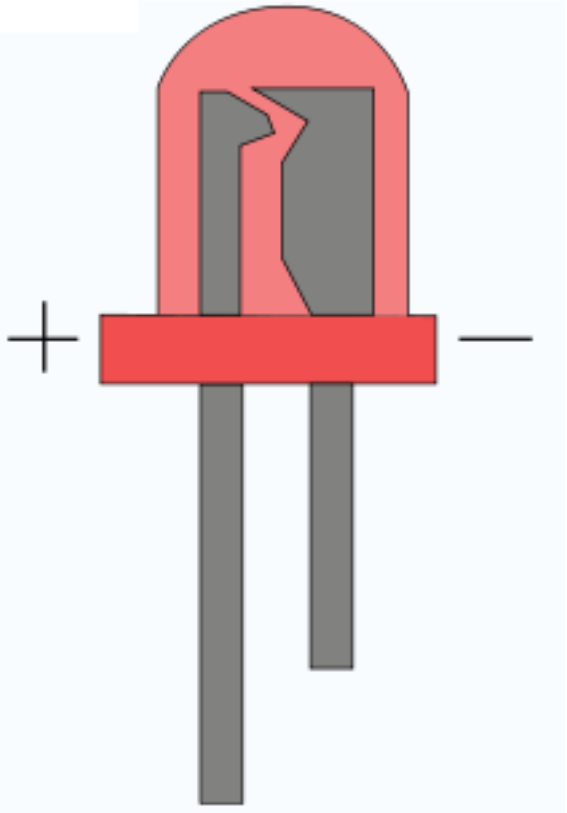
Espectro de emissão solar



$$\nu = \frac{c}{\lambda}$$

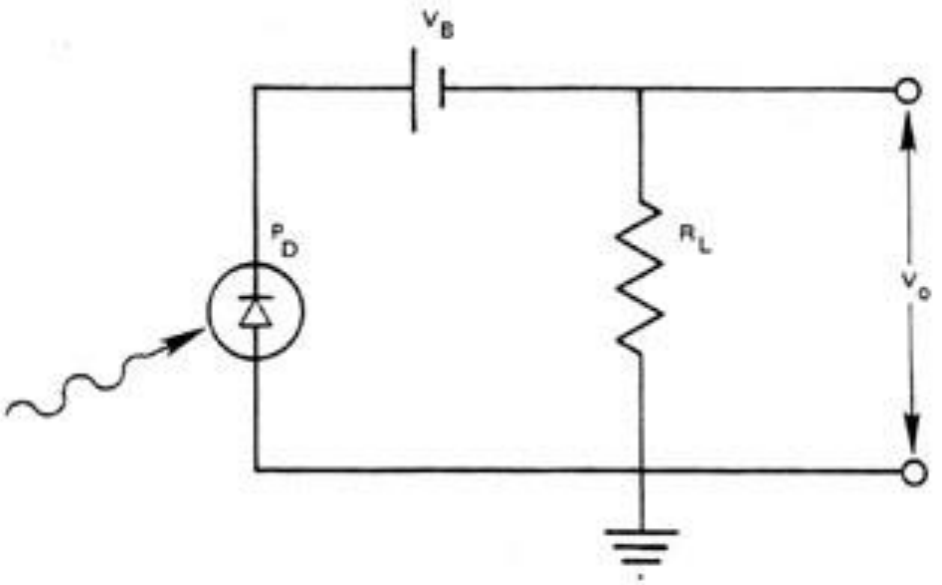
LED - Polarização



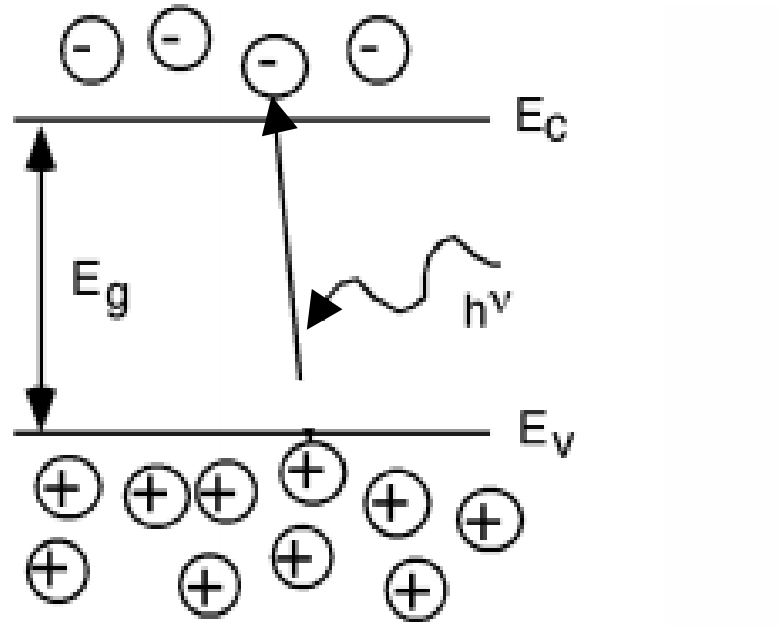


Diodos Especiais - Fotodetectores

