# FUNDAMENTALS OF NANOELECTRONICS

## *Basic Concepts*

**The New Perspective**

2. Energy Band Model

3. What and Where

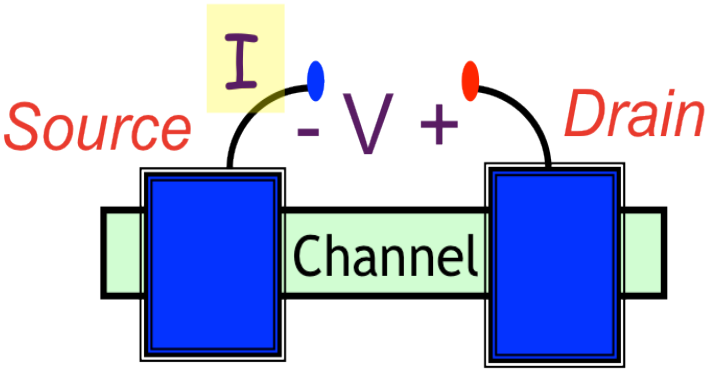
   is the Voltage?

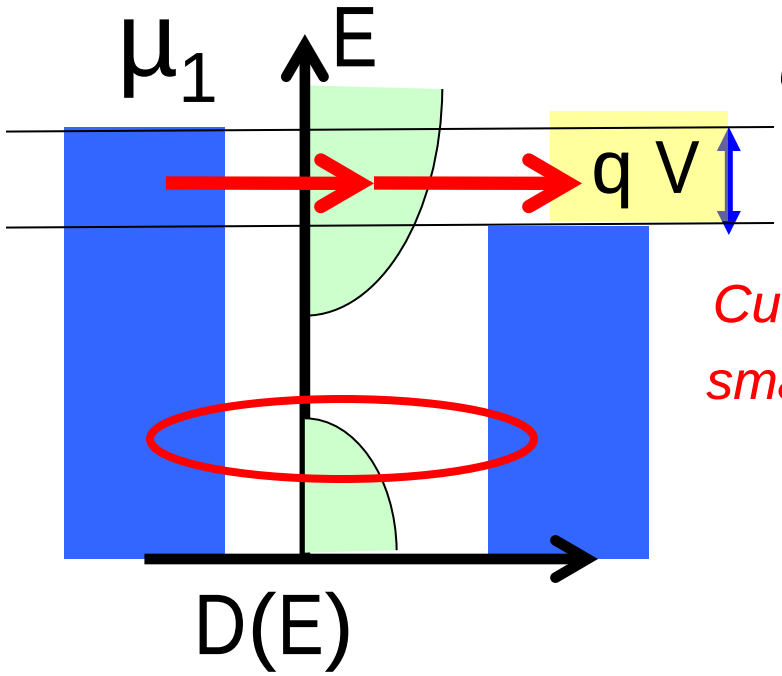
4. Heat & Electricity:

   Second Law & Information

- 1.1. Introduction
- 1.2. Two Key Concepts
- **1.3. Why Electrons Flow**
- 1.4. Conductance Formula
- 1.5. Ballistic(B) Conductance
- 1.6. Diffusive(D) Conductance
- 1.7. Connecting B to D
- 1.8. Angular Averaging
- 1.9. Drude Formula
- 1.10. Summing up ..

