Week 1: Thermoelectricity: Bottom-up Approach

L1.1. Elastic resistor

*L1.2. Current driven by temperature***

*L1.3. Seebeck coefficient***

*L1.4.Heat current***

*L1.5. One-level device***

L1.6. The bottom-up approach

Reference:

Lessons from Nanoelectronics (LNE)

World Scientific (2012)

Relevant sections available for download

TUTORIAL LECTURES

*T1.1: Keeping track of units***

*T1.2: Approximating the difference between Fermi functions***

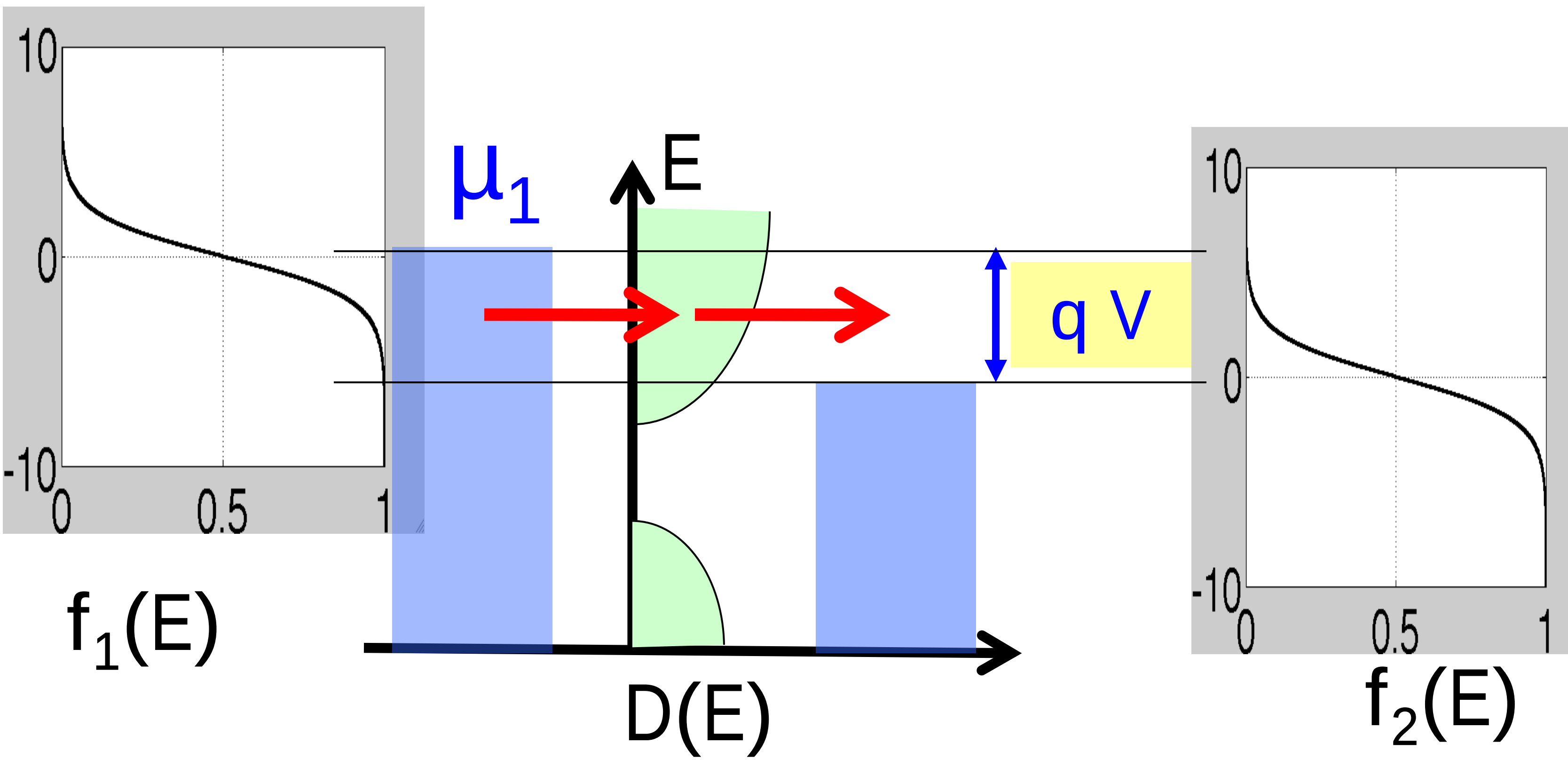
*T1.3. One-level device***

*T1.4. Non-degenerate conductors***