Reversamente Polarizados



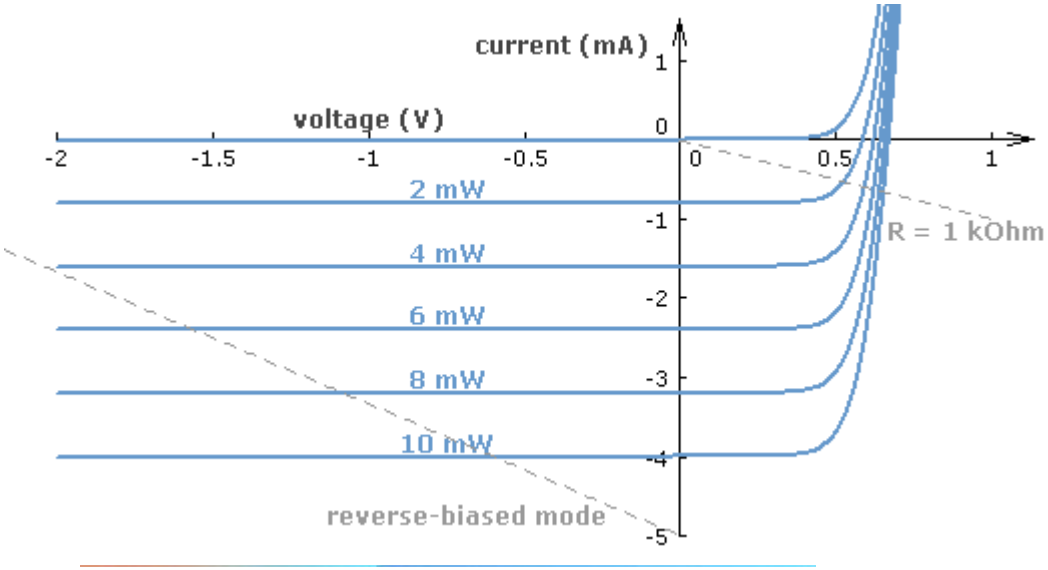
Recombinação elétron-lacuna



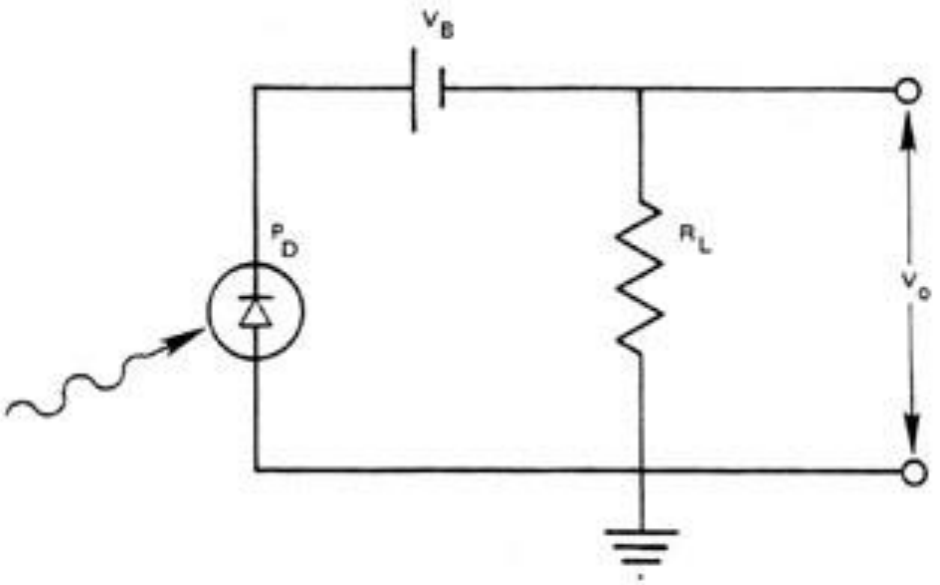
Incidência de Luz

$h = 6{,}62606957 \times 10^{-34}\ m^2\ kg\ /\ s$

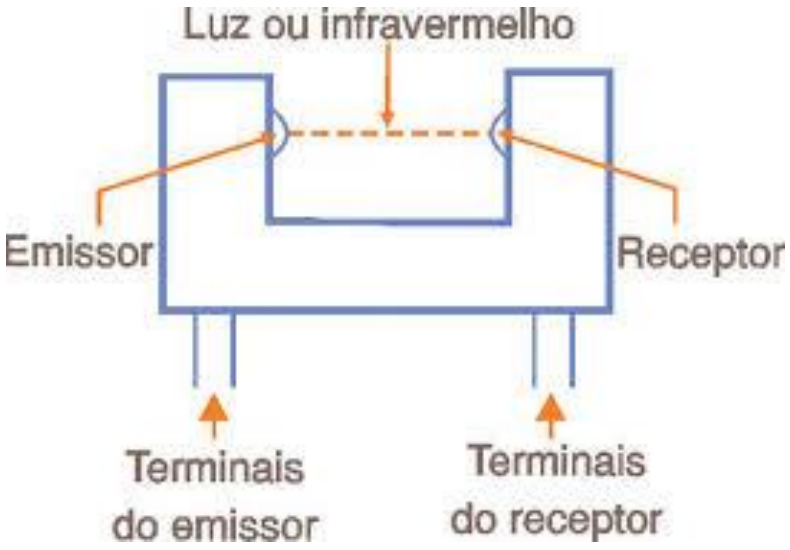
