Karlsruhe Institute of Technology

EEFK1 – Lecture 2

Matthieu Le Tacon

Transport Coefficients

	$\mathbf{B} = 0, \quad \mathbf{M} = 0$	
	$\hat{\boldsymbol{E}} = -\boldsymbol{\nabla}\phi_{el}$	$-\boldsymbol{\nabla}T$
J_q	Electrical Conductivity ($\overleftrightarrow{\sigma}$) or resistivity ($\overleftrightarrow{\rho}$)	Seebeck-Effect (S)
J_H	Peltier-Effect (P)	Heat Conductivity ($\overleftrightarrow{\kappa}$)
	$\mathbf{B} \neq 0$	
	$-\boldsymbol{\nabla}\phi_{el} \times \hat{\mathbf{B}}$	$-\boldsymbol{\nabla}T \times \hat{\mathbf{B}}$
J_q	Magnetoresistance $\rho_{xx}(B)$ Hall Effect (R_H)	Nernst Effect (N)
J_H	Ettinghausen-Effect	Thermal Hall Effect

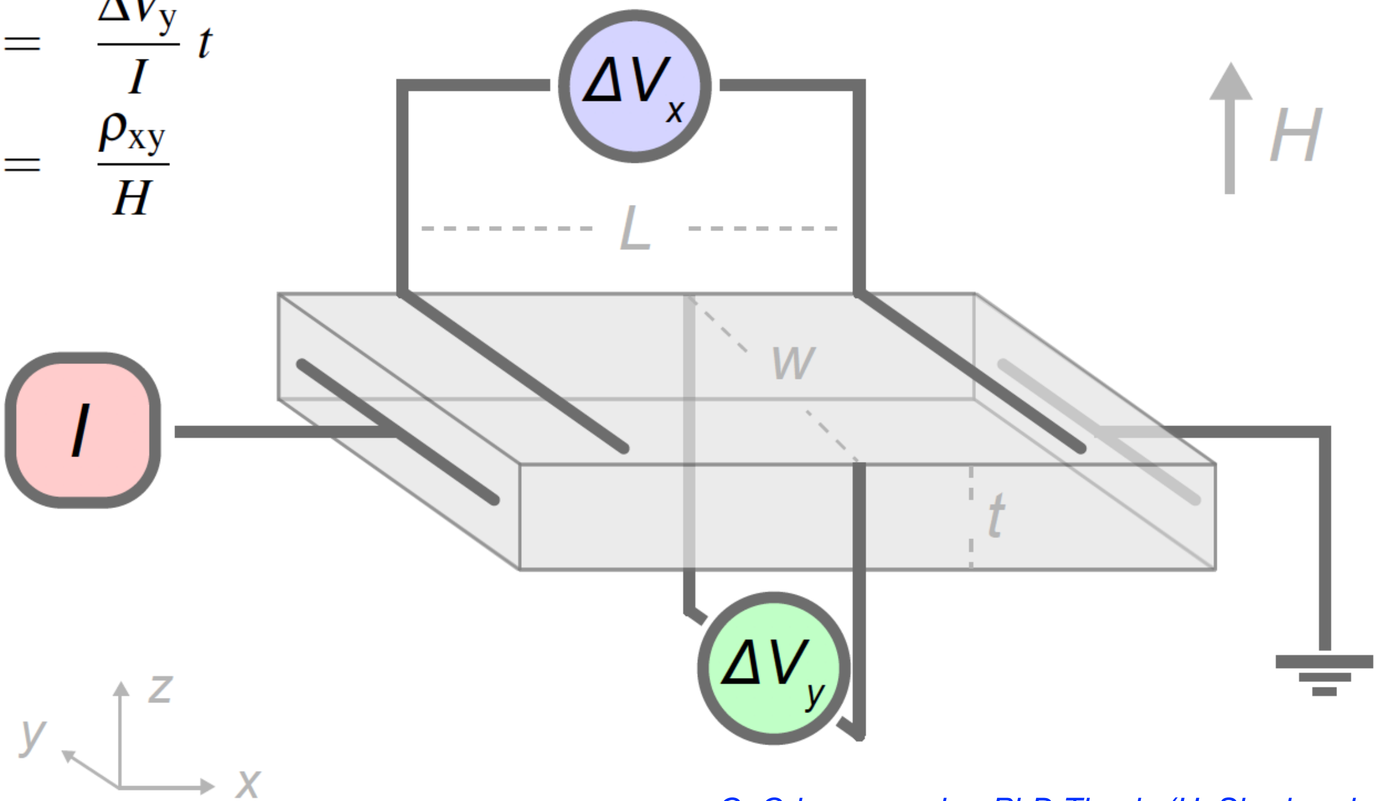
Electrical Transport

$$\rho_{xx} = \frac{\Delta V_x}{I}\alpha$$

$$\rho_{xy} = \frac{\Delta V_y}{I}t$$

$$R_H = \frac{\rho_{xy}}{H}$$

Geometrical factor: $\alpha = \frac{wt}{L}$



G. Grissonnanche, PhD Thesis (U. Sherbrooke)

Electrical Transport

Contacts for resistivity and Hall measurements on a high-temperature superconductor single crystal

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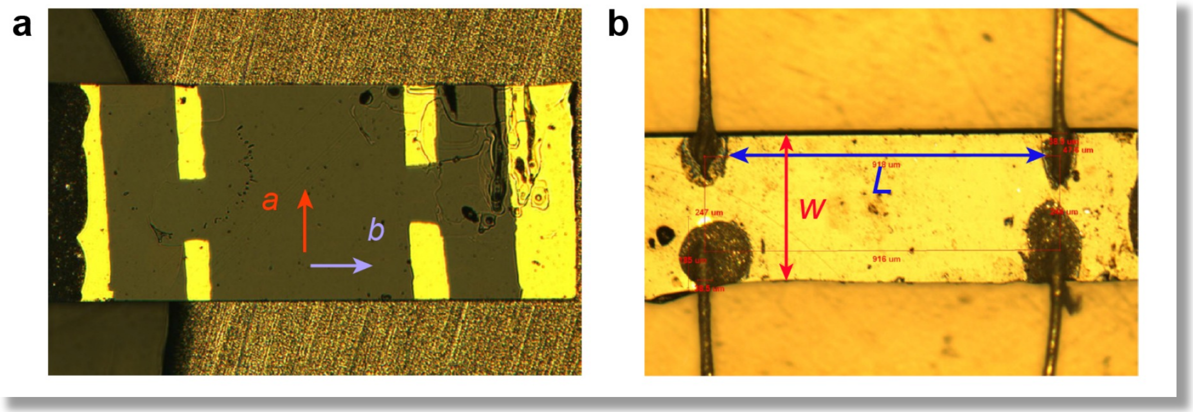
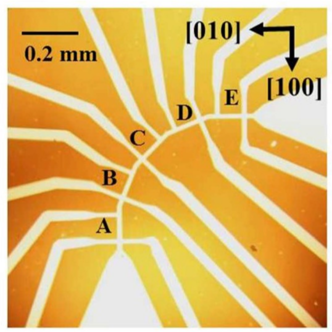
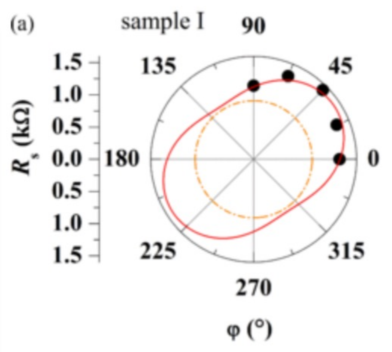