*** Reproduced from earlier nanoHUB-U course Fundamentals of Nanoelectronics, Part I, Weeks 1& 5*

L1.1. Elastic Resistor

$$I = \frac{1}{q}\int_{-\infty}^{+\infty} dE\, G(E)\left(f_1(E) - f_2(E) \right) \quad \rightarrow \quad I/V \simeq \int_{-\infty}^{+\infty} dE \left(-\frac{\partial f_0}{\partial E}\right) G(E)$$



Reference: Lectures 1-4

LNE, World Scientific (2012)

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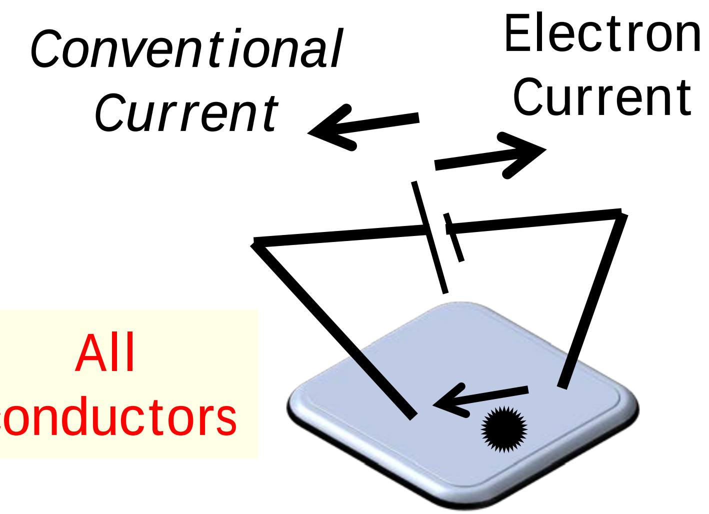
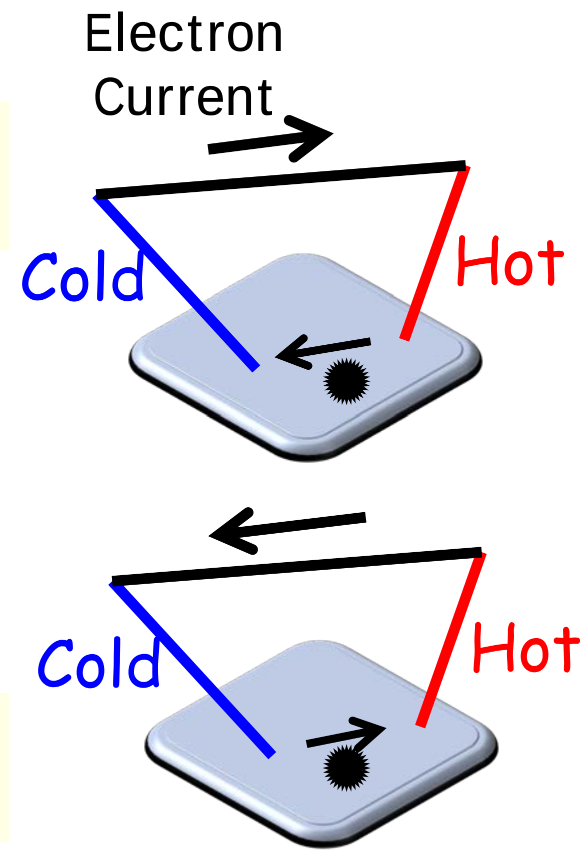
L1.2. Current driven by temperature