Diodos Especiais - Fotodetectores



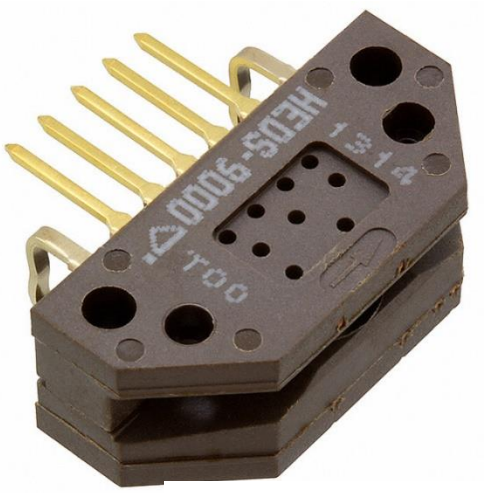
Reversamente Polarizados

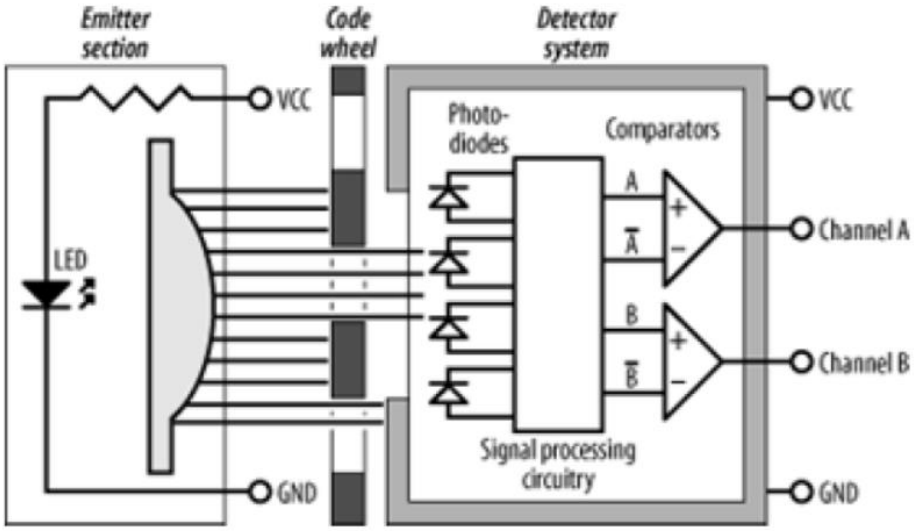


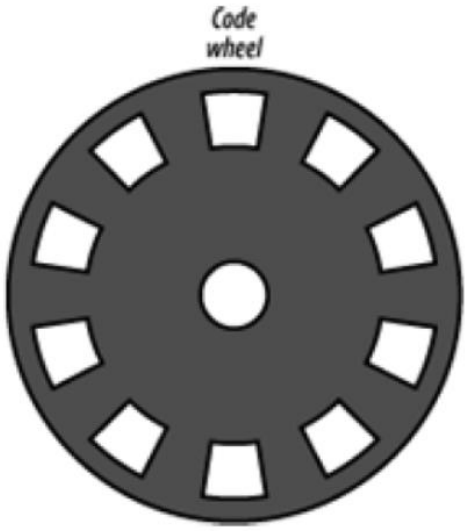
Diodos Especiais – Chave óptica



Aplicação

