The electron diffusion coefficient along the energy in bounded collisionless and weakly collisional plasmas

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Introduction

The characteristic electron energies in stationary gas discharges are fixed by the
plasma maintenance condition on the level of several eV.
So the electrons with energies by several eV exceeding □□ are usually practically absent.
In this energy range the elastic collisions cross-sections 1-2 orders of magnitude exceed
the excitation ones. It implies that the EDF anisotropy is small.
In the simplest case the ratio of the relaxation frequencies is of the order of $\delta=(2m/M)$.
At the EDF tail this ratio is (v^{□}/v)□10□^{1}-10□^{2}<<1, is small, too. So the EDF in this energy
range is close to the isotropic one, and the traditional two-term approximation is valid.
This fact remains valid in free-flight regime, $R \geq \lambda$.
The energy input usually occurs by relatively small portions. too.
So this process cal be treated, as a random walk along the energy axis it is described by
the diffusion coefficient along energy D_{□}.

2. The kinetic equation.

- The electron Boltzmann equation is of the form:

$$\frac{\partial f}{\partial t}+\left(\vec{v}.\vec{\nabla}\right) f+\frac{e}{m}\left(\vec{E}.\frac{\partial f}{\partial \vec{v}}\right)+St\left(f\right)=0$$

The two-term EDF expansion states

$$f_0\left(\vec{r},v,t\right)>>f_1\left(\vec{r},v,t\right).$$

$$f\left(\vec{r},\vec{v},t\right)=f_0\left(\vec{r},v,t\right)+\sum_{m=1,2,3} f_1^l\left(\vec{r},v,t\right)Y_1^l\left(\theta,\varphi\right) \quad ,$$

Introducing the total electron energy $\varepsilon = w+e\phi(r)$

the equation for takes the form:

$$\frac{\partial \vec{f}_1}{\partial t}+v\vec{\nabla}f_0+\frac{e}{m}\vec{E}\frac{\partial f_0}{\partial v}+\nu\vec{f}_1=\frac{\partial \vec{f}_1}{\partial t}+v\vec{\nabla}_\varepsilon f_0+\nu\vec{f}_1=0 \quad \text{for} \quad f_1$$

And $$\frac{\partial f_0}{\partial t}=\vec{\nabla}vD\vec{\nabla}f_0+\frac{\partial}{\partial \varepsilon}vD_\varepsilon\frac{\partial f_0}{\partial \varepsilon} \quad \text{for} \quad f_0$$

The diffusion coefficient along the energy axis (for the monochromatic oscillatory field with amplitude is $D=\lambda^2 v/3$ and the energy diffusion coeff. is

