Introduction to transport in solids

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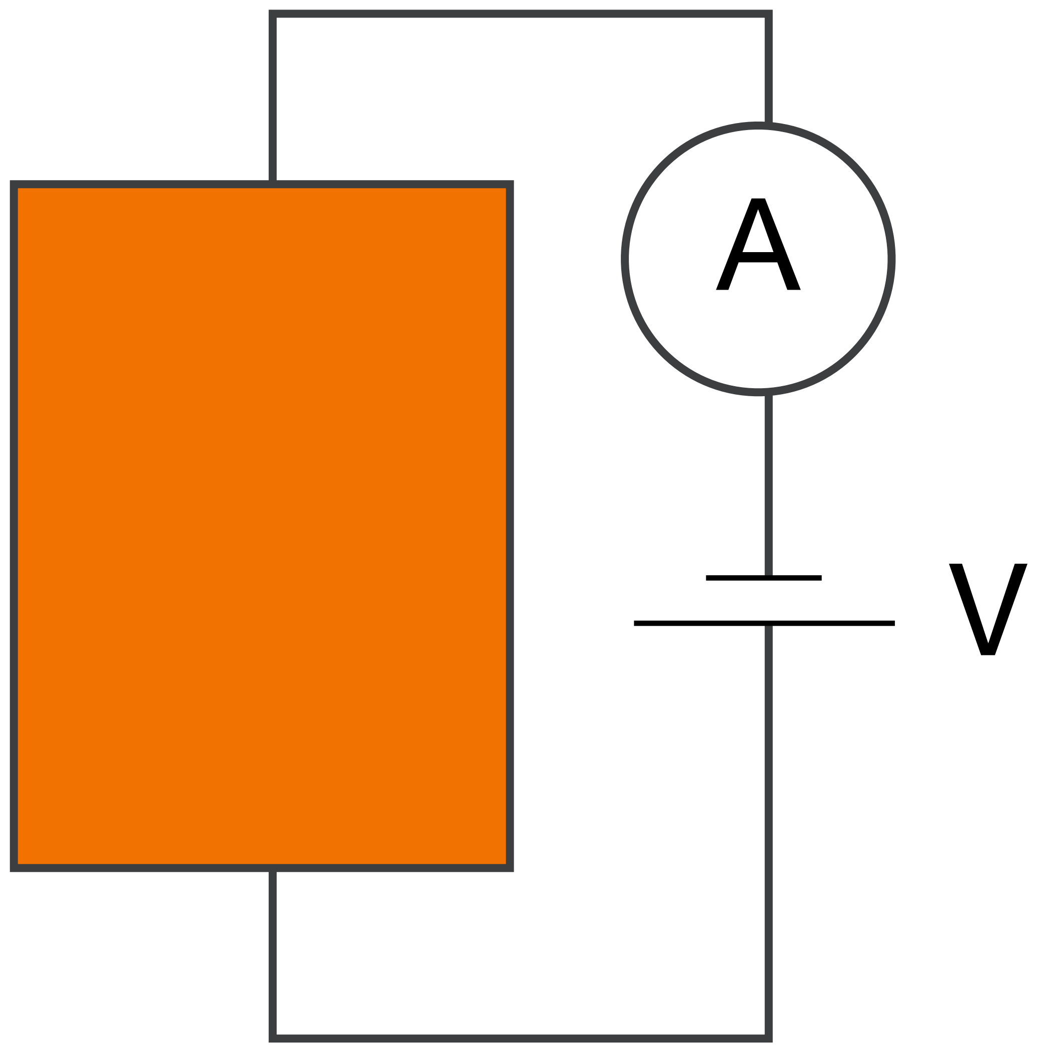
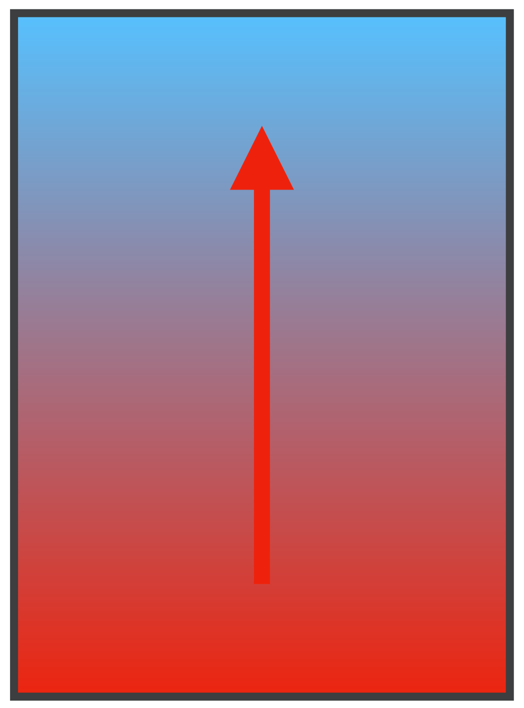
Transport