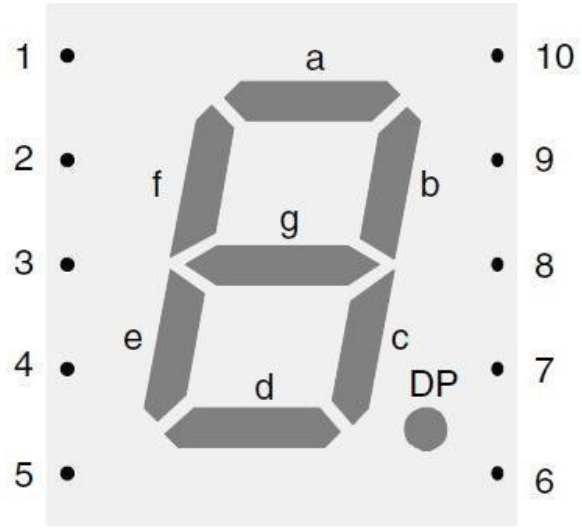

HEDS-9000
1514
T00

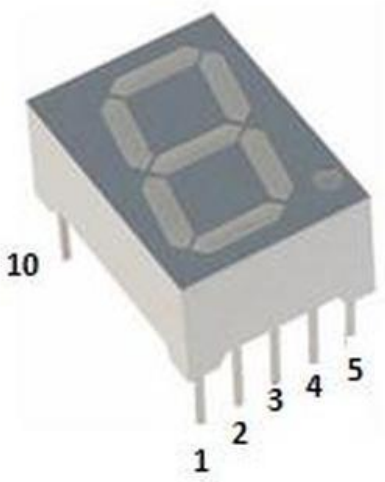

Emitter section
Code wheel
Detector system
VCC
LED
GND
Photo-diodes
Comparators
A
Ā
B
B̄
Channel A
Channel B
Signal processing circuitry
VCC
GND