$$D_\varepsilon=\frac{e^2 E^2{}_{0\omega}}{6(\omega^2+\nu^2)}v^2\nu$$

3. DC positive column.

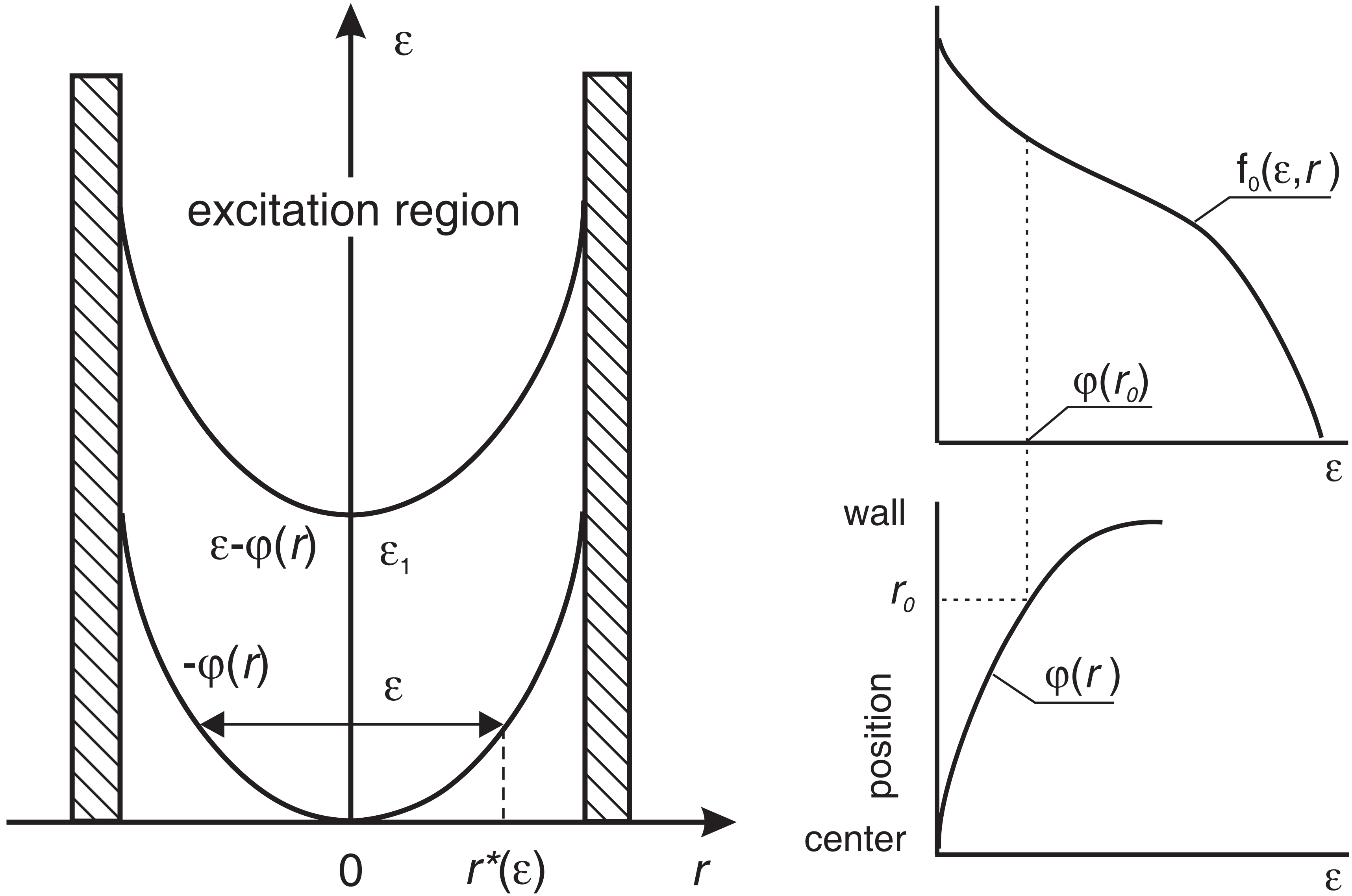
$$D_{\varepsilon} = e^2 E_z^2 v \lambda^2 / 3$$

I.B.Bernstein, T. Holstein, Phys. Rev., 94, 1475, 1954.