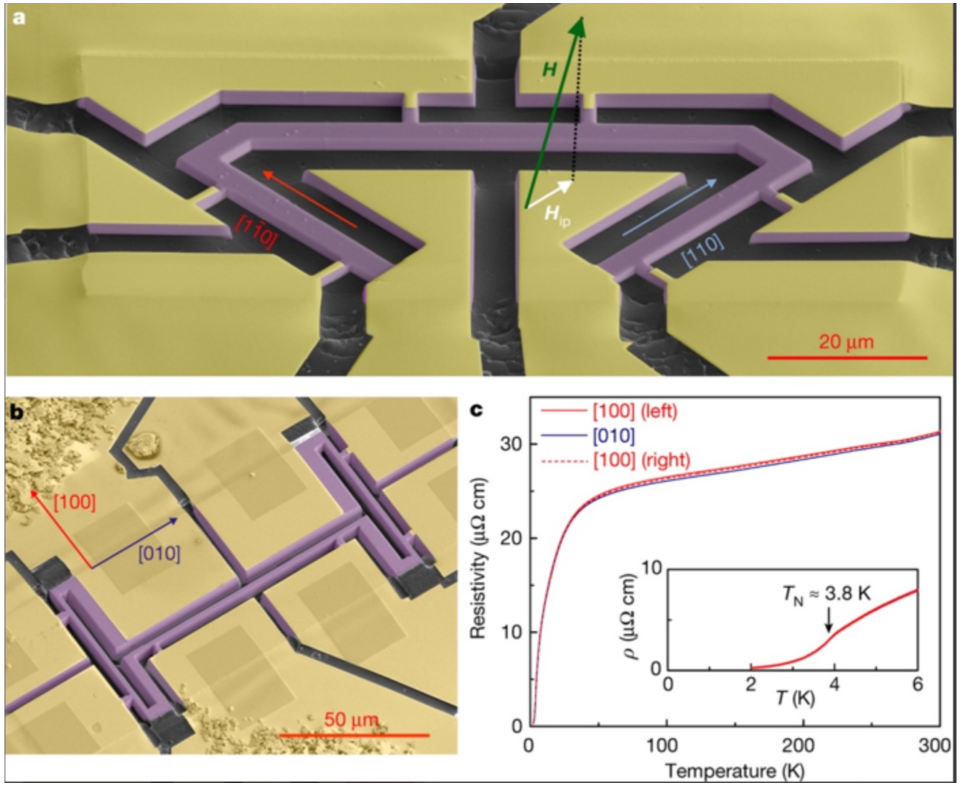
Contacts for angle-resolved resistivity measurements on 2D electron-system $SrTiO_3/LaAlO_3$

Wolff et al. Phys. Rev. B 95, 245132 (2017)