Code wheel

Diodos Especiais – SSD

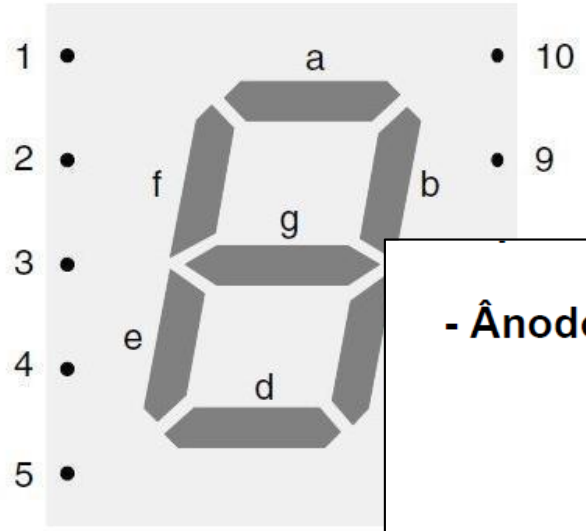
Display de Sete Segmentos

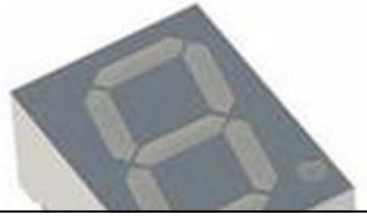




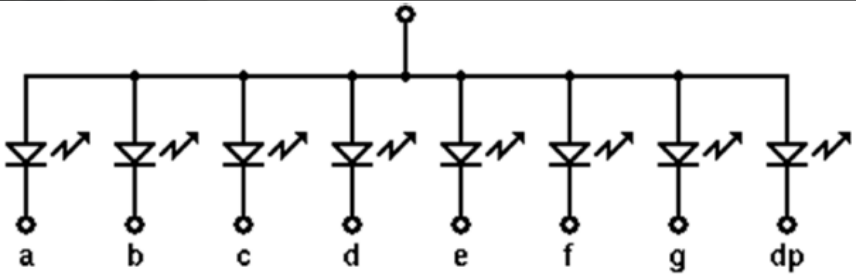
Diodos Especiais – SSD

Display de Sete Segmentos

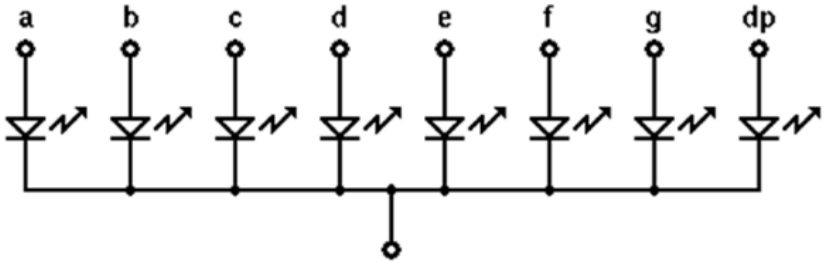




- Ânodo comum:

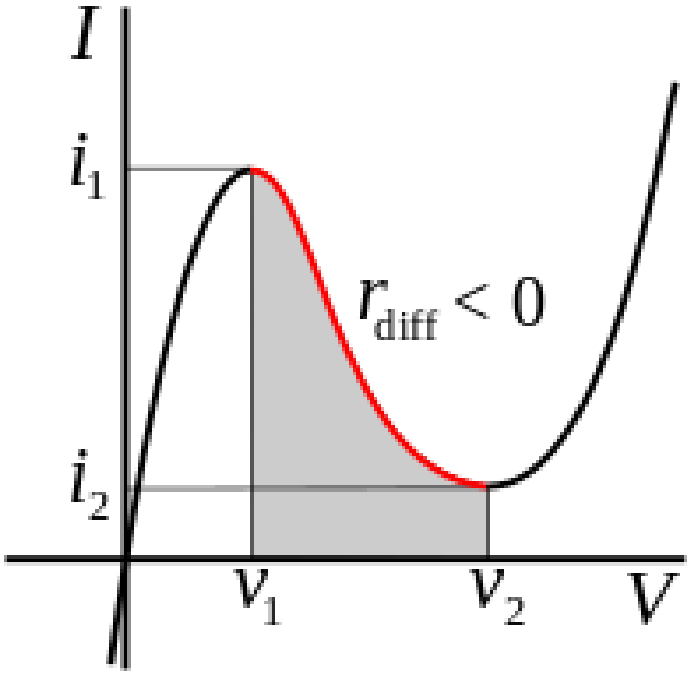


- Cátodo comum:



Diodos Especiais – Diodo túnel

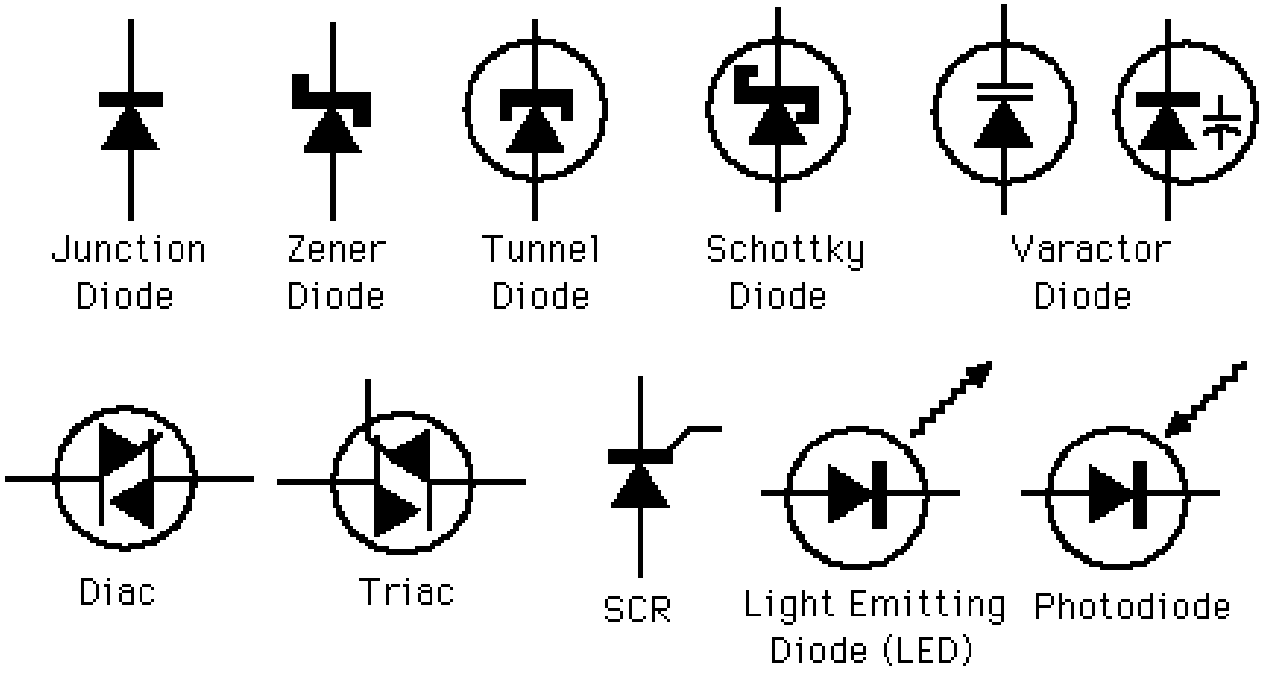
Resistência *negativa*



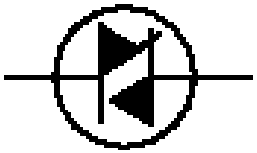
Aplicações:

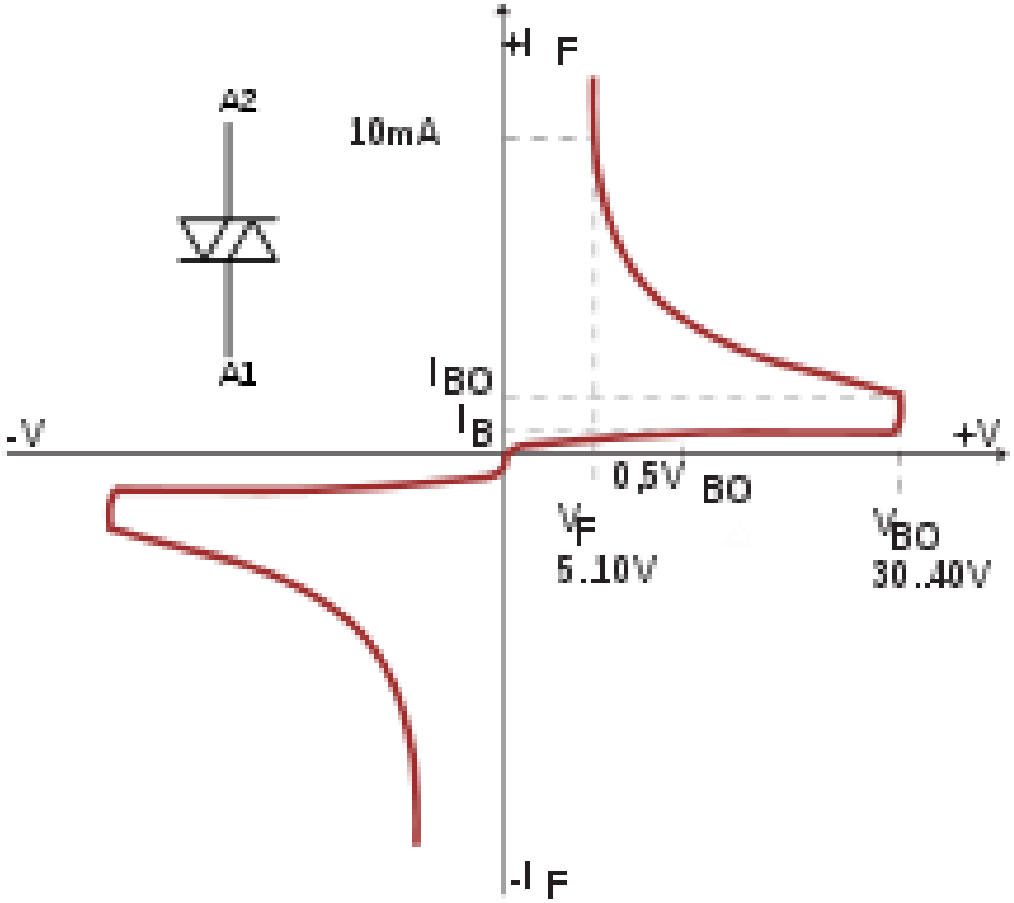
- Circuitos de alta frequência
- Osciladores de relaxação