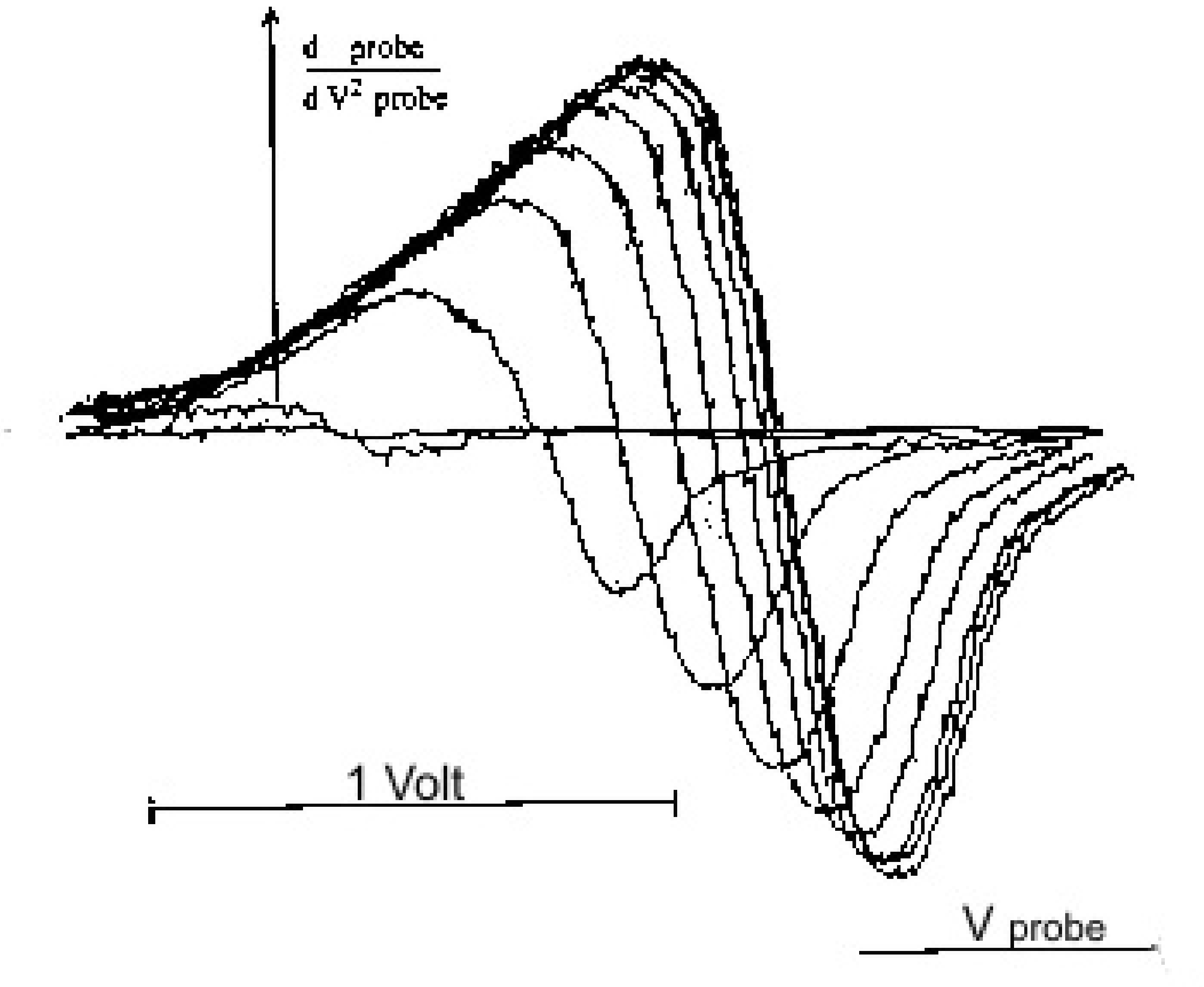
L.D.Tsendin, Sov. Phys. JETP, 39, 805-810, 1974.

The averaged kinetic equation becomes

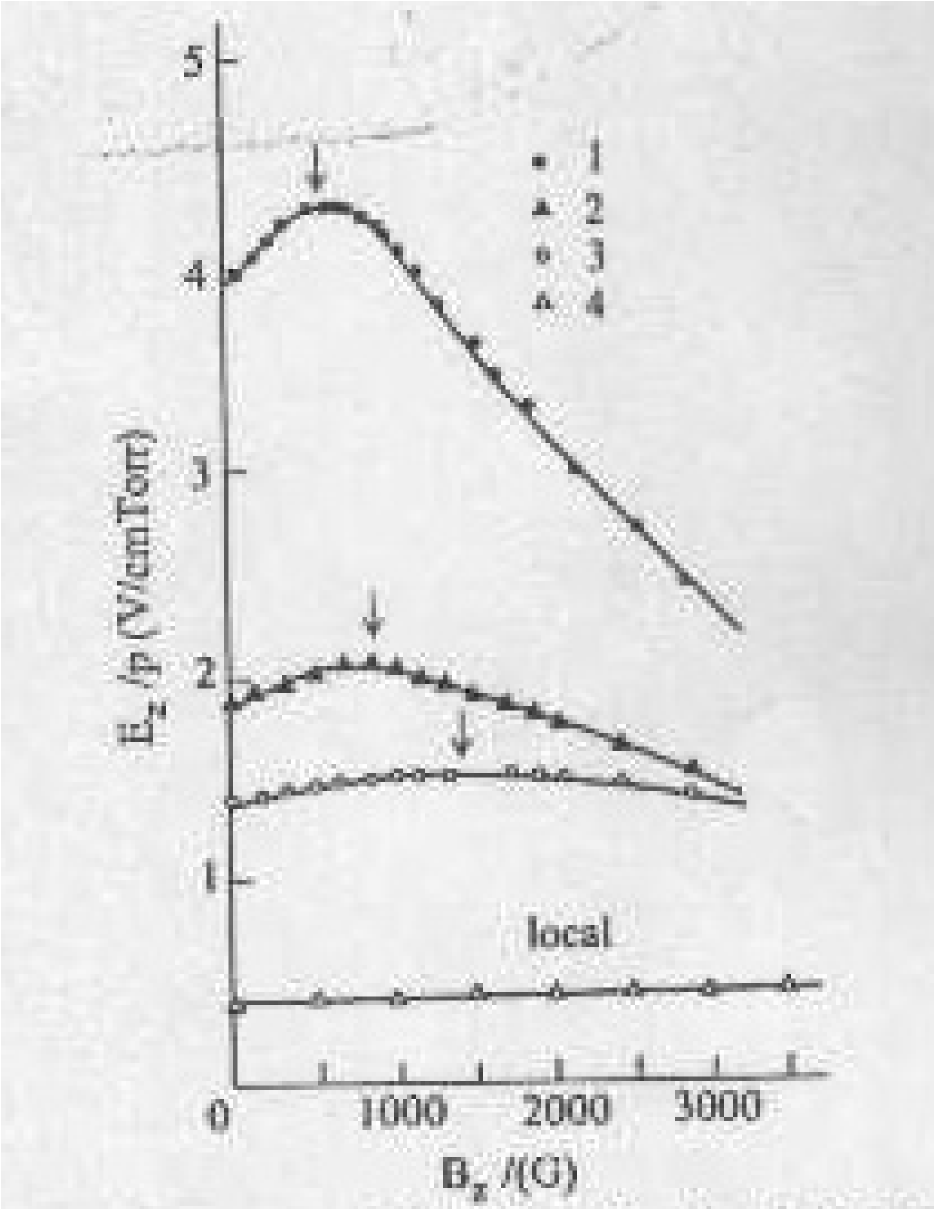
$$\frac{d}{d\varepsilon}\overline{vD_{\varepsilon}}\frac{df_0(\varepsilon)}{d\varepsilon} = \overline{St^{inel}(f_0(\varepsilon))}.$$



