

Non Equilibrium Statistical Physics - TD 4

Introduction to Transport Phenomena

1 Diffusion Current in a p-n Junction

1. Write the number of electrons per unit volume as a function of the density of states $g(E)$, the chemical potential μ and the Fermi-Dirac distribution.

2. Simplify this form using the classical limit.

3. We consider a p-n junction in equilibrium with no applied voltage (open circuit).

Is the density of electrons constant along the junction? Is the chemical potential constant along the junction? Is the current density non zero in the junction? What is the mechanism that compensates for the diffusion current?

4. Derive the diffusion current in the depletion region as a function of the electron density.

l is the mean free path, v^2 the quadratic mean square velocity, τ the average time between consecutive collisions, m_e the electron mass and $-e$ its charge. We assume that $v^2 = 3k_B T / m_e$.

5. Derive the induced electric field at equilibrium. Deduce an expression of the electrical conductivity σ .

2 Viscosity

We consider a laminar flow with a velocity field $V_x(z)\mathbf{e}_x$. We will derive the viscosity of the fluid that will be considered as incompressible, isothermal and composed of identical molecules of mass m .

1. Derive the transfer of \mathbf{e}_x -oriented momentum across the plane $z = z_0$. We introduce the quadratic mean velocity $v^2 = 3k_B T / m$ and the mean free path $l = v\tau$ where τ is the collision time.

2. Starting from a momentum balance on the half-space $z > 0$, show that the shear stress (force per unit surface) can be cast in the form :

$$F_{xz} = -\mu \frac{\partial V_x}{\partial z} \quad (1)$$

Derive the viscosity μ as a function of n, k_B, T, τ and m .