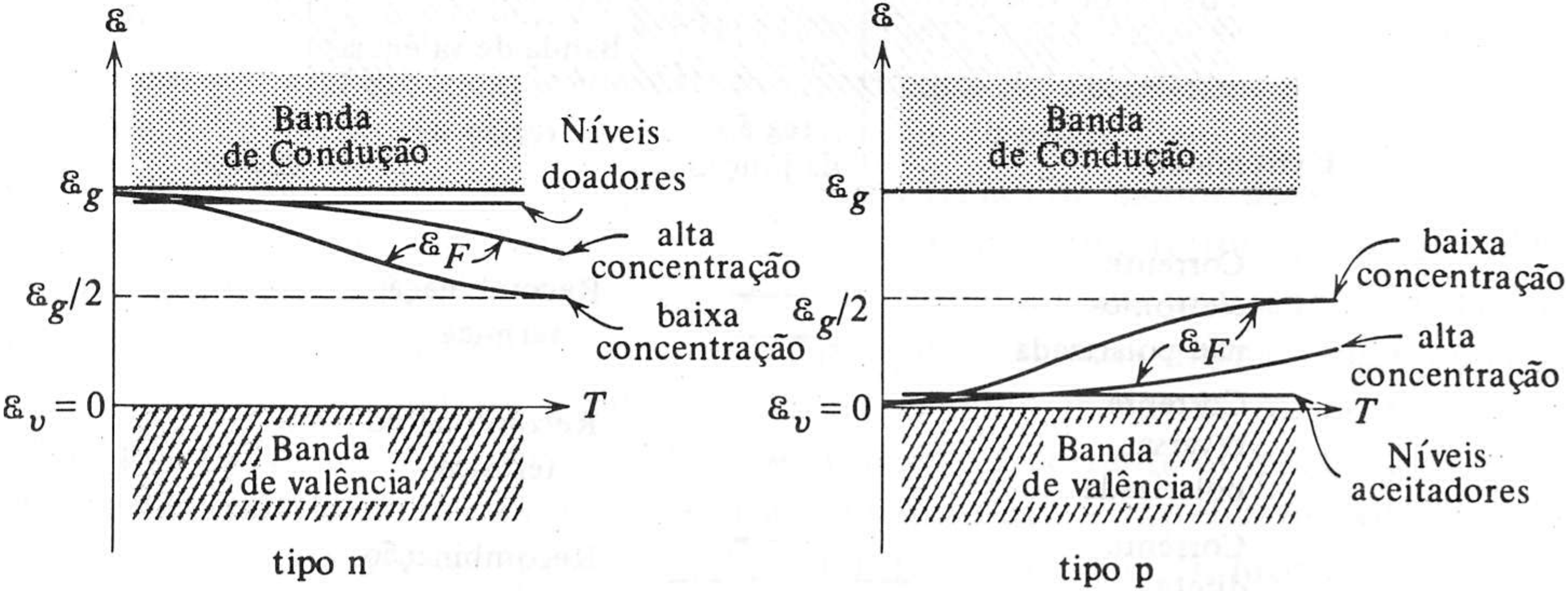
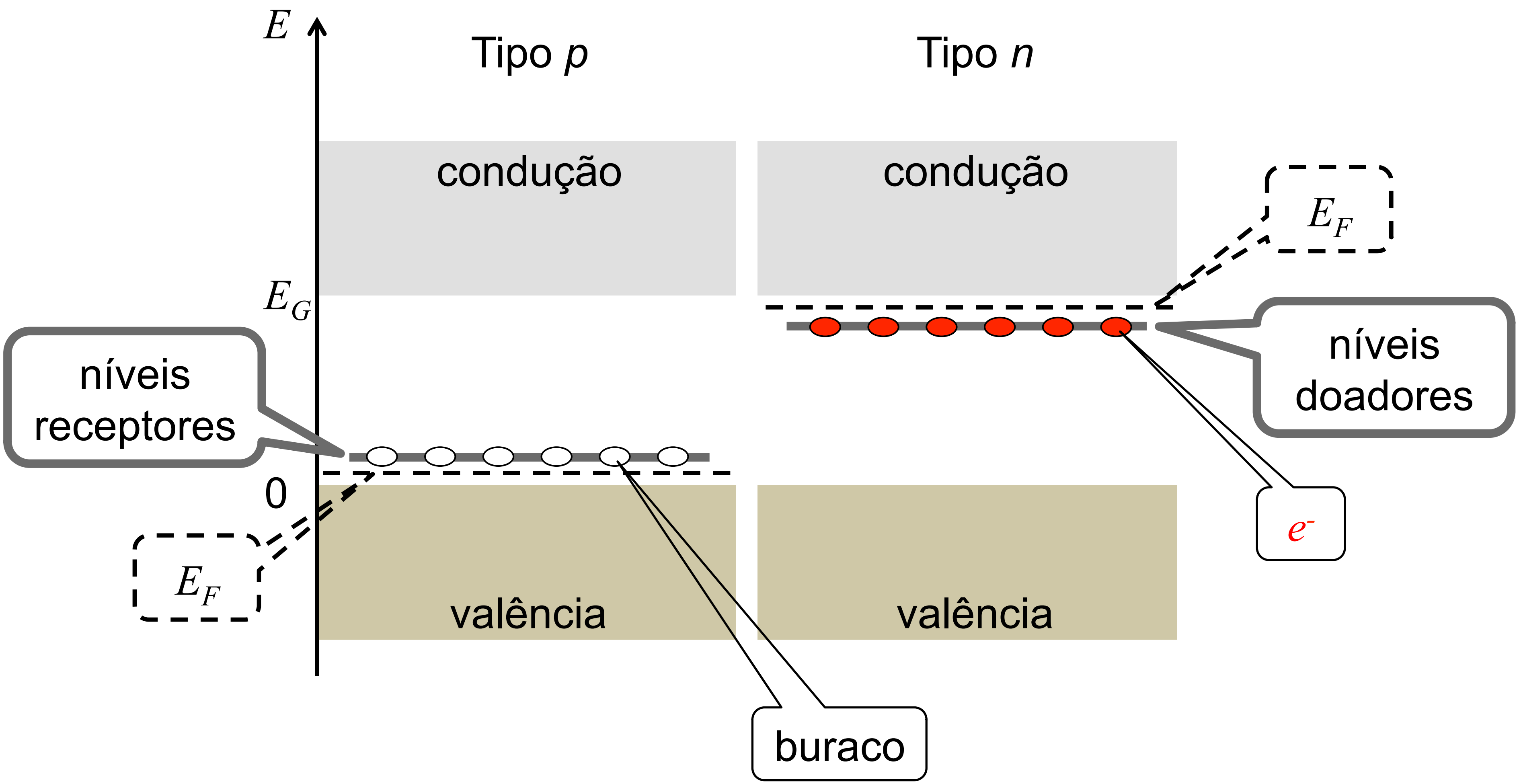
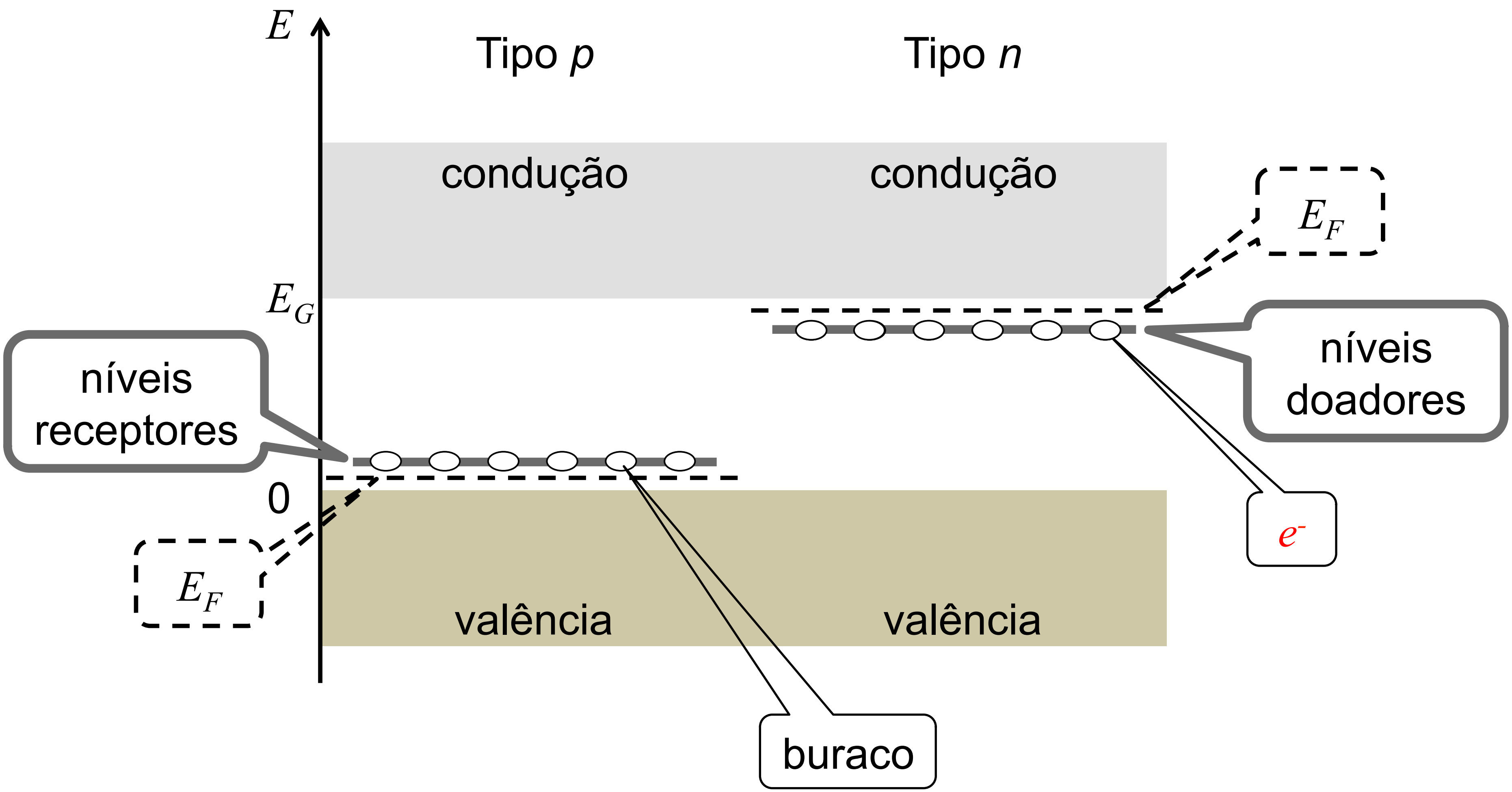
Dispositivos semicondutores