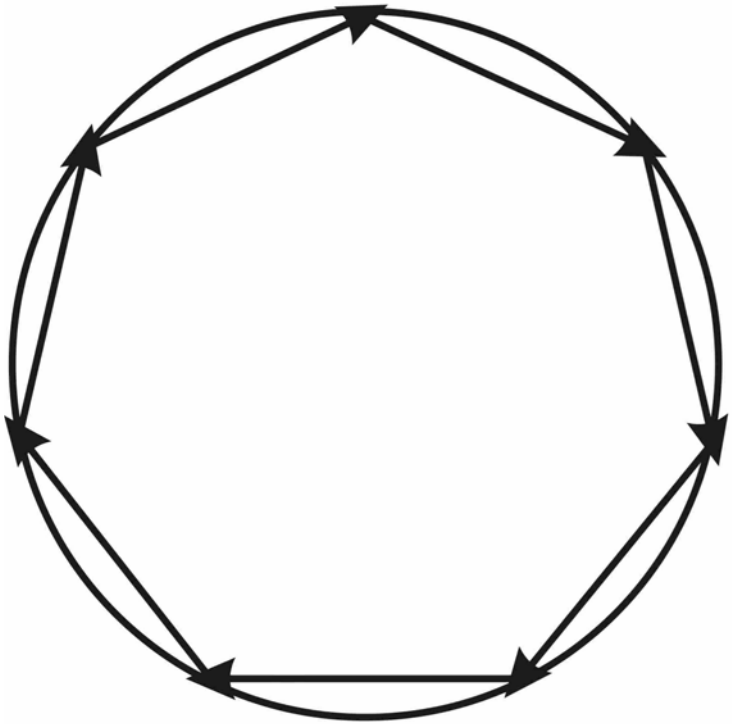
ε
excitation region
ε-φ(r)
ε1
-φ(r)
ε
0
r*(ε)
r
f0(ε,r)
φ(r0)
ε
wall
r0
φ(r)
position
center
ε