Transport refers to the movement and flow of physical quantities—such as **charge**, **spin**, **heat**, or **mass**—through a material system, typically as a response to external forces like electric fields, magnetic fields, or temperature gradients.

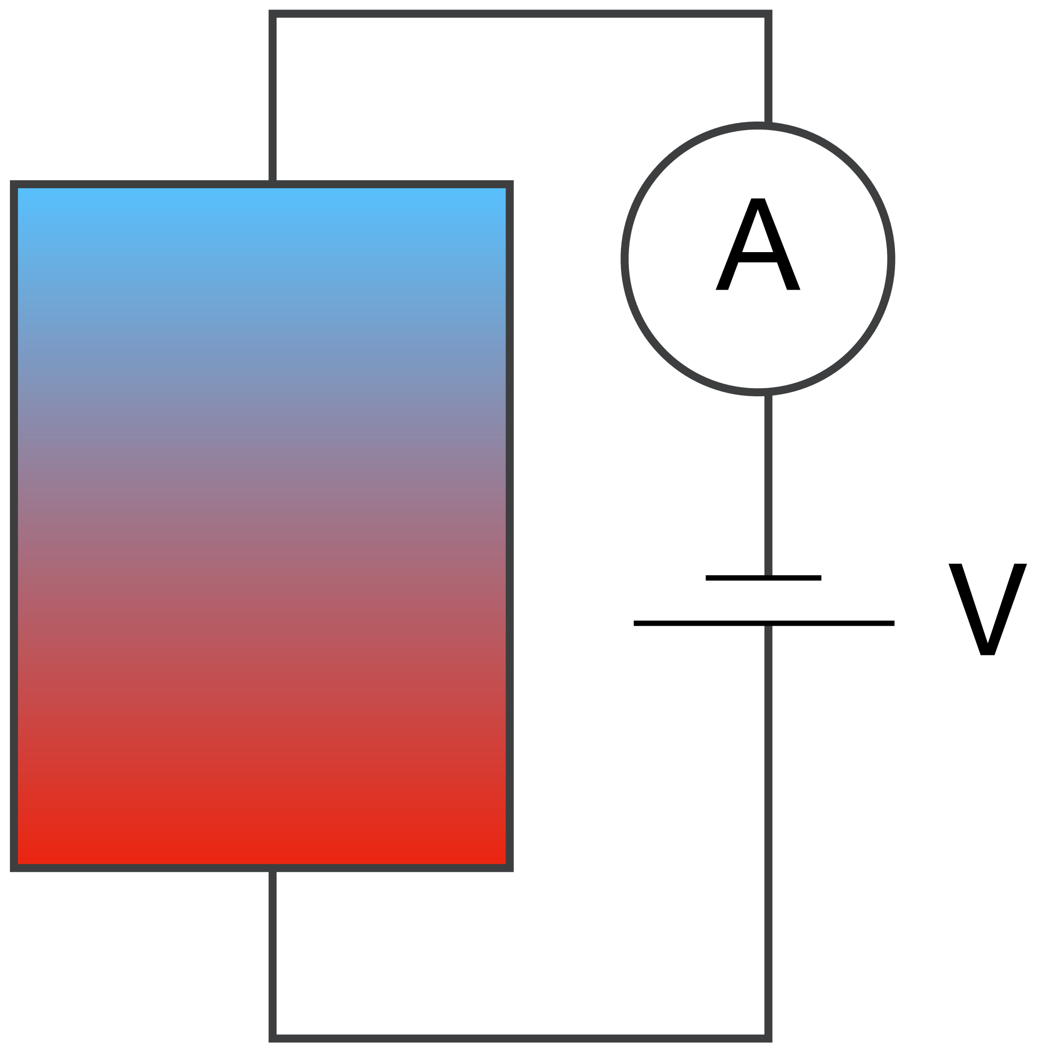
Case 1:
charge transport



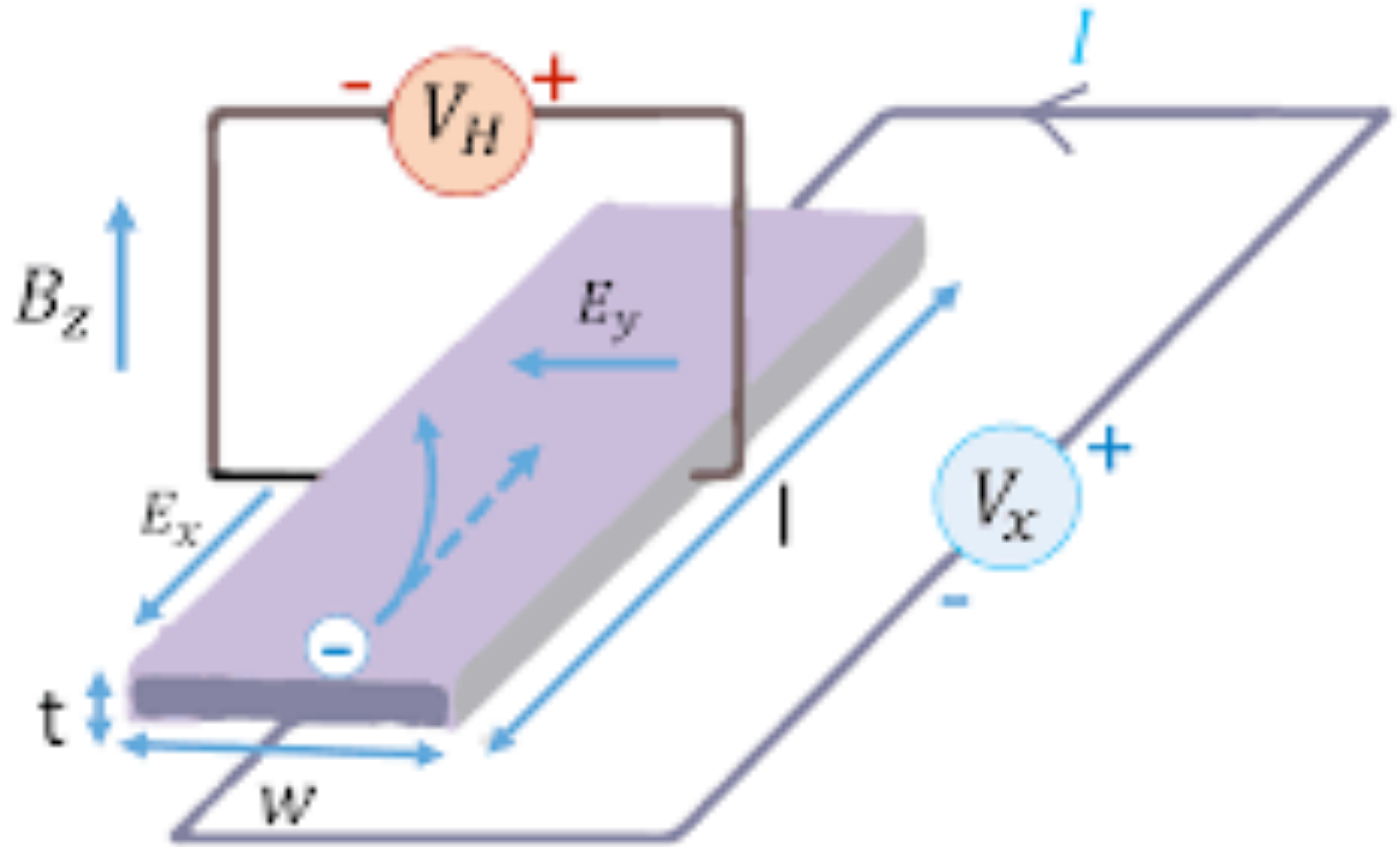