E_F em semicondutores dopados





E
Tipo p
Tipo n
condução
condução
E_F
E_G
níveis receptores
níveis doadores
0
E_F
e^-
valência
valência
buraco

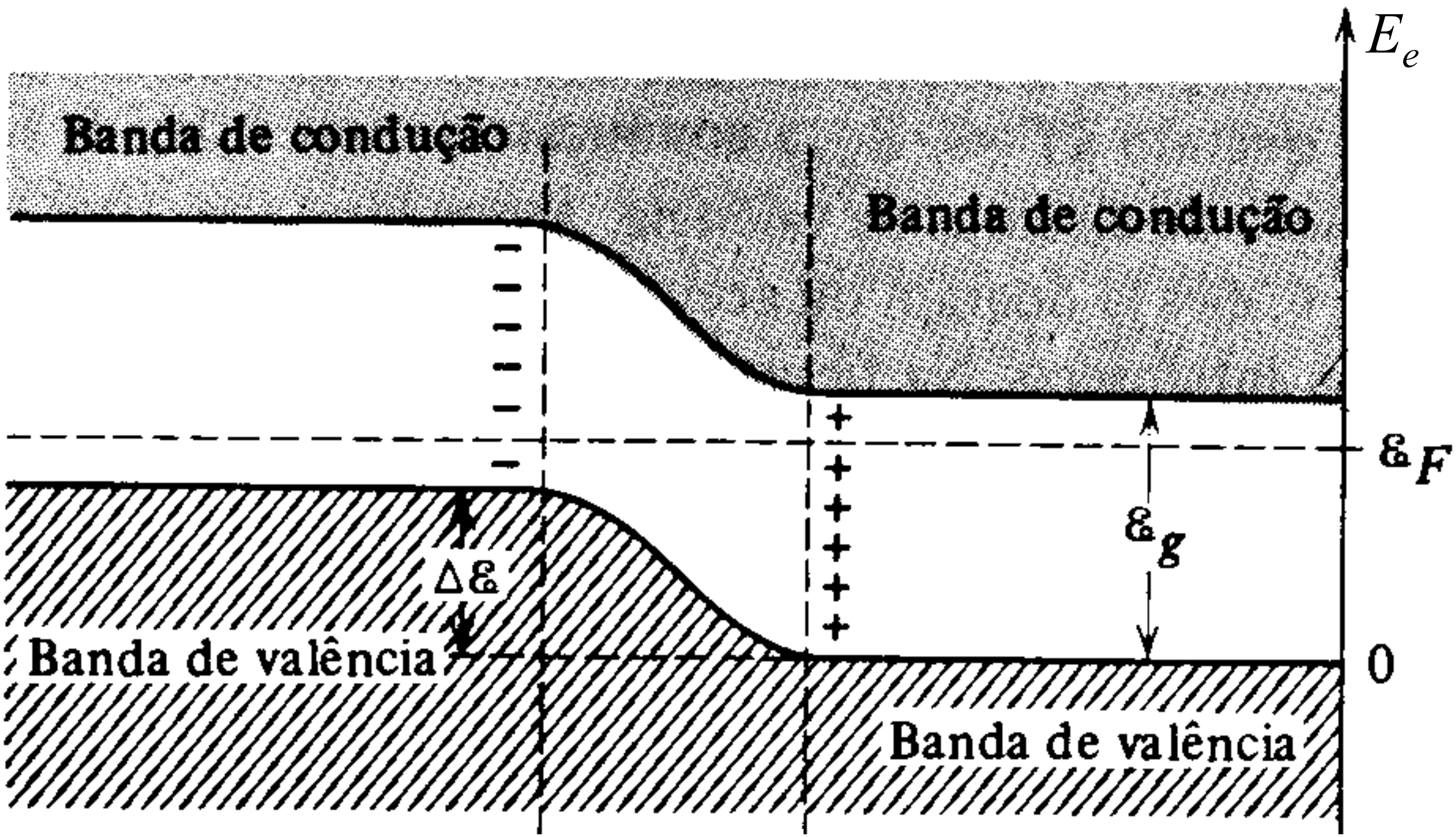


E
Tipo *p*
Tipo *n*
condução
condução
E_F
E_G
níveis receptores
níveis doadores
0
E_F
e^-
valência
valência
buraco

Dispositivos semicondutores

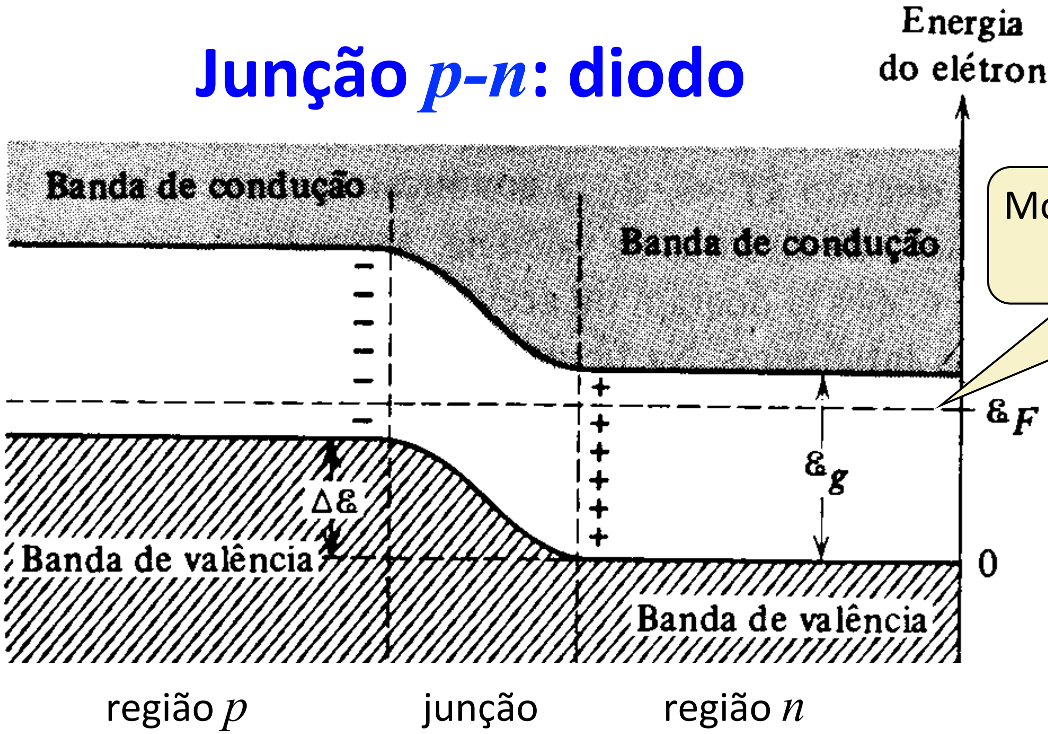
Estabelecimento de uma junção *pn*.

Contato íntimo entre regiões dopadas com tipo *p* e com tipo *n*.