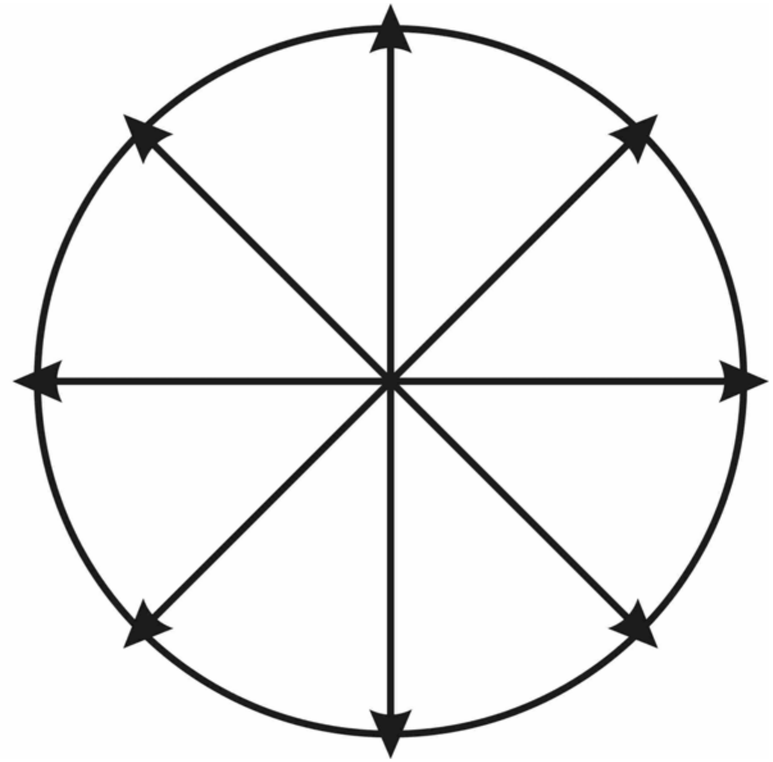


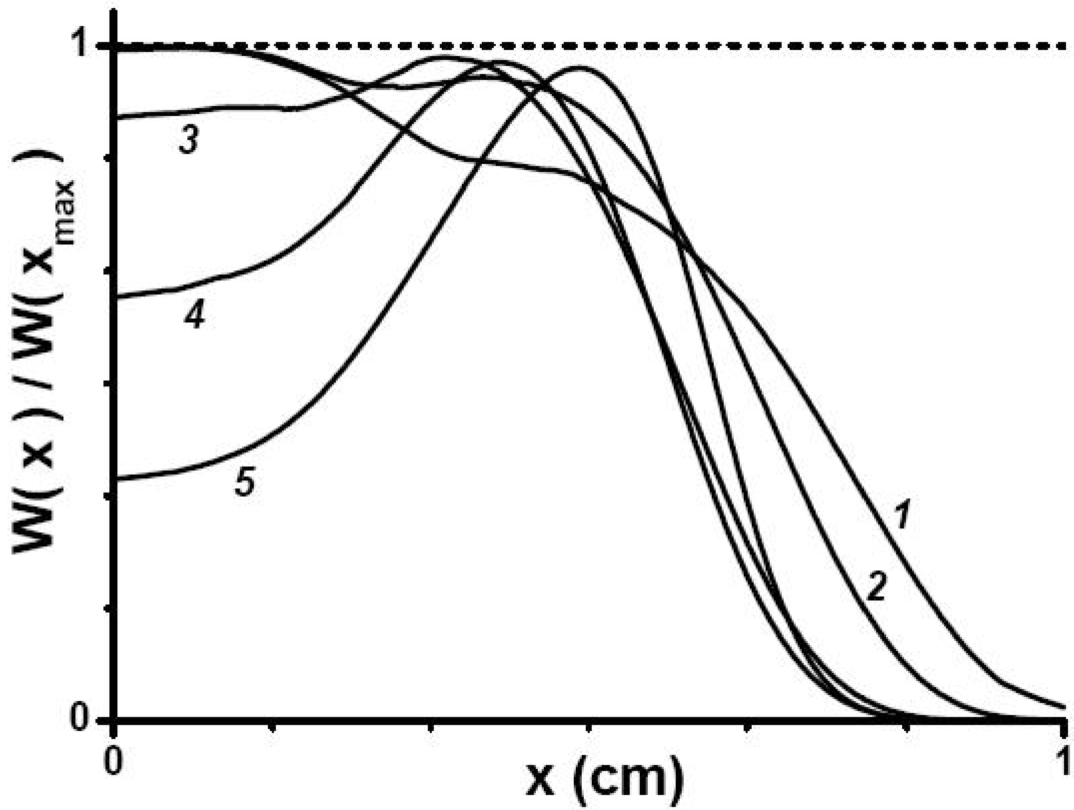
d probe
d V² probe
1 Volt
V probe