# 1.3a Why Electrons Flow

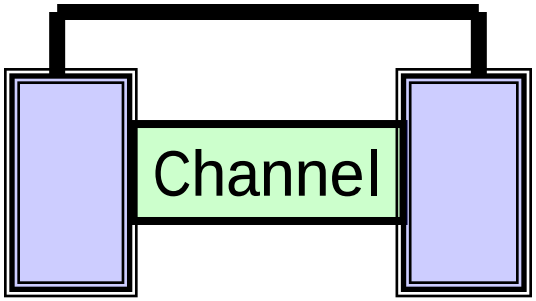


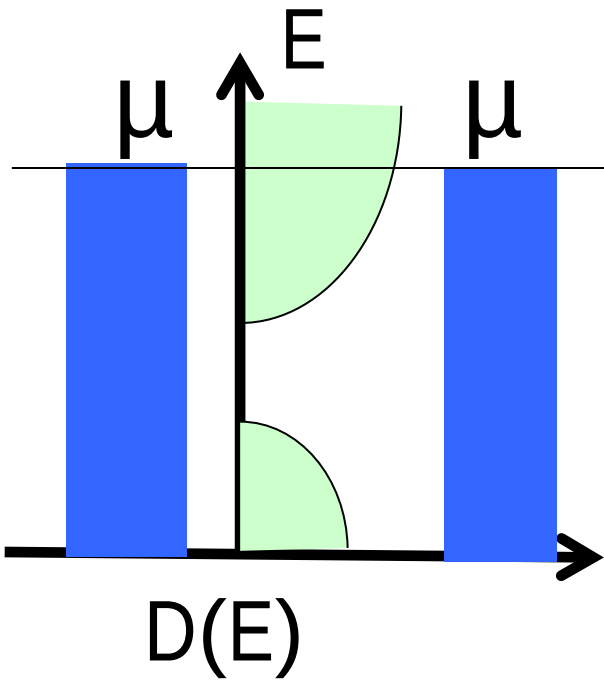




*Hard to understand if we say that electric field drives electrons*

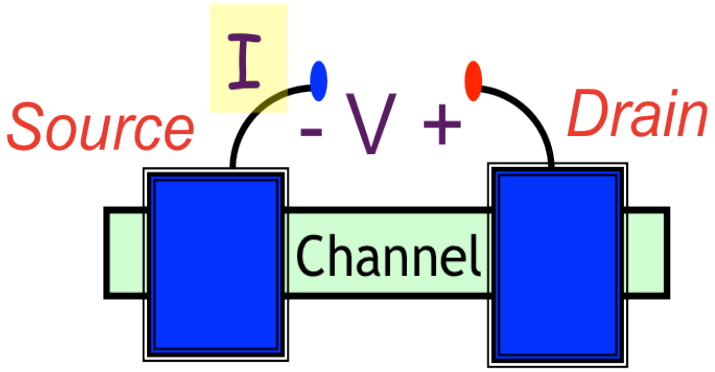
*Current flows only in small energy window*