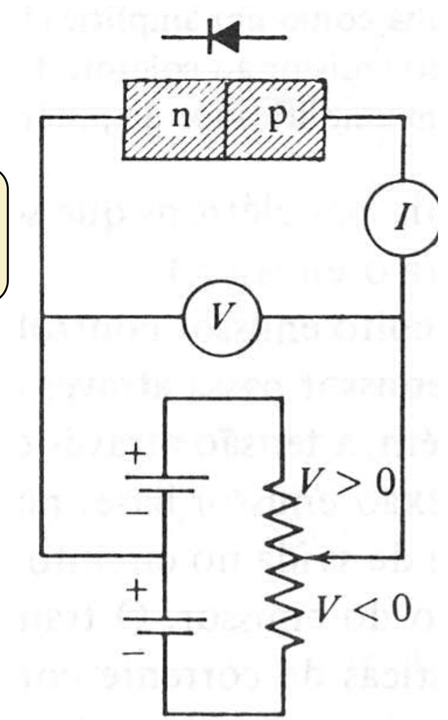


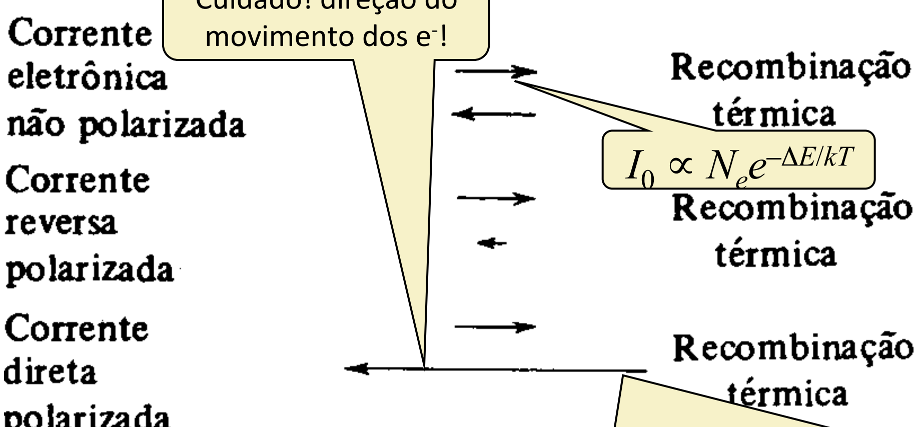
Região *p* Junção Região *n*

Junção *p-n*: diodo



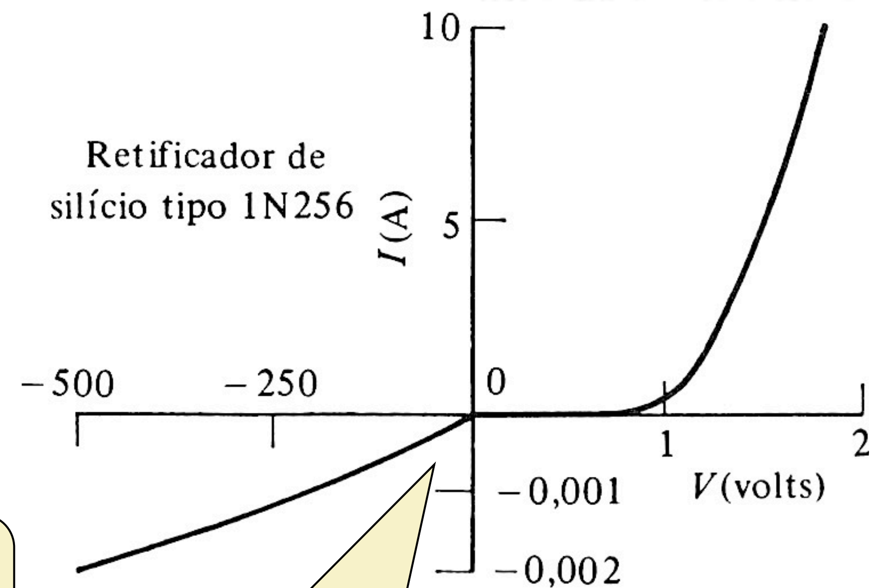
Movimento de cargas até igualar as E_F





Cuidado! direção do movimento dos e^-!

$I_0 \propto N_e e^{-\Delta E/kT}$

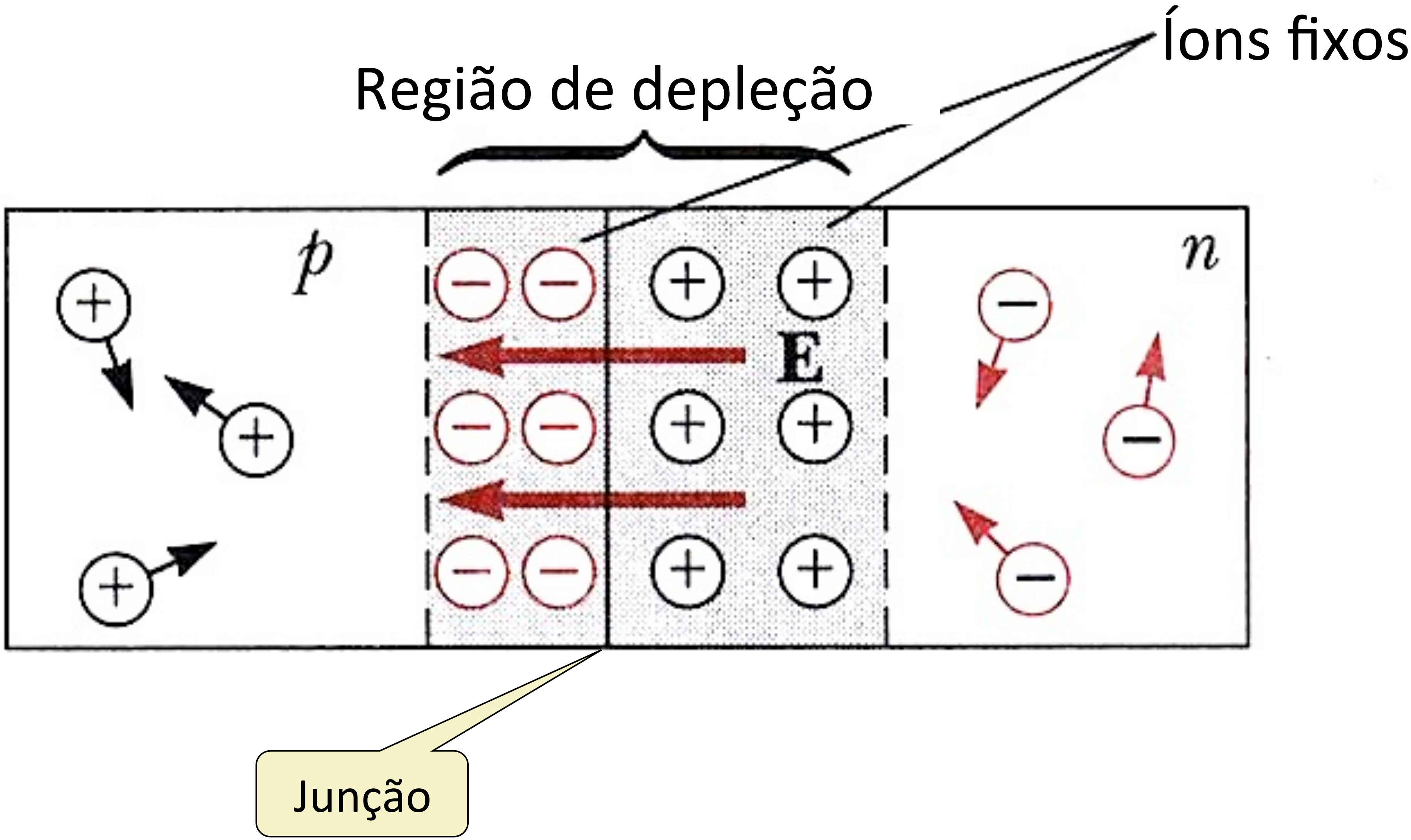


ddp direta V_b: $N_e e^{-(\Delta E - eV_b)/kT} = \left(N_e e^{-\Delta E/kT}\right) e^{eV_b/kT} \Rightarrow$