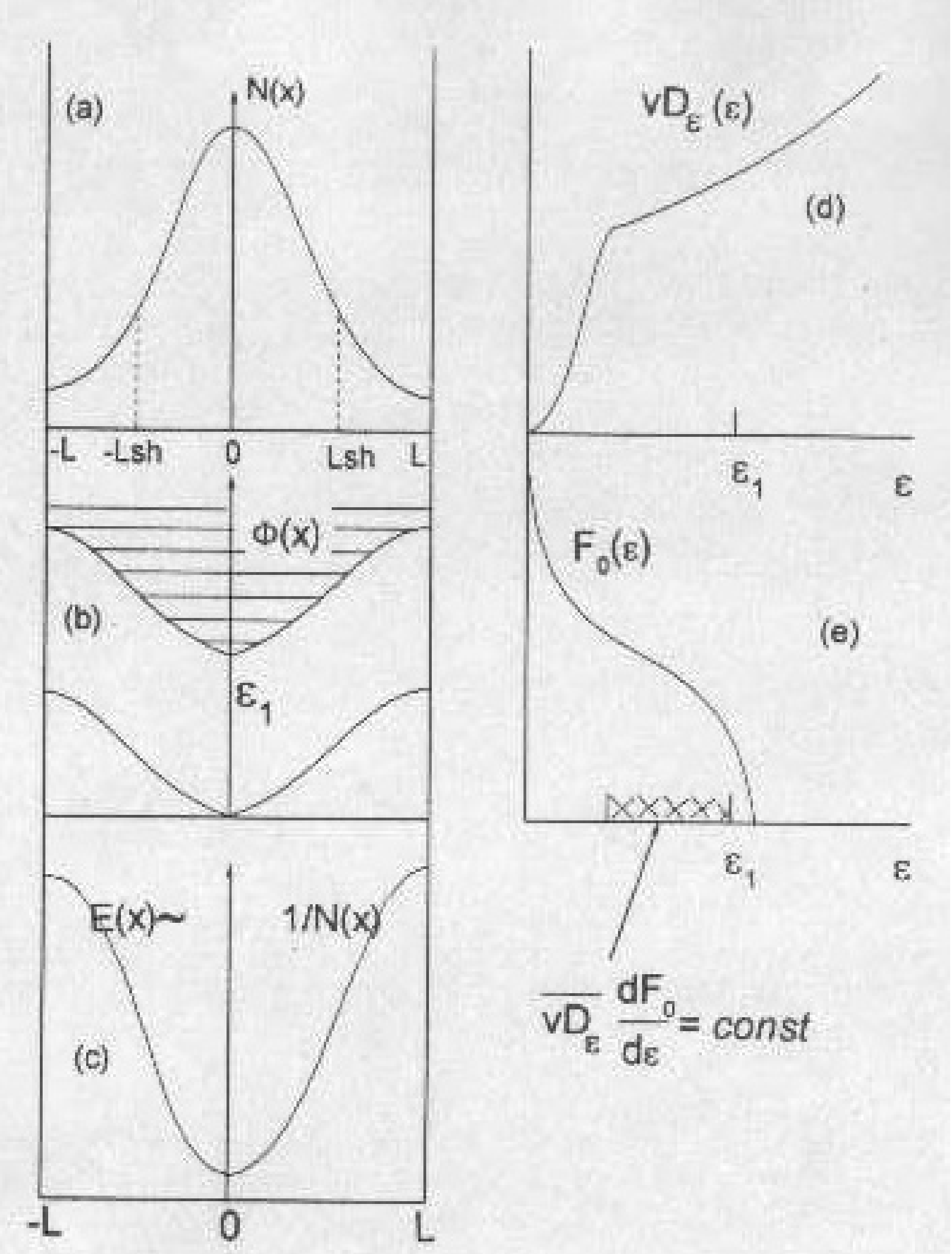
5
4
3
2
1
0
1000
2000
3000
1
2
3
4
local
E_z / p (V/cm Torr)
B_z /(G)