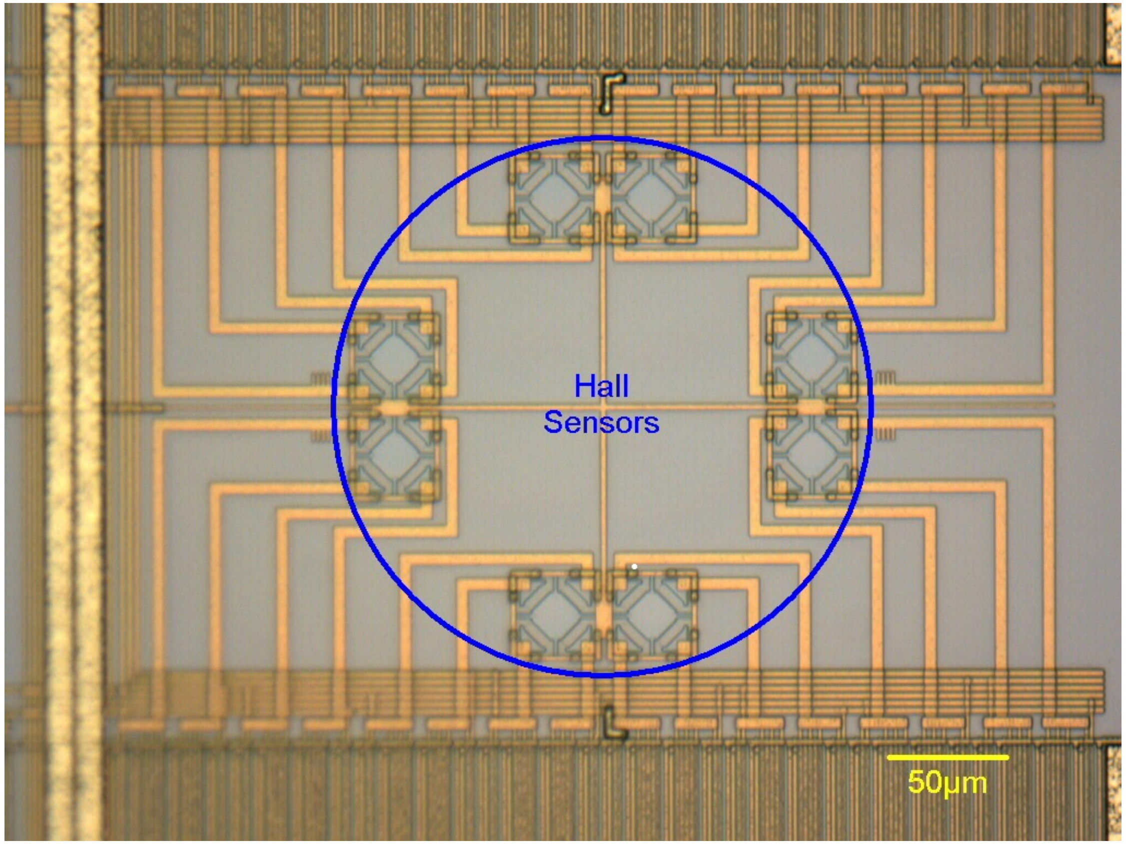


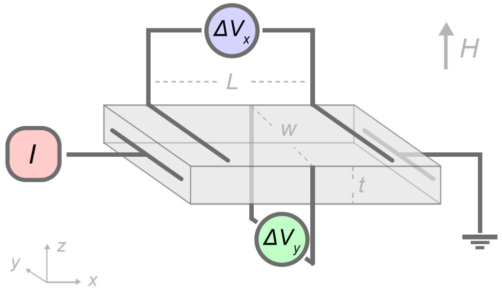
Electrical Transport



Electronic in-plane symmetry breaking at field-tuned quantum criticality in $CeRhIn_5$
F. Ronning et al. *Nature* **548**, 313–317 (2017)

Practical use of Hall effect





$$R_H = \frac{\rho_{xy}}{H}$$

Compass

Quantum Hall Effect (v. Klitzing 1980)

VOLUME 45, NUMBER 6 PHYSICAL REVIEW LETTERS 11 AUGUST 1980

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

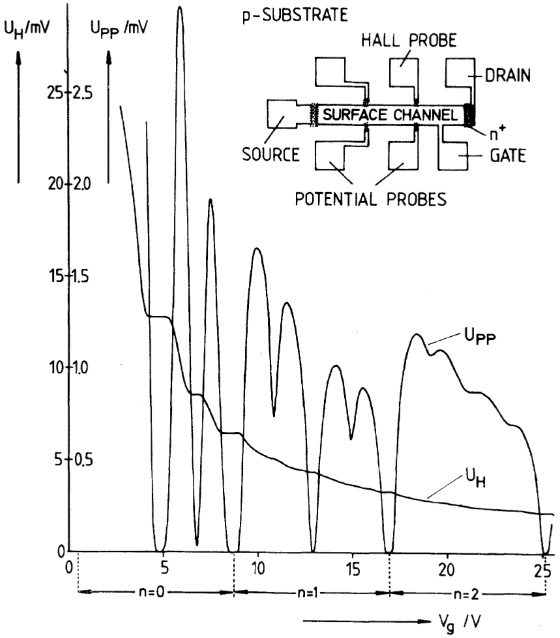
K. v. Klitzing
Physikalisches Institut der Universität Würzburg, D-8700 Würzburg, Federal Republic of Germany, and Hochfeld-Magnetlabor des Max-Planck-Instituts für Festkörperforschung, F-38042 Grenoble, France

and

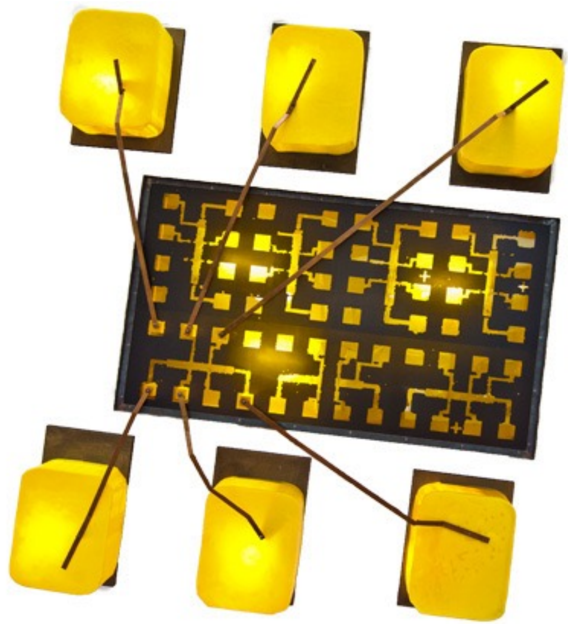
G. Dorda
Forschungslaboratorien der Siemens AG, D-8000 München, Federal Republic of Germany