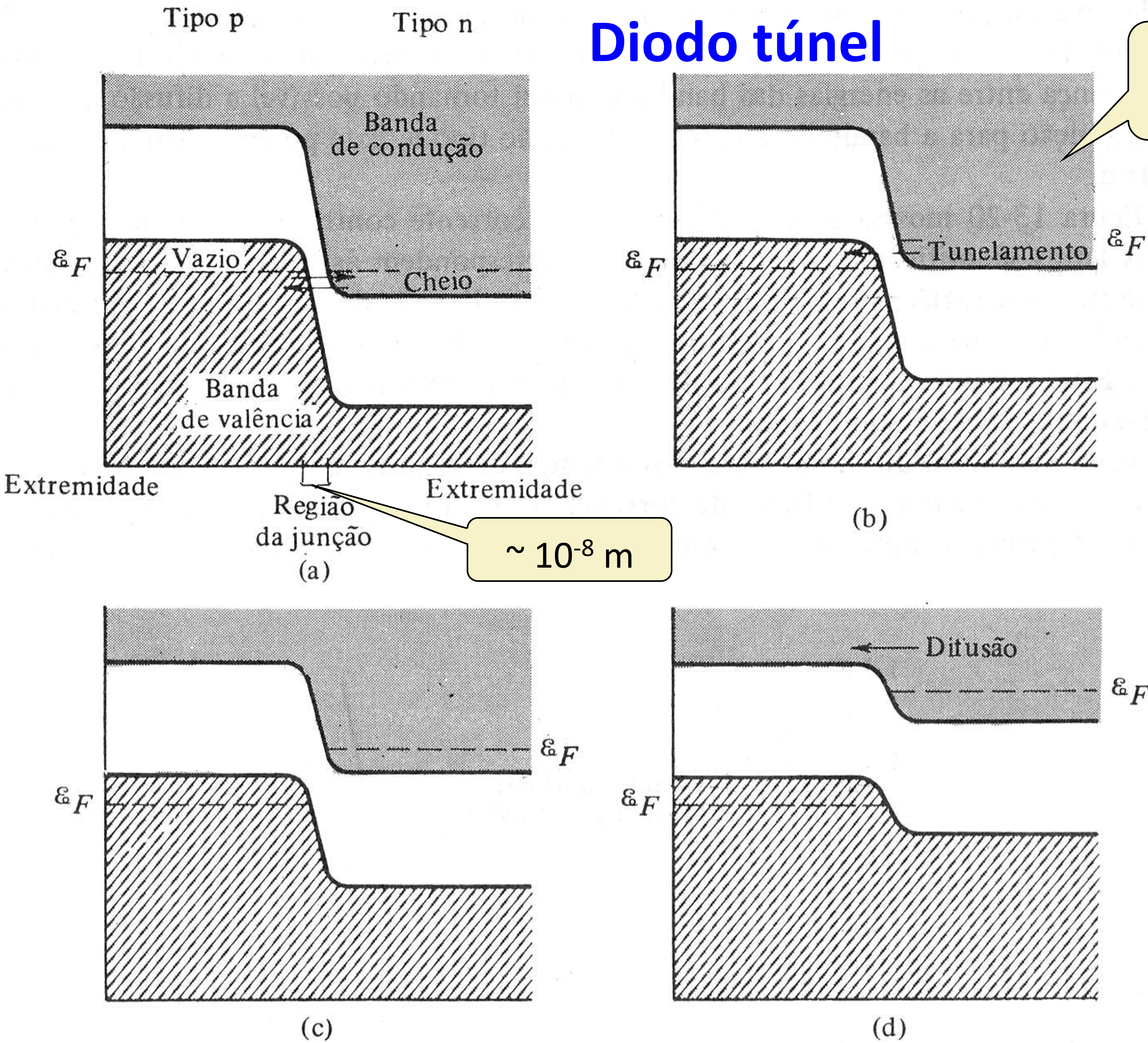
$$\Rightarrow I = I_0 e^{eV_b/kT} \quad \therefore I_{\text{total}} = I_0\left(e^{eV_b/kT} - 1\right)$$

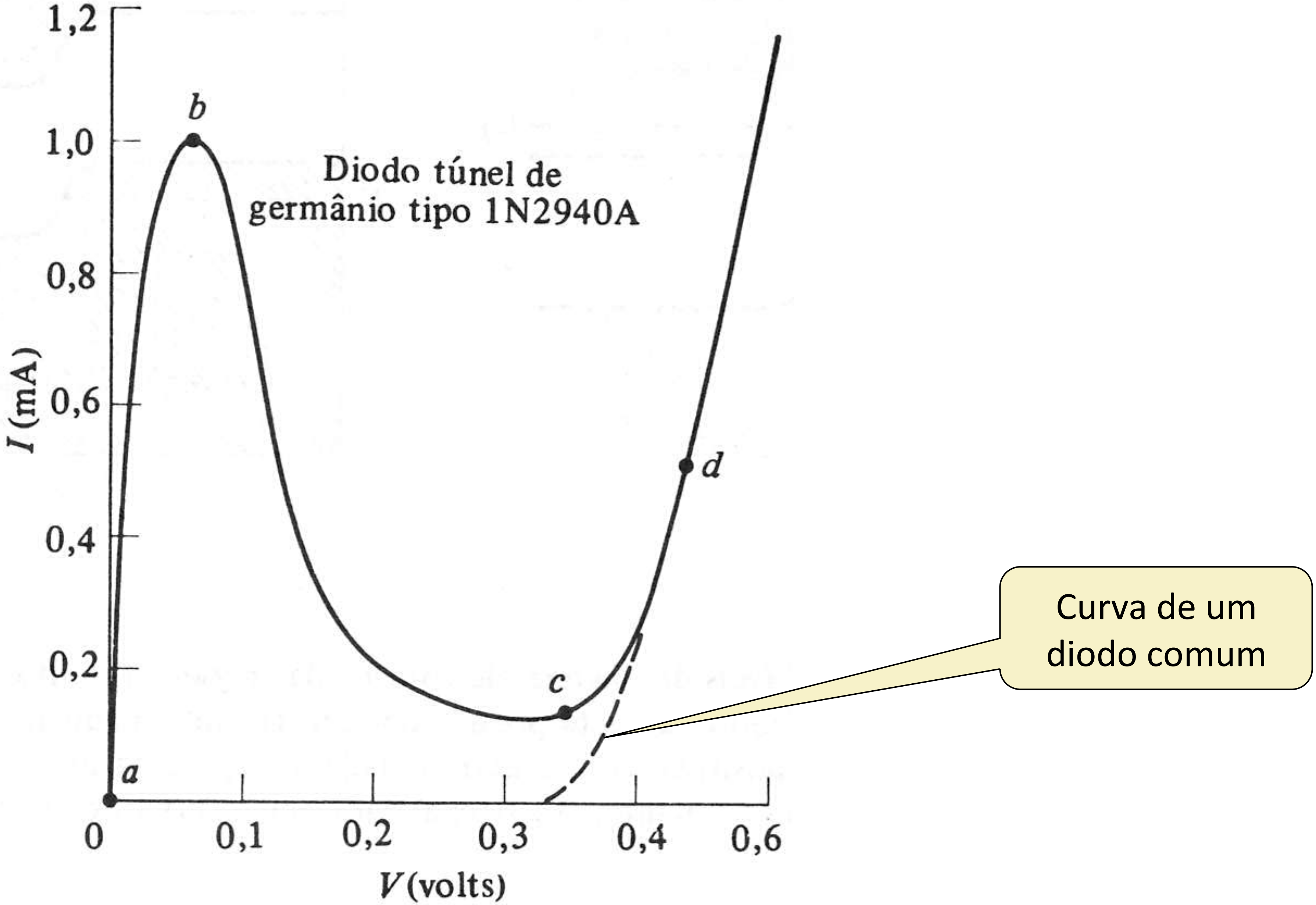
Cuidado com as escalas!

Junção *p-n*: diodo



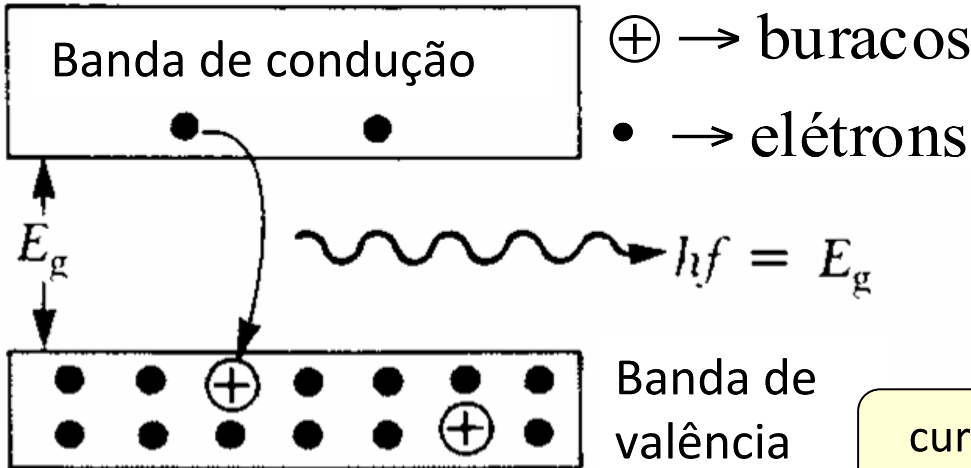
Diodo túnel

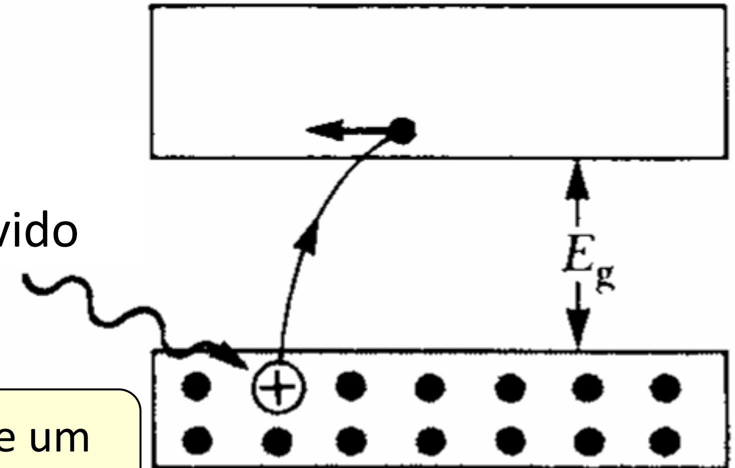

Tipo p
Tipo n
Banda de condução
Vazio
Cheio
$\mathcal{E}_F$
Banda de valência
Extremidade
Região da junção
Extremidade
(a)
~ 10^{-8} m
Tunelamento
$\mathcal{E}_F$
(b)
alta concentração de dopantes
$\mathcal{E}_F$
(c)
Difusão
$\mathcal{E}_F$
(d)