Case 2:
heat/energy transport



Case 3:
heat and charge transport



Example 1: The Hall effect



Lorentz force: $\mathbf{F} = -e\mathbf{E} + e\mathbf{v} \times \mathbf{B}$

If $\mathbf{B} = B_z\,\hat{z}$ and $\mathbf{v} = v_x\,\hat{x}$:

1) $\mathbf{v} \times \mathbf{B} = v_x B_z$
2) $eE_y = ev_x B_z$

3) Drift velocity: $j_x = env_x$ (into 2)):

$$R_{\mathrm{H}} = \frac{E_y}{j_x B_z} = -\frac{v_x B_z}{j_x B_z} = \frac{1}{en}$$

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Hall Coefficients of Cu, Ag, and Au in the Range 4.2–300°K

J. E. A. ALDERSON, T. FARRELL,* AND C. M. HURD
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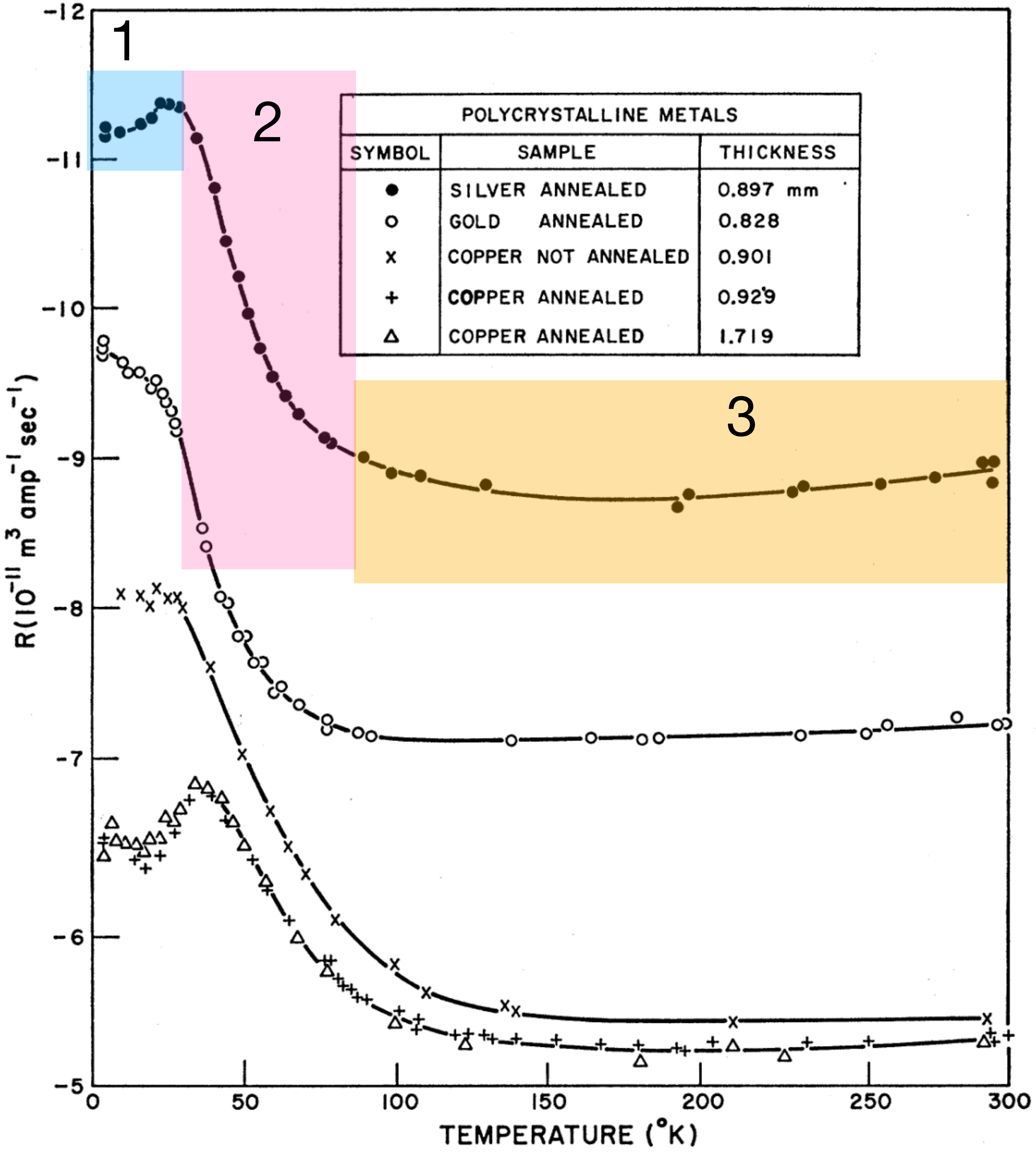
(Received 3 May 1968)