All conductors

(a) n-type conductor

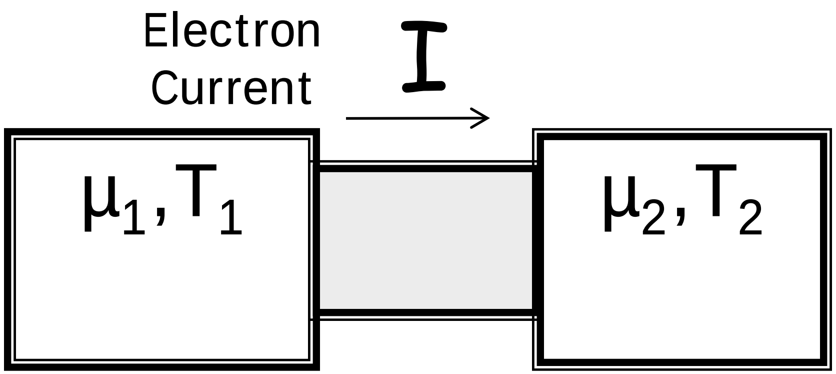


(b) p-type conductor

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

Reference: Lecture 10.1

L1.3: Seebeck coefficient



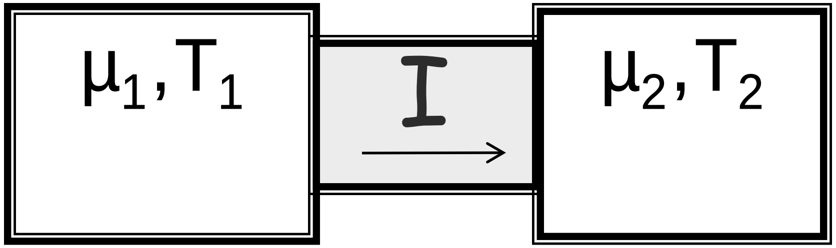
$$G = \int_{-\infty}^{+\infty} dE \left(-\frac{\partial f_0}{\partial E} \right) G(E)$$

$$G_S = \int_{-\infty}^{+\infty} dE \left(-\frac{\partial f_0}{\partial E} \right) \frac{E - \mu_0}{qT} G(E)$$

$$I = G\,(V_1 - V_2) + G_S\,(T_1 - T_2)$$

$$\Delta V = \frac{1}{G} I + \underbrace{-\frac{G_S}{G}}_{\substack{Seebeck \\ Coefficient}} \Delta T$$

Reference: Lecture 10.1



L1.4: Heat current

$$I_Q \approx \frac{1}{q}\int_{-\infty}^{+\infty} dE\,\frac{E-\mu_0}{q}\,G(E)\big(f_1(E)-f_2(E)\big) \approx G_P(V_1-V_2)+G_Q(T_1-T_2)$$

$$G_P = \int_{-\infty}^{+\infty} dE\left(-\frac{\partial f_0}{\partial E}\right)\frac{E-\mu_0}{q}\,G(E)$$

$$G_Q = \int_{-\infty}^{+\infty} dE\left(-\frac{\partial f_0}{\partial E}\right)\frac{(E-\mu_0)^2}{q^2 T}\,G(E)$$