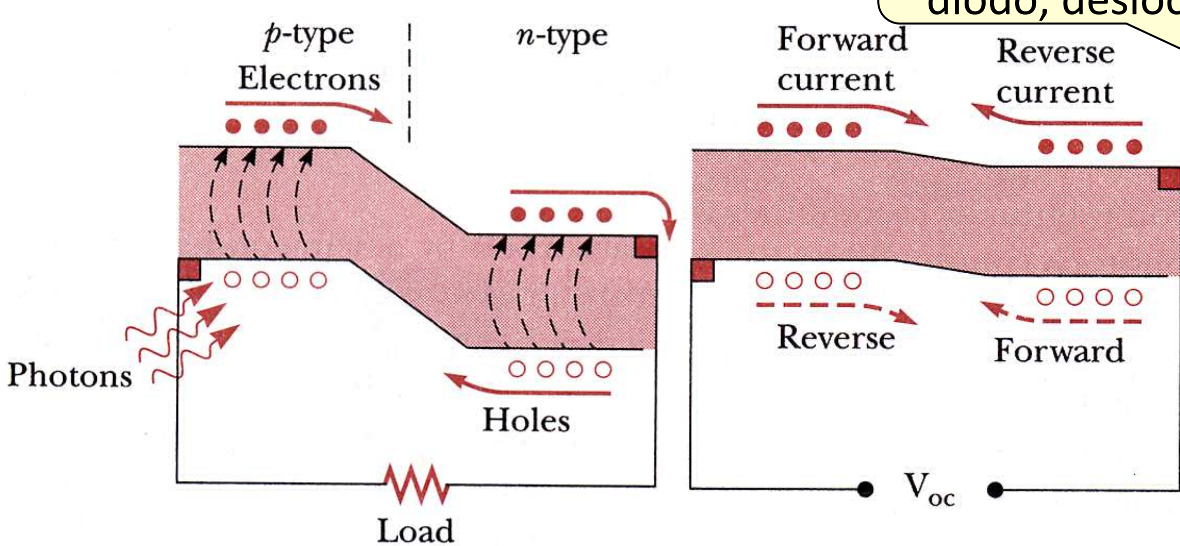

1,2
1,0
0,8
0,6
0,4
0,2
0
I (mA)
b
a
c
d
Diodo túnel de
germânio tipo 1N2940A
0,1
0,2
0,3
0,4
0,6
V (volts)
Curva de um
diodo comum

Absorção e emissão de luz

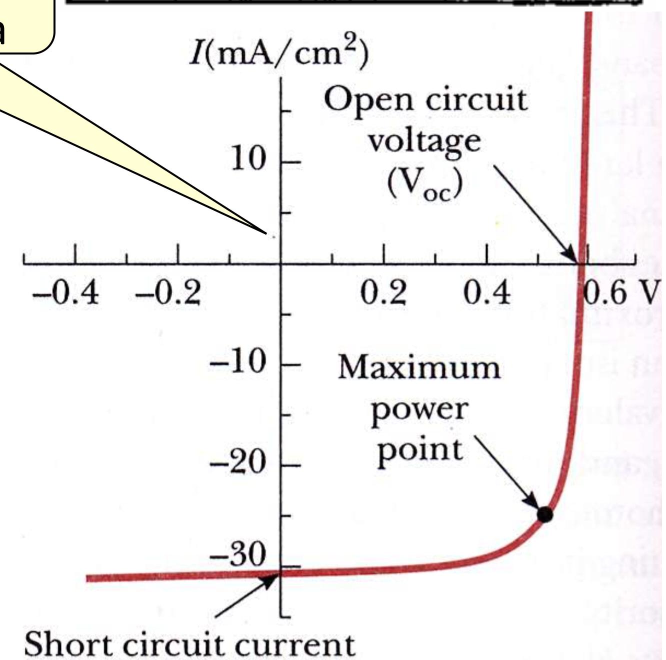
Absorção e emissão de luz por semicondutores são processos análogos àqueles que ocorrem em átomos isolados, com a diferença de que níveis atômicos são substituídos por bandas.