The Hall coefficient R of high-purity polycrystalline group-IB metals and some single-crystal Cu samples has been determined with high precision in the approximate temperature range 4.2–300°K and in a magnetic field of 15 kG. The general temperature dependence of R for each IB metal can be explained for temperatures down to about 50°K in terms of what is known about the electronic relaxation times associated with different electron scattering processes. But at lower temperatures these data show a new behavior: The $|R|$-versus-temperature curve for each metal shows an apparent maximum centered at about 40°K. Experiments are described which show this is not a sample-size effect, not an effect of trace impurities, but probably a result of a phonon-drag contribution to R. The work has involved similar measurements of some very dilute *Ag*Au, *Ag*Zn, and *Ag*Cd alloys.



$$R_H = \frac{E_y}{j_x B_z} = -\frac{v_x B_z}{j_x B_z} = \frac{1}{en}$$

2: Increase in carrier density
3: Increase of relaxation time
1: phonon drag ?

Example 2: The Quantum Hall effect

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New Method for High-Accuracy Determination of the Fine-Structure Constant Based on Quantized Hall Resistance

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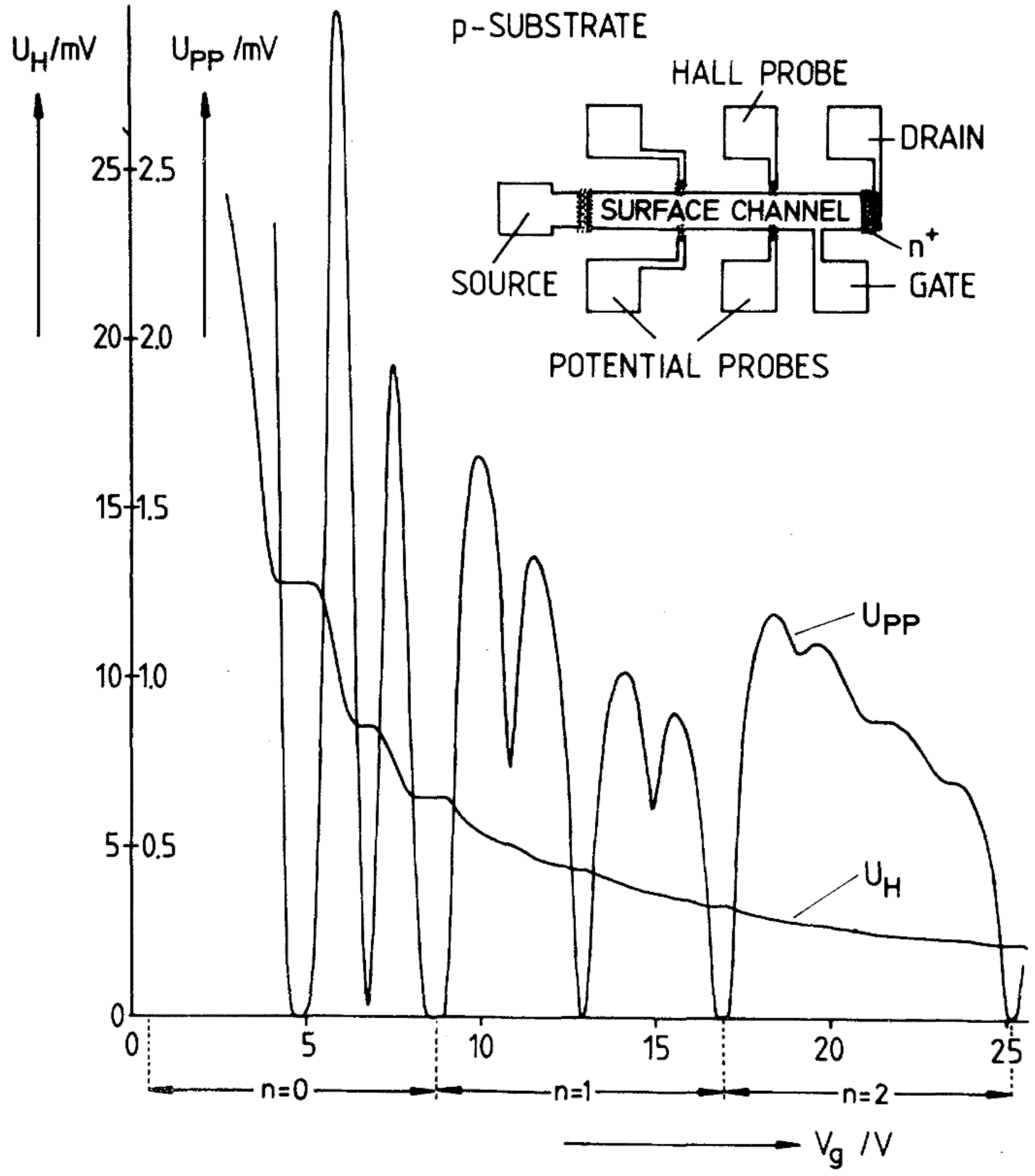
(Received 30 May 1980)