and

M. Pepper
Cavendish Laboratory, Cambridge CB3 0HE, United Kingdom
(Received 30 May 1980)



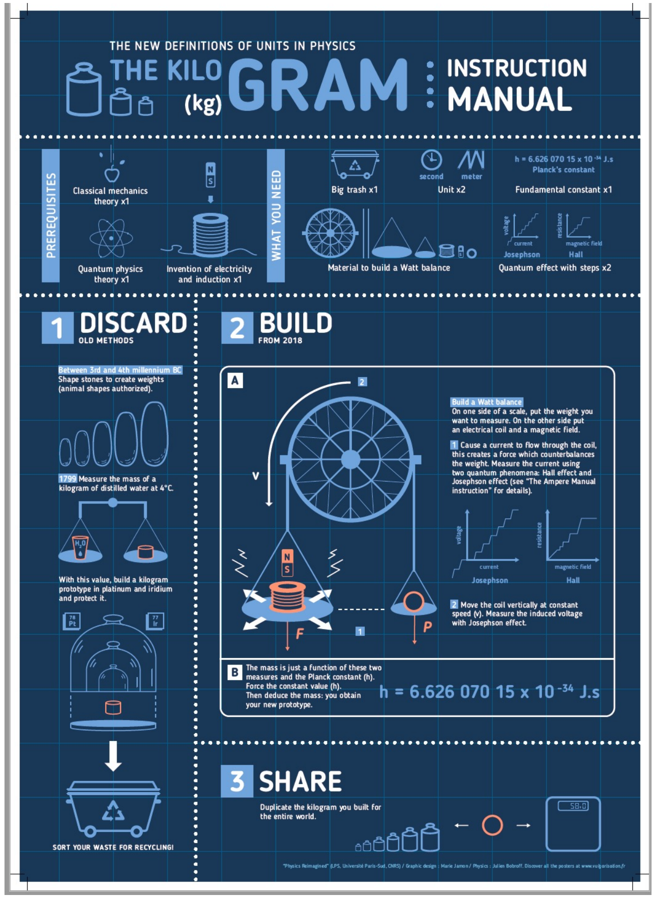
Nobel Prize contacts

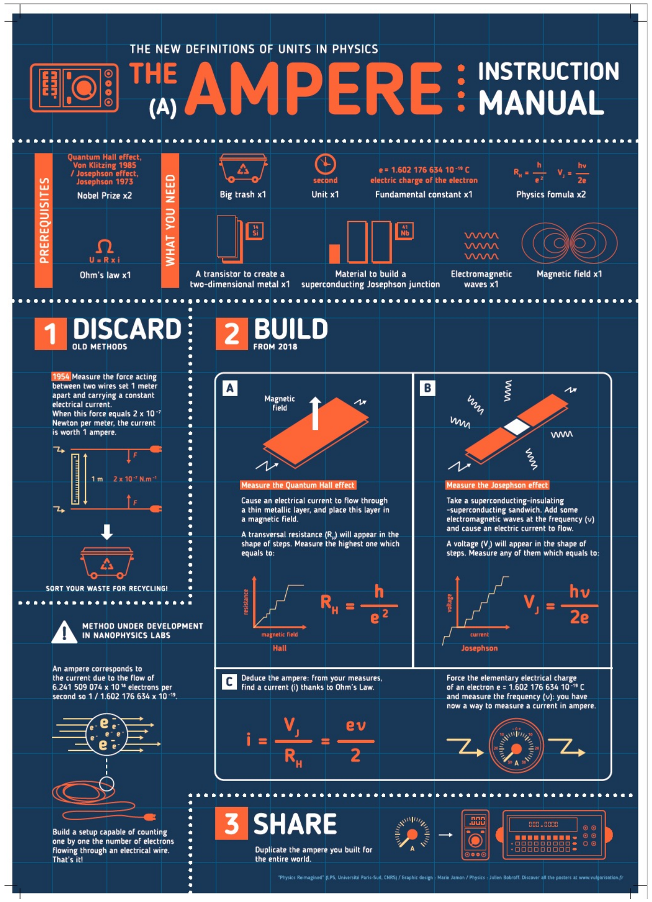


$$\sigma = \frac{I_{\text{channel}}}{V_{\text{Hall}}} = \nu \frac{e^2}{h}$$