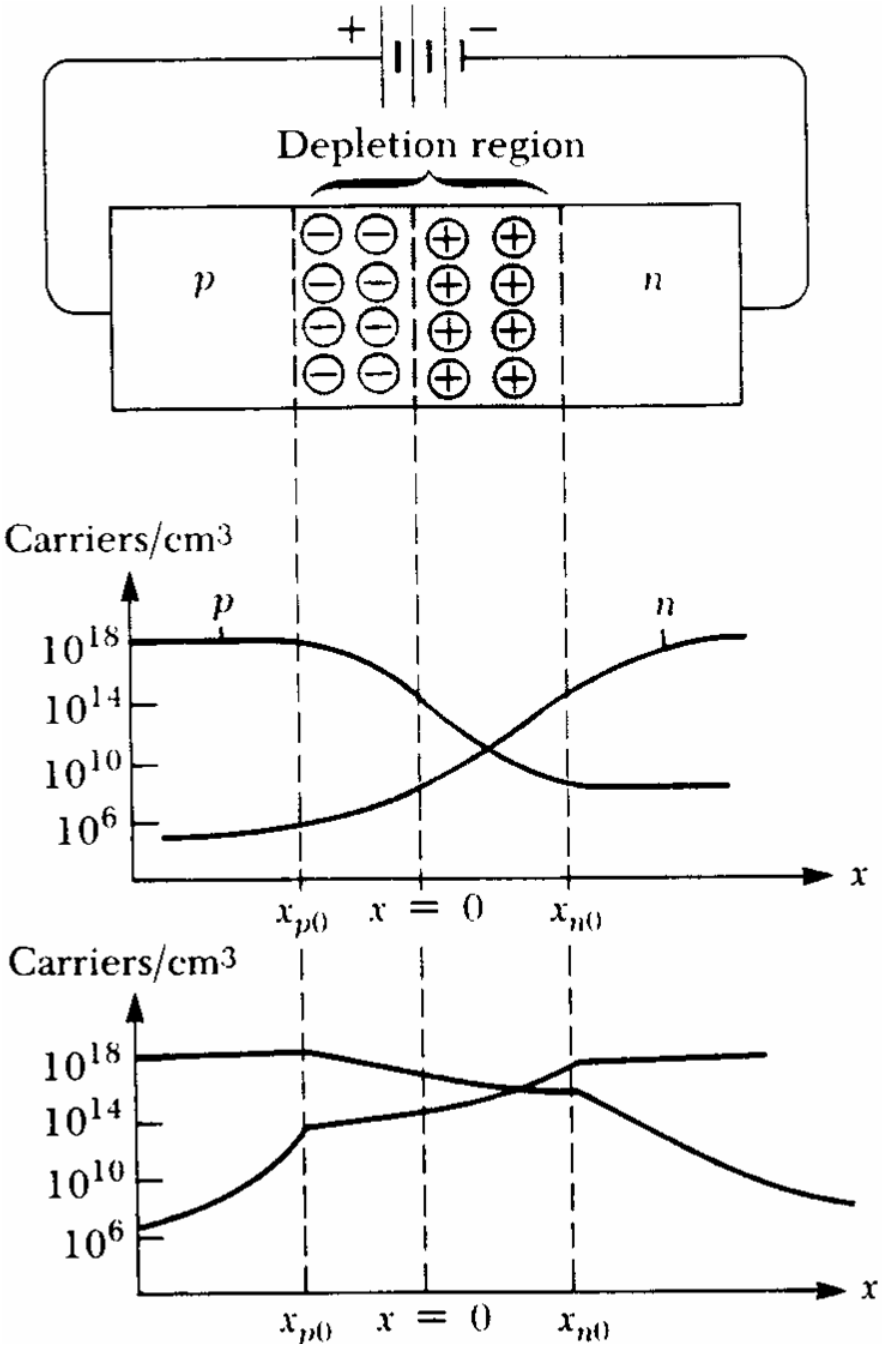


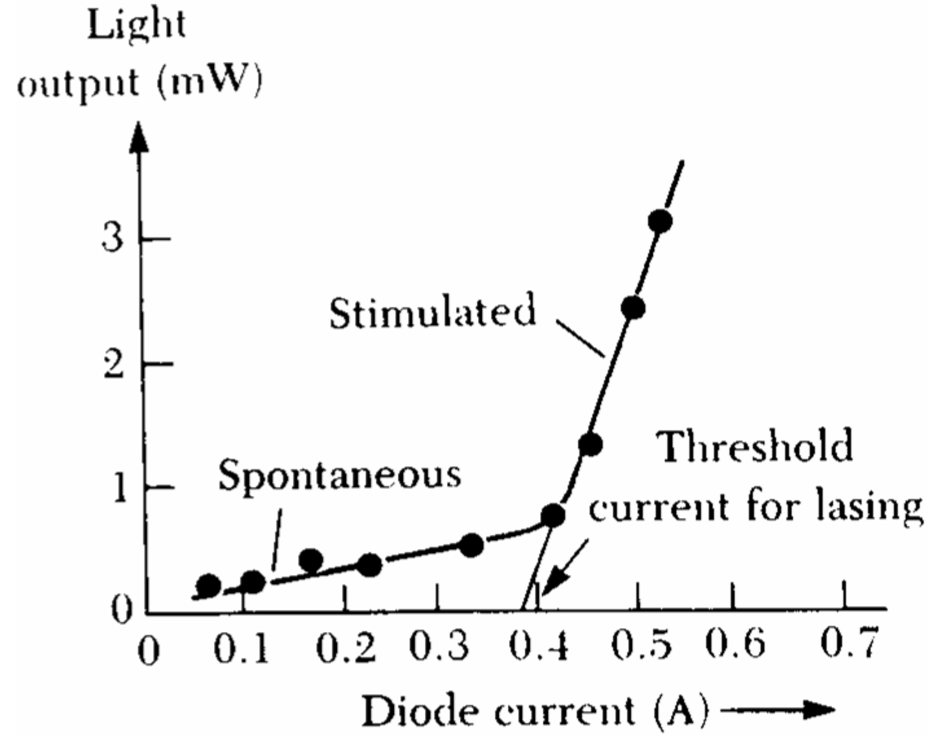


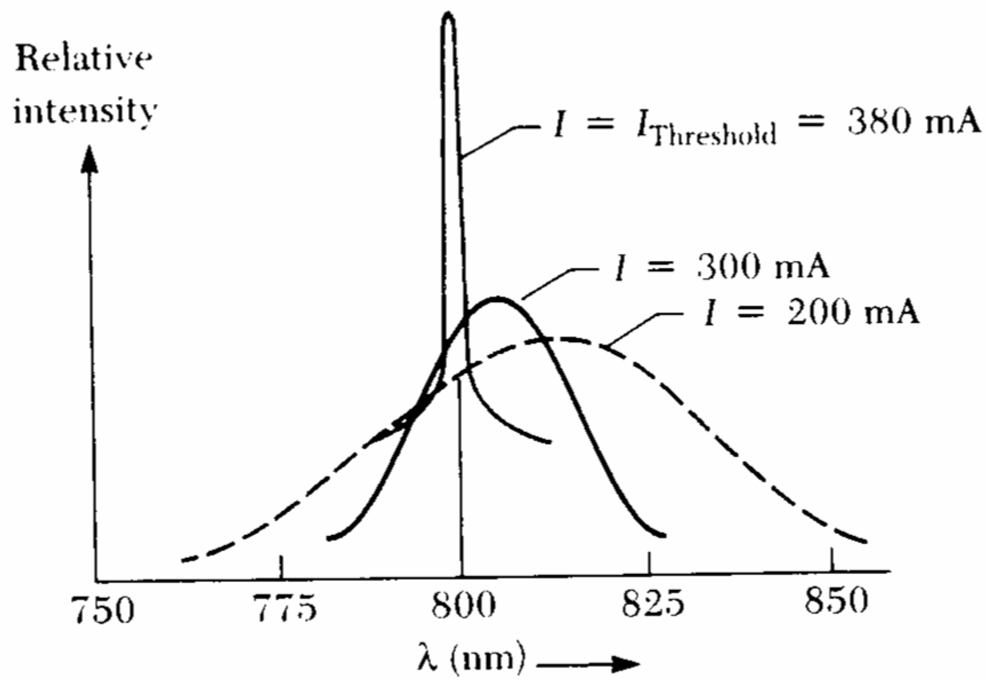
curva IxV de um diodo, deslocada



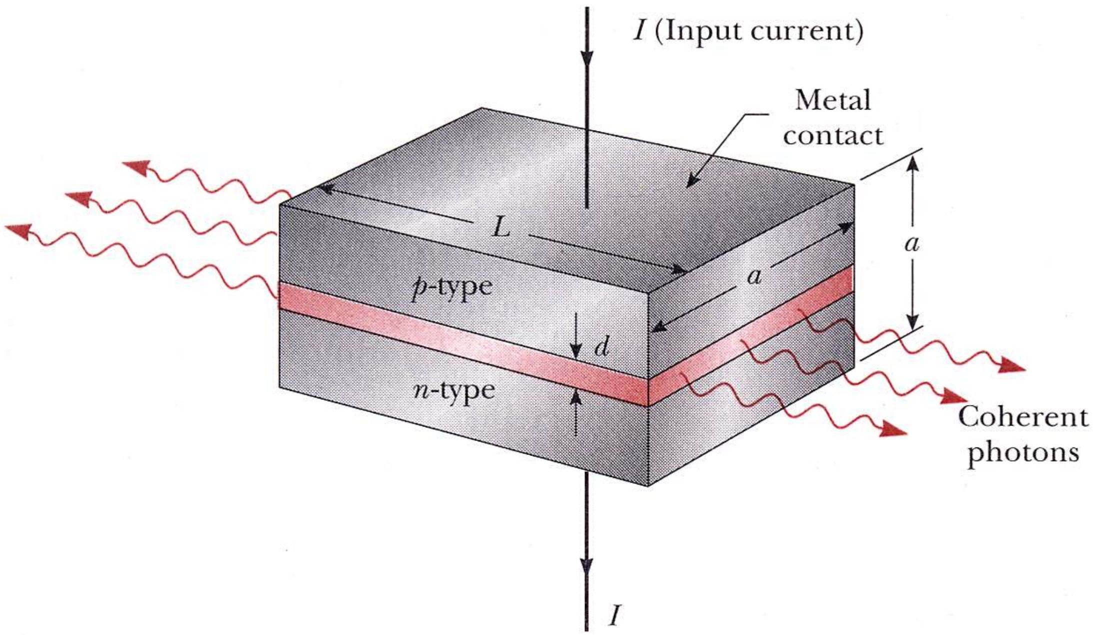
Laser de estado sólido





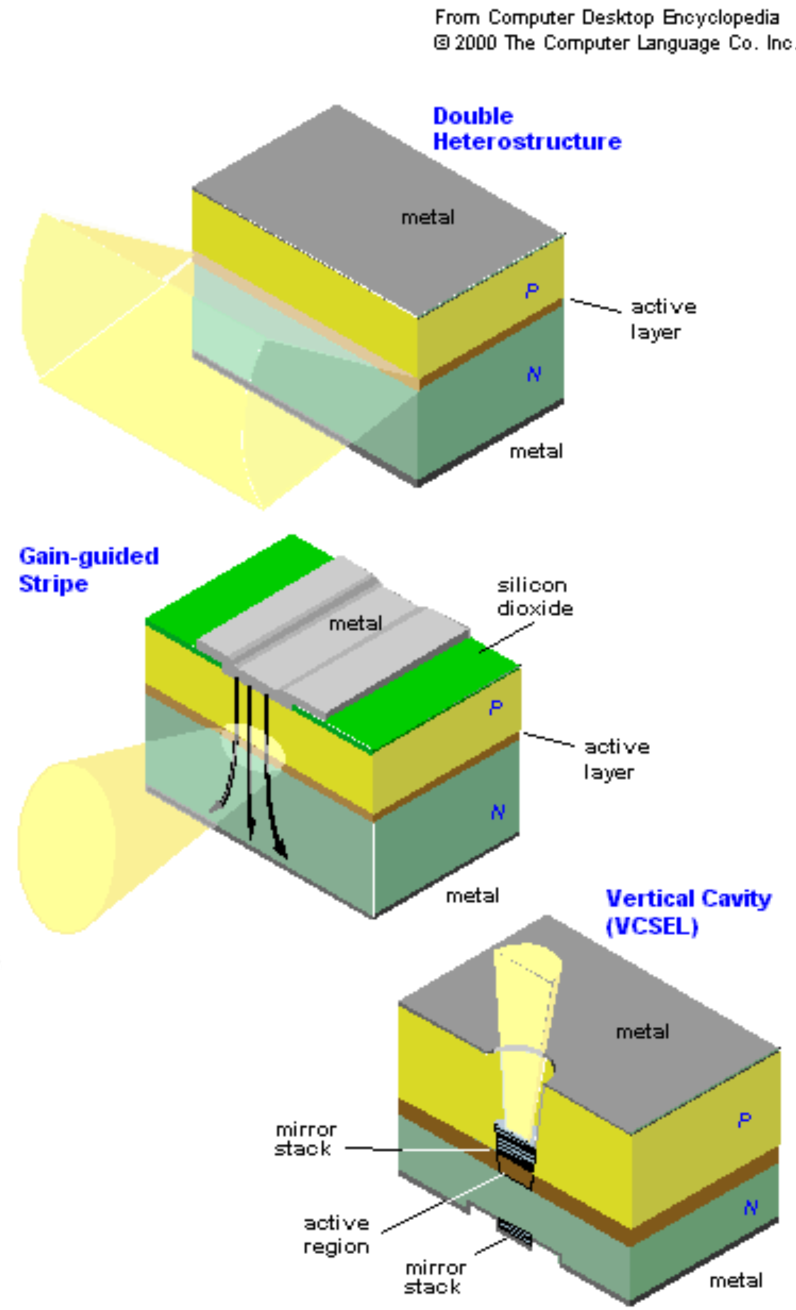


Laser de estado sólido



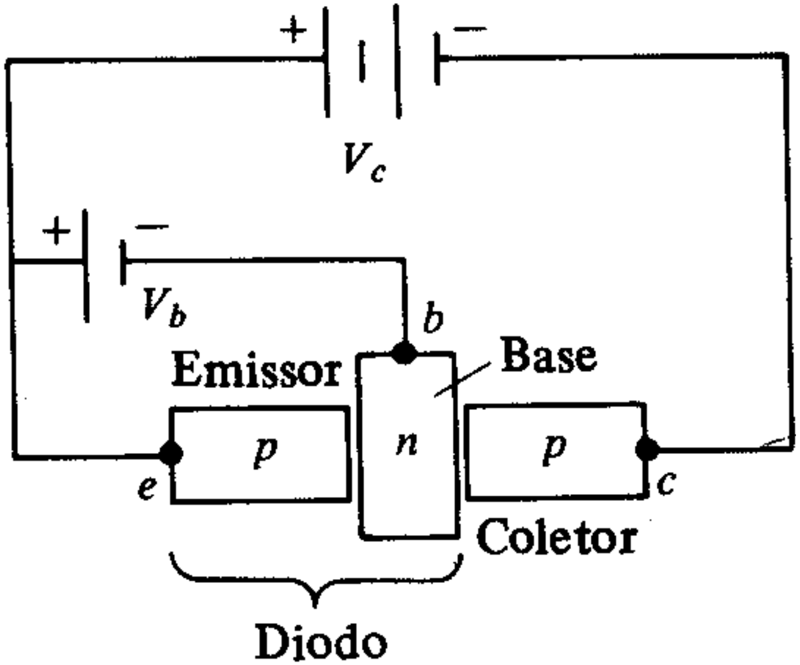
Typical values

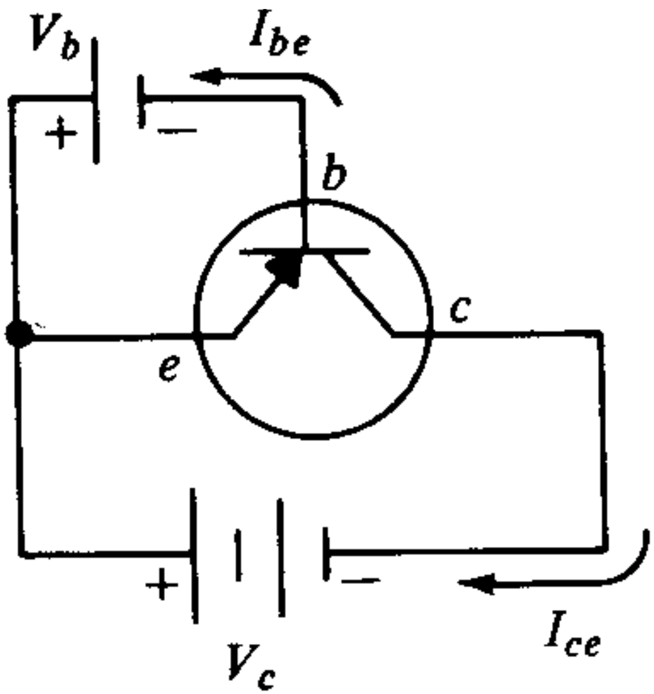
$L = 0.3$ mm	I (at 300 K) = 20 A
$a = 0.1$ mm	Input power = 136 W
$d = 2.0\ \mu$m	Light output power = 9 W
$\lambda = 840$ nm	

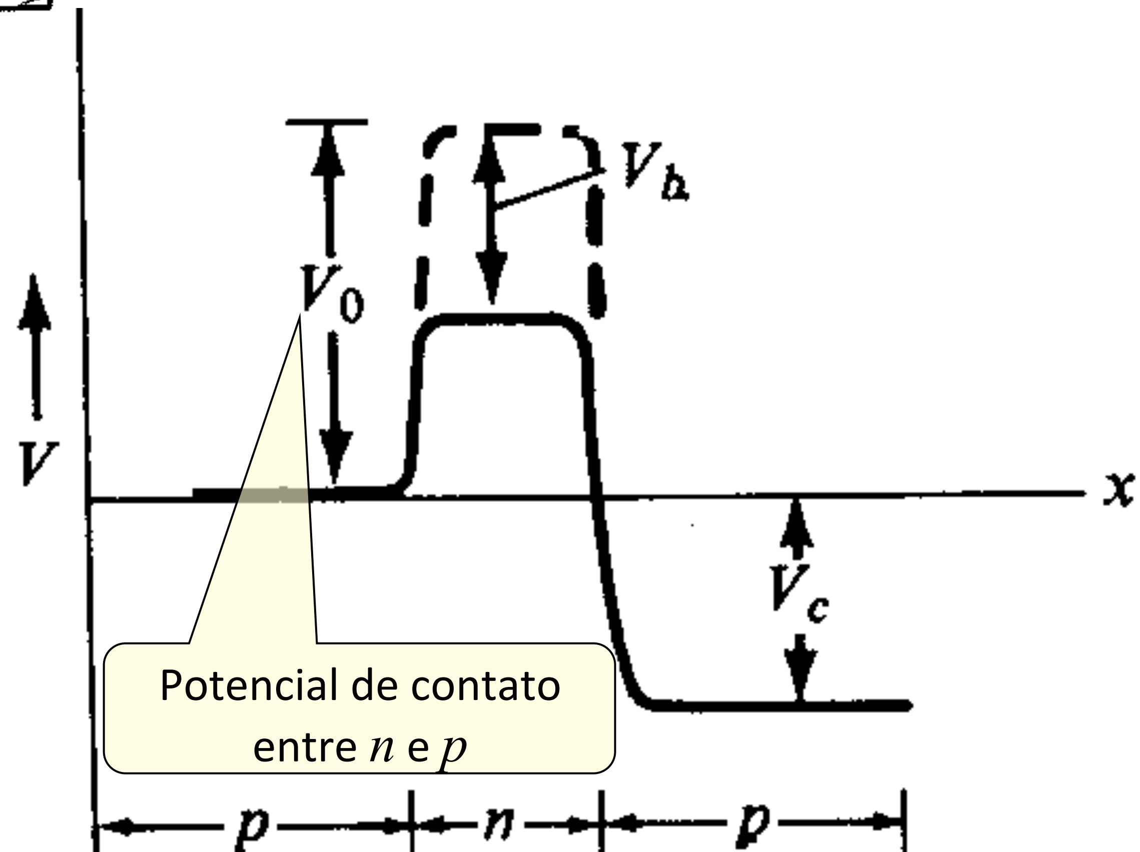


Transistor

Um sinal aplicado à fonte V_b modula a corrente entre o emissor e o coletor, que tem valor muito mais elevado. Assim o transistor funciona como amplificador de sinais.







Nuclear Science

Nuclear Science is the study of the structure, properties, and interactions of the atomic nuclei. Nuclear scientists calculate and measure the masses, shapes, sizes, and decays of nuclei at rest and in collisions. They ask questions, such as: Why do nucleons stay in the nucleus? What combinations of protons and neutrons are possible? What happens when nuclei are compressed or rapidly rotated? What is the origin of the nuclei found on Earth?