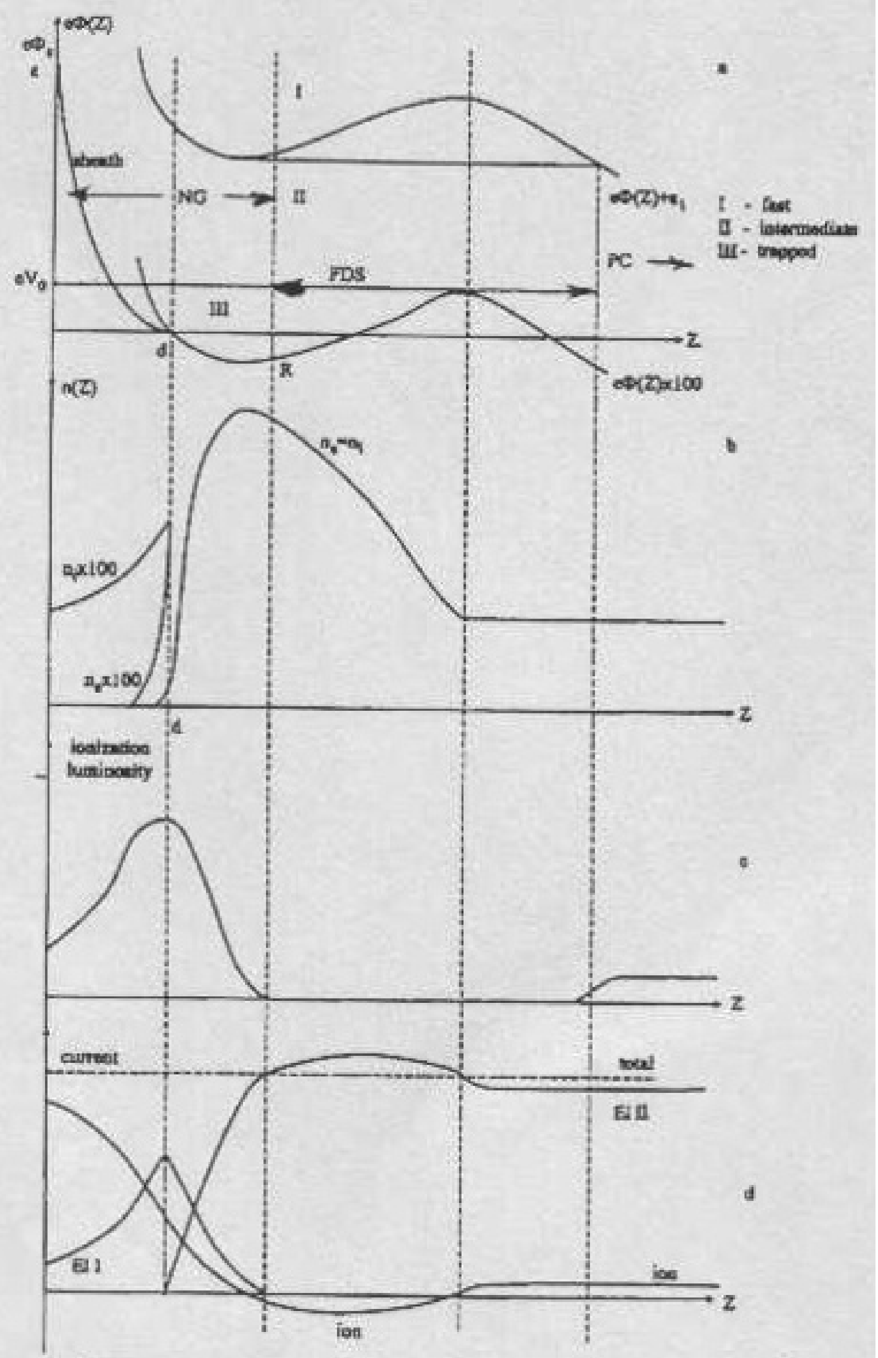




1
0
W(x) / W(x_max)
0
1
x (cm)
1
2
3
4
5



(a)
N(x)
-L
-Lsh
0
Lsh
L
Φ(x)
(b)
ε1
E(x)~
1/N(x)
(c)
-L
0
L
vDε (ε)
(d)
ε1
ε
F0(ε)
(e)
ε1
ε
vDε dF0/dε = const



eΦ(Z)
a
I
sheath
NG
II
eΦ(Z)+ε_i
I - fast
II - intermediate
III - trapped
PC
eV_0
FDS
III
Z
d
R
eΦ(Z)x100
n(Z)
b
n_e=n_i
n_i x100
n_e x100
Z
d
ionization
luminosity
c
Z
current
total
Ei II
d
Ei I
ion
Z
ion