www.fkf.mpg.de

New definition of units in Physics





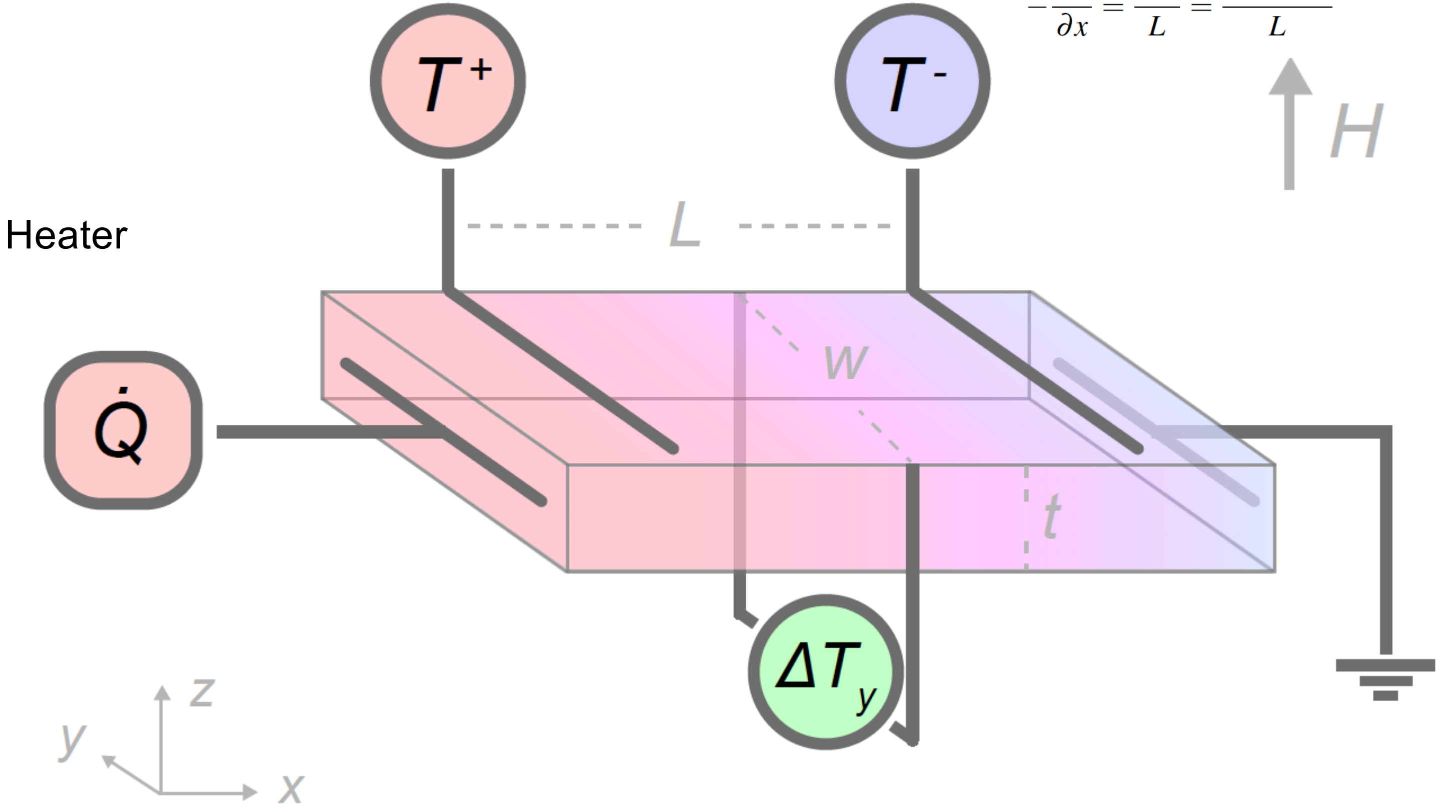
Outreach project by Julien Bobroff

http://hebergement.u-psud.fr/supraconductivite/projet/unitas_mode_demploi/?lang=en