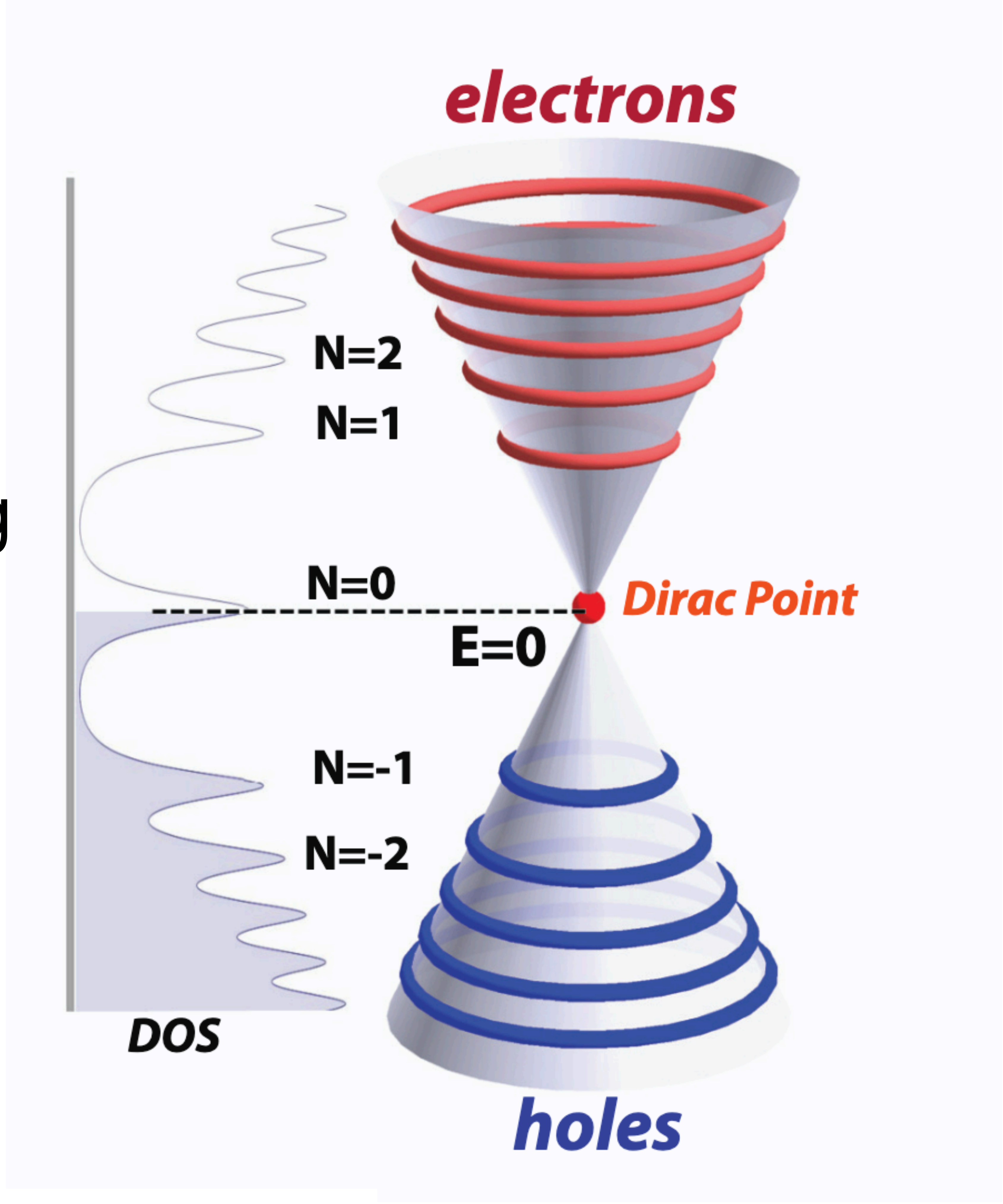
Measurements of the Hall voltage of a two-dimensional electron gas, realized with a silicon metal-oxide-semiconductor field-effect transistor, show that the Hall resistance at particular, experimentally well-defined surface carrier concentrations has fixed values which depend only on the fine-structure constant and speed of light, and is insensitive to the geometry of the device. Preliminary data are reported.