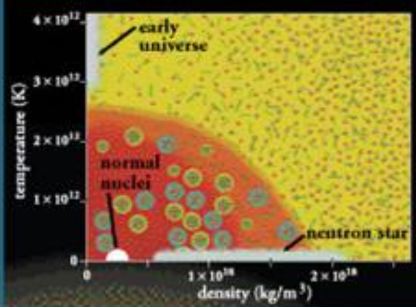
Legend: proton; neutron; electron (e^-); positron (e^+); neutrino (ν); antineutrino ($\bar{\nu}$); quark; gluon field; gluon; photon (γ); $A_{\text{mass number}}$, $Z_{\text{atomic number}}$: $^{14}_{6}C$; $N_{\text{neutron number}} = A - Z$

Expansion of the Universe

After the Big Bang, the universe expanded and cooled. At about 10^{-6} second, the universe consisted of a soup of quarks, gluons, electrons, and neutrinos. When the temperature of the Universe, $T_{universe}$, cooled to about 10^{12} K, this soup coalesced into protons, neutrons, and electrons. As time progressed, some of the protons and neutrons formed deuterium, helium, and lithium nuclei. Still later, electrons combined with protons and these low-mass nuclei to form neutral atoms. Due to gravity, clouds of atoms contracted into stars, where hydrogen and helium fused into more massive chemical elements. Exploding stars (supernovae) form the most massive elements and disperse them into space. Our earth was formed from supernova debris.