Thermal Transport

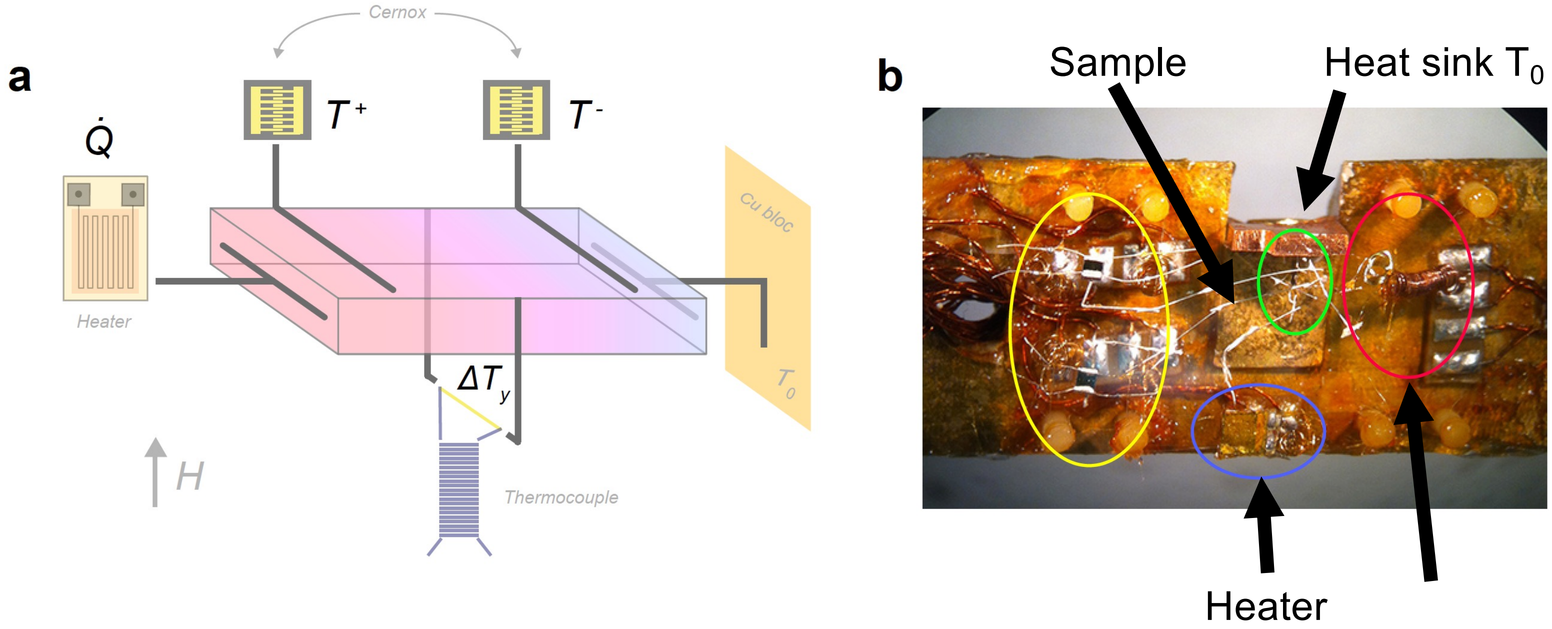
$$\begin{pmatrix} j_{Q,x} \\ 0 \end{pmatrix} = -\begin{pmatrix} \kappa_{xx} & \kappa_{xy}(H) \\ -\kappa_{yx}(H) & \kappa_{yy} \end{pmatrix} \begin{pmatrix} \frac{\partial T}{\partial x} \\ \frac{\partial T}{\partial y} \end{pmatrix}$$