1: 2D electron system
2: strong magnetic field

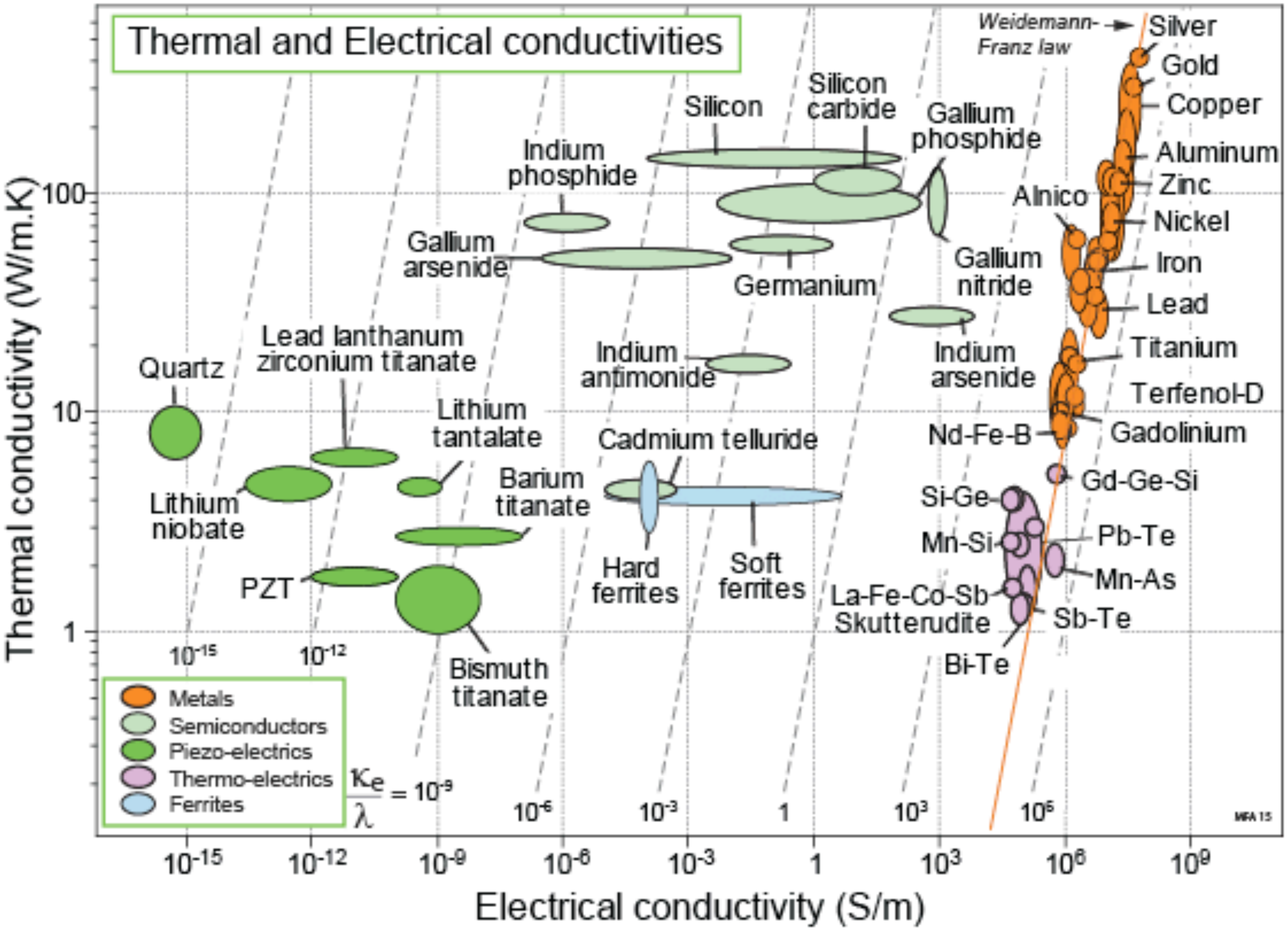
Landau levels

K. von Klitzing



Nobel Prize in Physics 1985

The Wiedemann-Franz law



$$\frac{\kappa}{\sigma} = \frac{3}{2}\left(\frac{k_B}{e}\right)^2 T$$