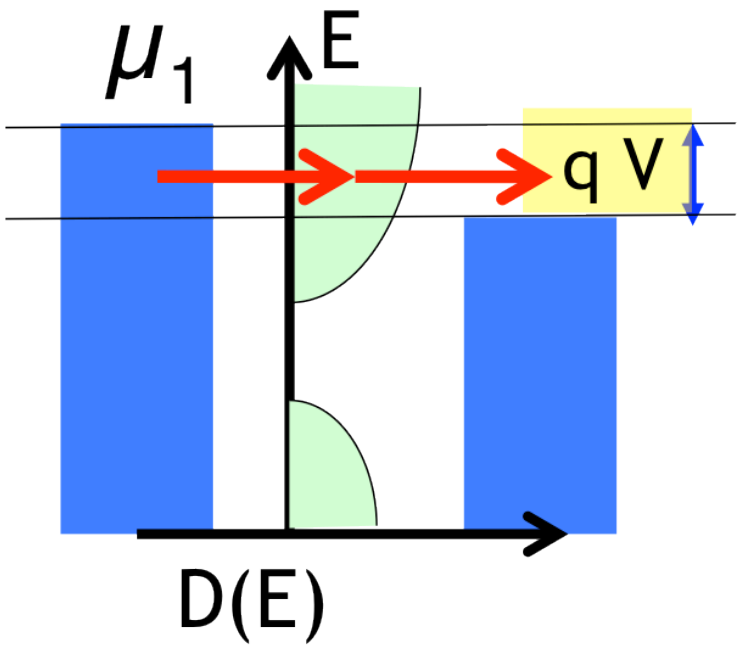
## Equilibrium



# 1.3b Why Electrons Flow




*No energy loss in channel*

*# of PhD students* = *PhD's /year* *Time spent getting PhD*

*# of electrons in channel* = *Electrons /second* *Time spent in channel*

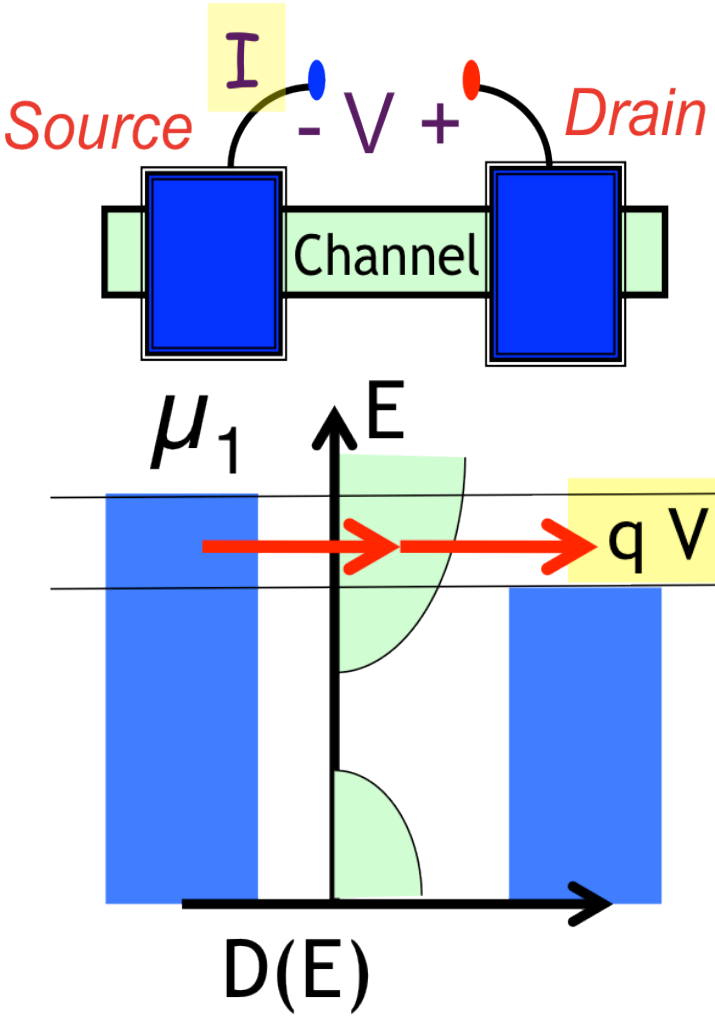
$$\frac{D.\,qV}{2} = \frac{I}{q} \times t$$

$$G \equiv \frac{I}{V} = \frac{q^2 D}{2t}$$

D: Density of states

t : transfer time

# 1.3c Why Electrons Flow




*Electrons /second* *Time spent in channel* = *# of electrons in channel*

$$\frac{I}{q} \times t = \frac{D.\,qV}{2}$$

$$\frac{I}{q} \times t(E) = \frac{D(E)\,dE}{2}$$

$$I = \int_{-\infty}^{+\infty} dE\ \frac{q\,D(E)}{2\,t(E)} \times \left( f_1(E) - f_2(E) \right)$$

$$G(E) \equiv \frac{q^2\,D(E)}{2\,t(E)}$$

$$= \frac{1}{q} \int_{-\infty}^{+\infty} dE\ G(E) \left( f_1(E) - f_2(E) \right)$$

$$I = \frac{1}{q}\int_{-\infty}^{+\infty} dE\, G(E)\,\left(\, f_1(E) - f_2(E)\,\right)$$

$$G(E) \equiv \frac{q^2\, D(E)}{2\, t(E)}$$

$$I/V = \int_{-\infty}^{+\infty} dE \left(-\frac{\partial f_0}{\partial E}\right) G(E)$$

## Coming up next ..