$$-\frac{\partial T}{\partial x} = \frac{\Delta T_x}{L} = \frac{T^+ - T^-}{L}$$



G. Grissonnanche, PhD Thesis (U. Sherbrooke)

Thermal Transport



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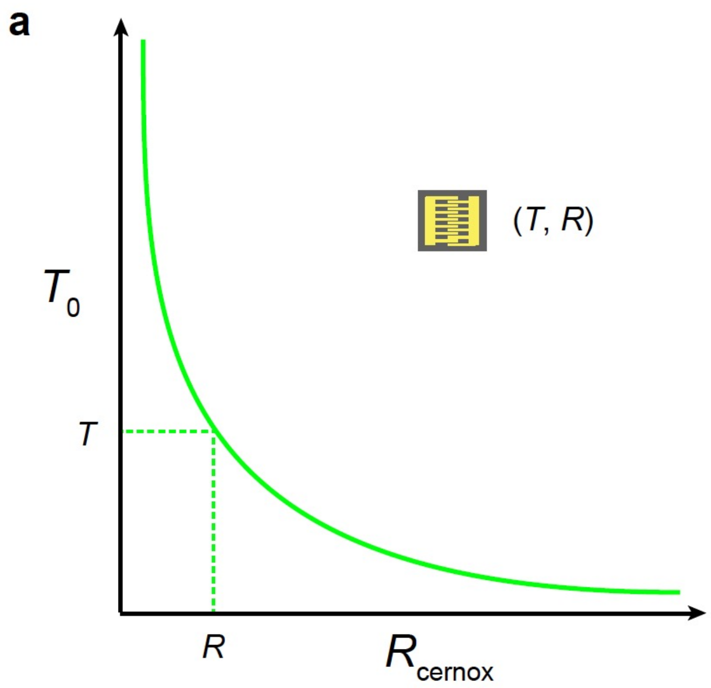
Application: Thermometry

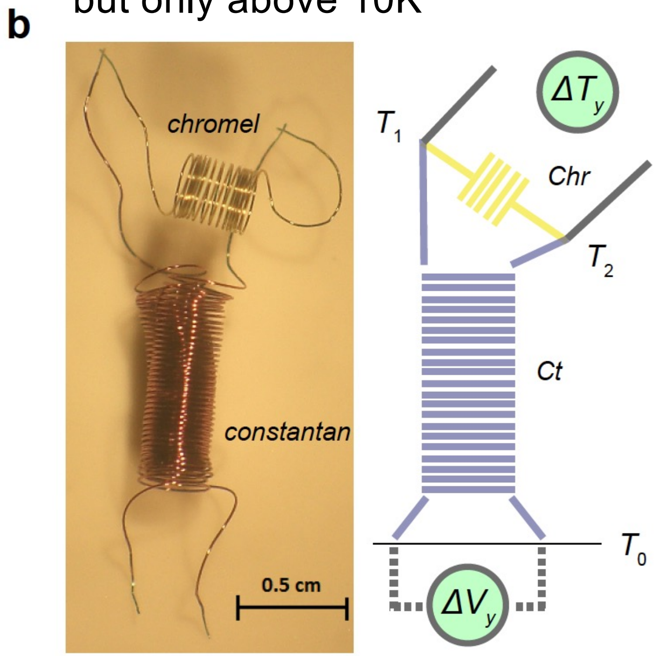
Cernox
1-100K very sensitive (calibration!)
But strong magnetoresistance

Thermocouples

$$\Delta T_y = -\frac{\Delta V_y}{S_{ther}(T)}$$

Very sensitive (ΔT~mK)
but only above 10K





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Hall Effect

Metal	Observed R_H	Calculated R_H	j
Li	-17.0	-13.1	1
Na	-25.0	-24.4	1
Cu	-5.5	-7.4	1
Ag	-8.4	-10.4	1
Zn	+4.1	-4.6	2
Cd	+6.0	-6.5	2

Table 1.1: Observed and calculated values of the Hall coefficient R_H in units of $10^{-11}\mathrm{m}^3\mathrm{C}^{-1}$ for several metals. The calculated values assume j free electrons per atom.

Hall Resistivity of Al