	Big Bang	quark-gluon plasma	proton & neutron formation	formation of low-mass nuclei	formation of neutral atoms	star formation	dispersion of massive elements	today
$T_{universe}$		$>10^{12}$ K	10^{12} K	10^{9} K	4,000 K	50 K–3 K	<50 K–3 K	3 K
time		10^{-6} s	10^{-4} s	3 min	400,000 yr	3×10^{8} yr	$>3 \times 10^{8}$ yr	14×10^{9} yr

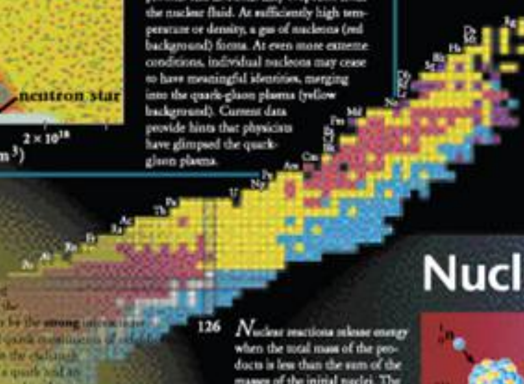
Phases of Nuclear Matter



Nuclear matter can exist in several phases. When collisions excite nuclei, individual protons and neutrons may evaporate from the nuclear fluid. At sufficiently high temperature or density, a gas of nucleons (red background) forms. At even more extreme conditions, individual nucleons may cease to have meaningful identities, merging into the quark-gluon plasma (yellow background). Current data provide hints that physicists have glimpsed the quark-gluon plasma.

Unstable Nuclei

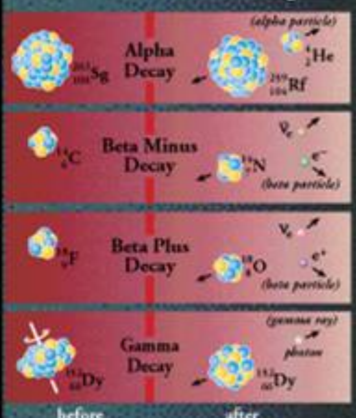
Stable nuclides form a narrow white band on the Chart of the Nuclides. Scientists produce unstable nuclides far from this band and study their decays, thereby learning about the extremes of nuclear conditions. In its present form, this chart contains about 2500 different nuclides. Nuclear theory predicts that there are at least 4000 more to be discovered with Z ≤ 112.



Element 112

Scientists first synthesized Element 112 in a particle accelerator experiment. They identified it by observing its characteristic six alpha particle decay chain.

Radioactivity

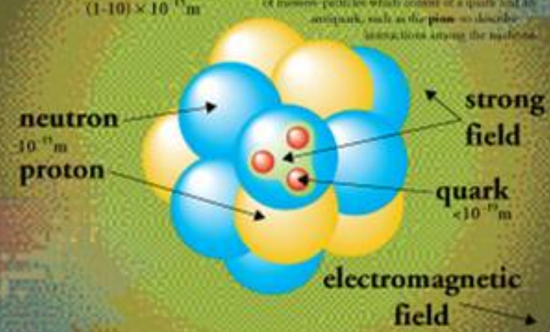


Radioactive decay transforms a nucleus by emitting different particles. In **alpha** decay, the nucleus releases a $^{4}_{2}$He nucleus—an alpha particle. In **beta** decay, the nucleus either emits an electron and antineutrino (or a positron and neutrino) or captures an atomic electron and emits a neutrino. A positron is the name for the antiparticle of the electron. Antimatter is composed of antiparticles. Both alpha and beta decays change the original nucleus into a nucleus of a different chemical element. In **gamma** decay, the nucleus lowers its internal energy by emitting a photon—a gamma ray. This decay does not modify the chemical properties of the atom.

The Nucleus

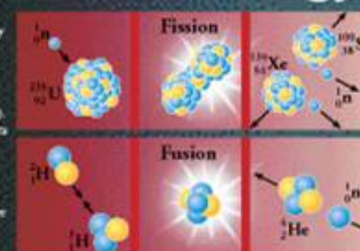
(1–10) × 10^{-15} m

At the center of the atom is a nucleus formed from **nucleons**—protons and neutrons. Each nucleon is made from three **quarks** held together by their strong interactions, which are mediated by gluons. In turn, the nucleus is held together by the **strong** interaction between the gluon and quark constituents of neighboring nucleons. Nuclear physicists often use the exchange of mesons—particles which consist of a quark and an antiquark, such as the **pion**—to describe interactions among the nucleons.



In an atom, **electrons** range around the nucleus at distances typically up to 10,000 times the nuclear diameter. If the electron cloud were drawn to scale, this chart would cover a small town.

Nuclear Energy

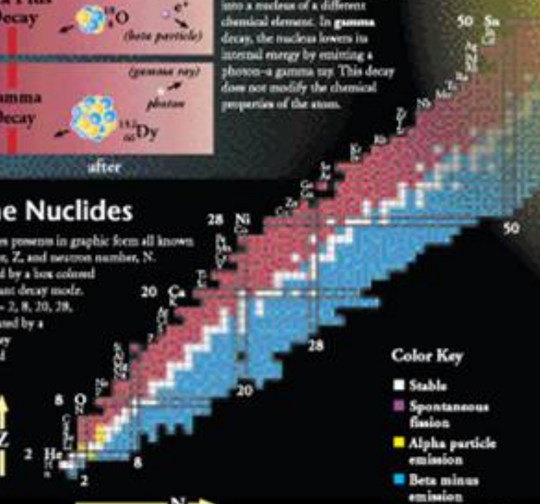


Nuclear reactions release energy when the total mass of the products is less than the sum of the masses of the initial nuclei. The "lost mass" appears as kinetic energy of the products ($E = mc^2$). In fission, a massive nucleus splits into two major fragments that usually eject one or more neutrons. In fusion, low mass nuclei combine to form a more massive nucleus plus one or more ejected particles—neutrons, protons, photons, or alpha particles.

In the early stages of stellar evolution of our sun and other stars, hydrogen fuses to form helium, releasing energy in the form of photons (light) and neutrinos. During the later stages of stellar evolution, more massive nuclei up to and beyond uranium are synthesized by fusion. By measuring the number of neutrinos that come from the Sun, scientists recently have demonstrated that neutrinos must have a mass greater than zero.

Chart of the Nuclides

The Chart of the Nuclides presents in graphic form all known nuclei with atomic number, Z, and neutron number, N. Each nuclide is represented by a box colored according to its predominant decay mode. **Magic numbers** (N or Z = 2, 8, 20, 28, 50, 82 and 126) are indicated by a rectangle on the chart. They correspond to major closed shells and show regions of greater nuclear binding energy.



Color Key

- Stable
- Spontaneous fission
- Alpha particle emission
- Beta minus emission
- Beta plus emission or electron capture

Applications

Radioactive Dating

Naturally occurring radioactive isotopes such as $^{14}_{6}C$ are used to date objects that were once living, such as wood. For example, from a study of artifacts found at the site, scientists determined that Stonehenge was built nearly 4,200 years ago.

Space Exploration

Sojourner used alpha particles to identify chemical elements present in Martian rocks. On Earth, nuclear reactions are used in many areas from criminal investigations to art authentication.

Nuclear Reactors

Nuclear reactors use the fission of $^{235}_{92}U$ or $^{239}_{94}Pu$ nuclei to produce electric power. Reactors and most other nuclear applications generate radioactive waste; disposal of this waste is a subject of current research.

Smoke Detectors

Many smoke detectors use a small amount of the alpha emitter $^{241}_{95}Am$ to ionize the air. Smoke entering the detector reduces the current and sets off the alarm.

Nuclear Medicine

Radioactive isotopes, such as $^{99m}_{43}Tc$, $^{60}_{27}Co$ and $^{131}_{53}I$, are commonly used in the diagnosis and treatment of disease. Positron emitters such as $^{18}_{9}F$ are used in Positron Emission Tomography (PET) to generate images of brain activity.

Magnetic Resonance Imaging

Magnetic Resonance Imaging (MRI) makes use of atomic transitions involving the magnetic field of a nucleus to study the local chemical environment. This technique accurately maps the density of hydrogen to produce three-dimensional images of the human body.

Astrophysical pictures courtesy NASA/JPL/Caltech and AURA/STScI.

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Física Nuclear: cronologia do início

Descoberta da Radioatividade (Becquerel)	1896
Separação química do Ra (Marie e Pierre Curie)	1898
Modelo atômico de Rutherford	1911
Descoberta de isótopos (J.J. Thomson)	1912
Transmutação nuclear induzida (Rutherford)	1919
Aplicação da MQ à radioatividade:	
– Decaimento α (Gamow, Gurney e Condon)	1928
– Decaimento β (Fermi)	1934
Descoberta do nêutron (Chadwick)	1932
Hipótese n-p (Heisenberg)	1932
Descoberta do pósitron (Anderson)	1932
Mésons e a força nuclear (Yukawa)	1935
Descoberta do méson μ (Anderson e Neddermeyer)	1936
Descoberta do méson π (Powell)	1946
Quebra da paridade no decaimento β (Lee e Yang)	1956