Outros Diodos



Ex.: Diac

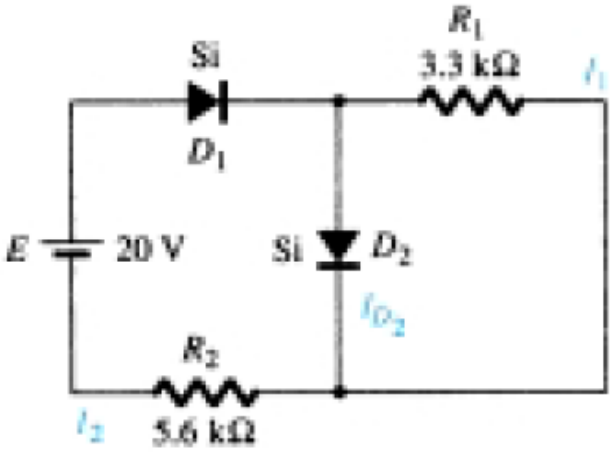




Perguntas

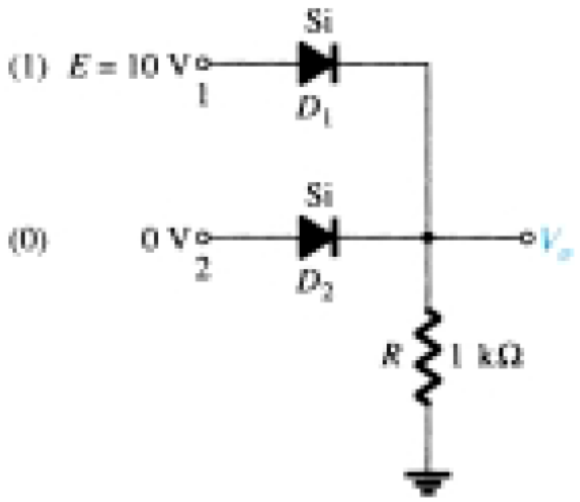
- Defina recombinação elétron-buraco.
- O que é região de depleção?
- O que é corrente de saturação reversa?
- O diodo conduz quando polarizado reversamente?
- Quais são os modelos do diodo?
- O que é ponto de operação do diodo?
- Qual a função que relaciona I_d *x* V_d?

Exercício



Determinar I_1, I_2 e I_D

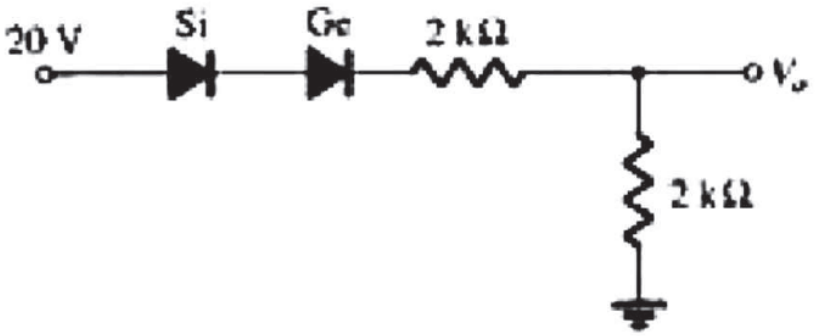
Exercício



Calcule v_o

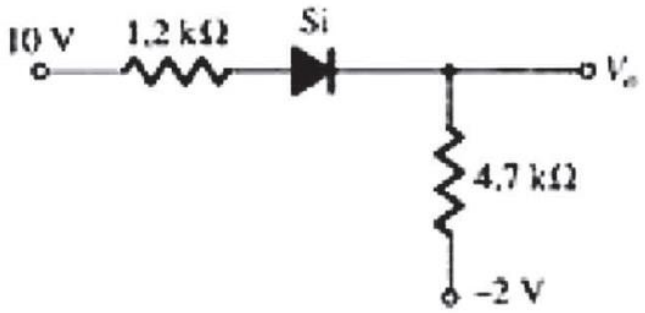
O circuito se comporta com uma *Porta Lógica*. De que tipo?

Exercício



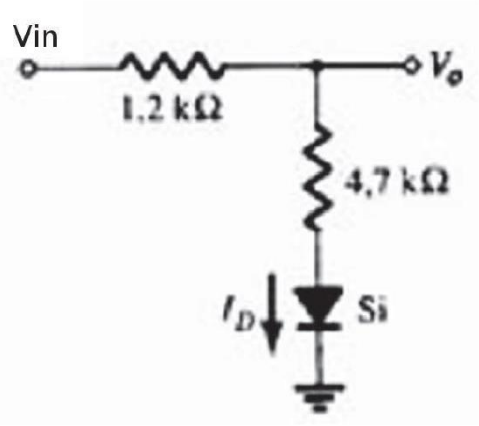
Calcule v_o

Exercício



Calcule v_o

Exercício



Calcule v_o para as seguintes situações:

- $V_{in} = 8\text{V}$
- $V_{in} = 3,3\text{V}$
- $V_{in} = 1,5\text{V}$

Exercícios recomendados

Cap 1 R. Boylestad – Dispositivos eletrônicos e teoria de circuitos
4ª. Edição

1, 2, 5, 9, 11, 12, 13, 14, 15, 18, 20, 27, 56