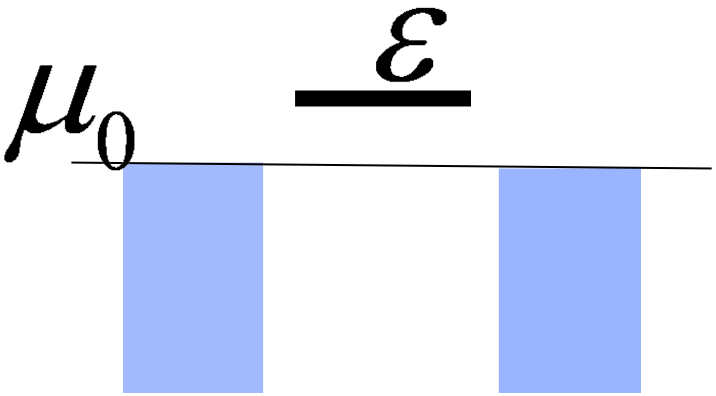
$$\approx G_P(V_1-V_2)+G_Q(T_1-T_2)$$

$$= (G_P/G)I + G_\kappa(T_1-T_2)$$

$$G_\kappa = \overbrace{G_Q-(G_P G_S/G)}$$

Reference: Lecture 10.3

L1.5: One-level device



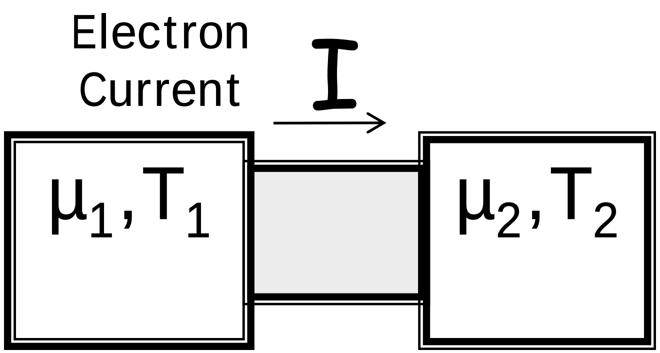
$$|S| = \frac{\varepsilon - \mu_0}{qT}$$

$$|\Pi| = \frac{\varepsilon - \mu_0}{q}$$

$$\kappa = 0$$

Reference: Lecture 10.4

L1.6. Bottom-up approach



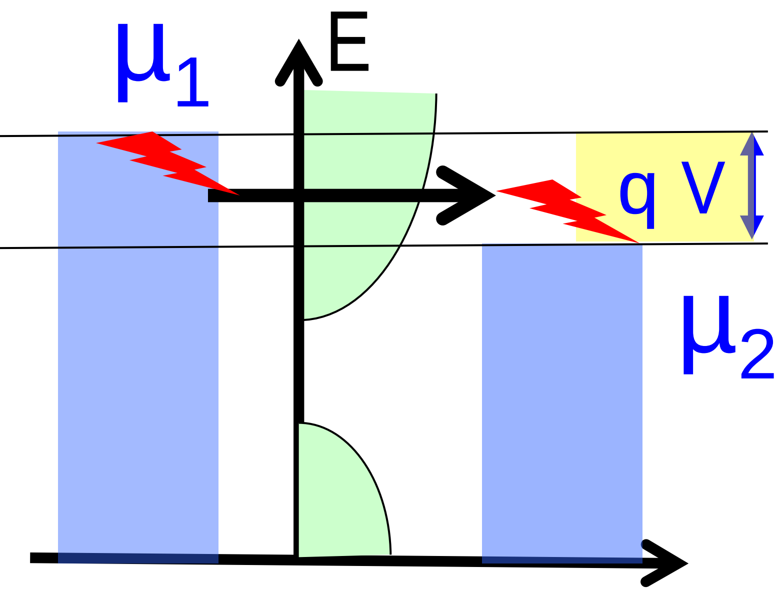
$$I \approx \; G(V_1 - V_2) + G_S(T_1 - T_2)$$

$$I_Q \approx \; G_P(V_1 - V_2) + G_Q(T_1 - T_2)$$

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

$$G_P = T G_S = \int_{-\infty}^{+\infty} dE \left(-\frac{\partial f_0}{\partial E} \right) \frac{E - \mu_0}{q} G(E)$$

$$G_Q = \int_{-\infty}^{+\infty} dE \left(-\frac{\partial f_0}{\partial E} \right) \frac{(E - \mu_0)^2}{q^2 T} G(E)$$



Lectures 10, 11

$$G(E) = \frac{2q^2}{h} M(E) \mathcal{T}(E) \quad , \quad \mathcal{T}(E) = \frac{\lambda}{L + \lambda}$$

$$M = \frac{hD\nu}{2L} \left\{ 1 \quad , \quad \frac{2}{\pi} \quad , \quad \frac{1}{2} \right\}$$

Lecture 5

$$= \left(\frac{p}{h} \right)^{d-1} \left\{ 1 \quad 2W \quad \pi A \right\}$$