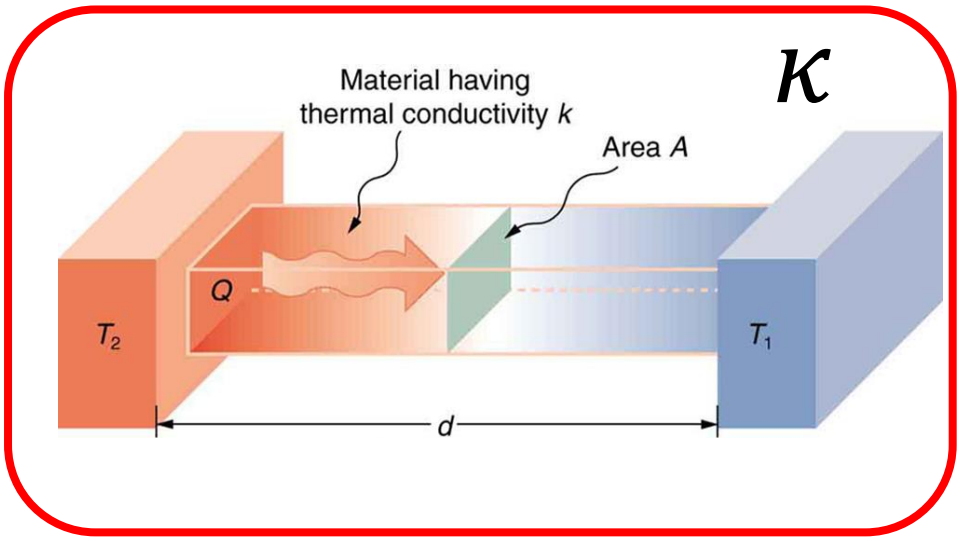
The Wiedemann-Franz Law

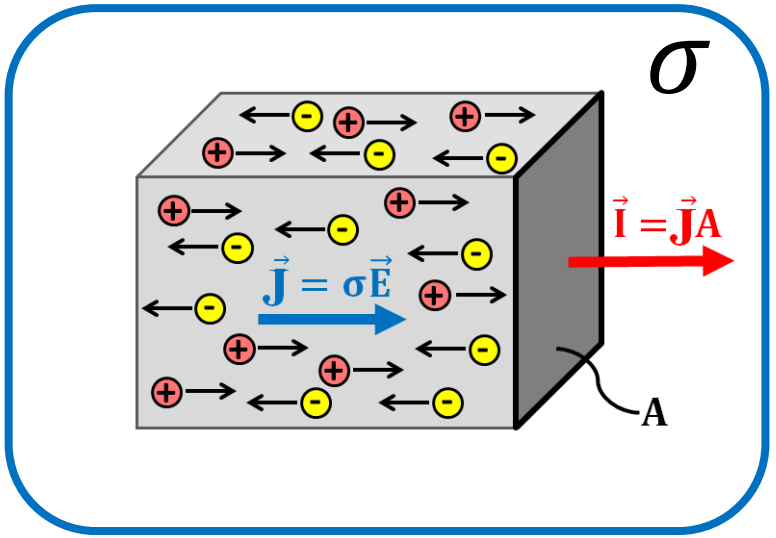
Asaf Rozen, Alexander Palevski, Eli Raz

The Wiedemann-Franz Law

- Heat and electrical transport involve free electrons

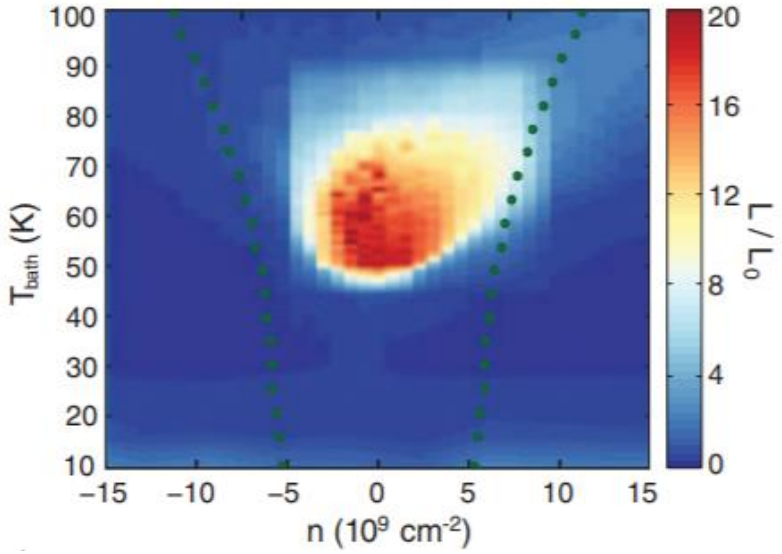
$$L = \frac{\kappa}{\sigma T} = \frac{\pi^2}{3}\left(\frac{k_B}{e}\right)^2 = 2.44 \cdot 10^{-8}\left[\frac{W\Omega}{K^2}\right]$$

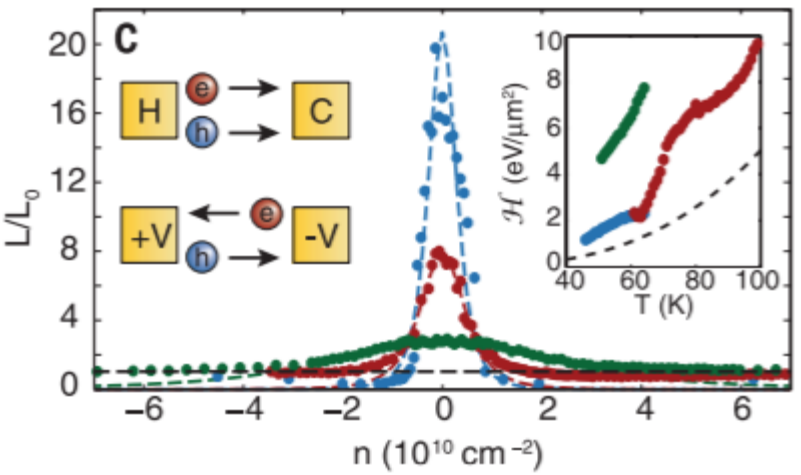




The Wiedemann-Franz Law

- Discovered in 1853 by Gustav Wiedemann and Rudolph Franz
- Broadly used in modern solid state physics

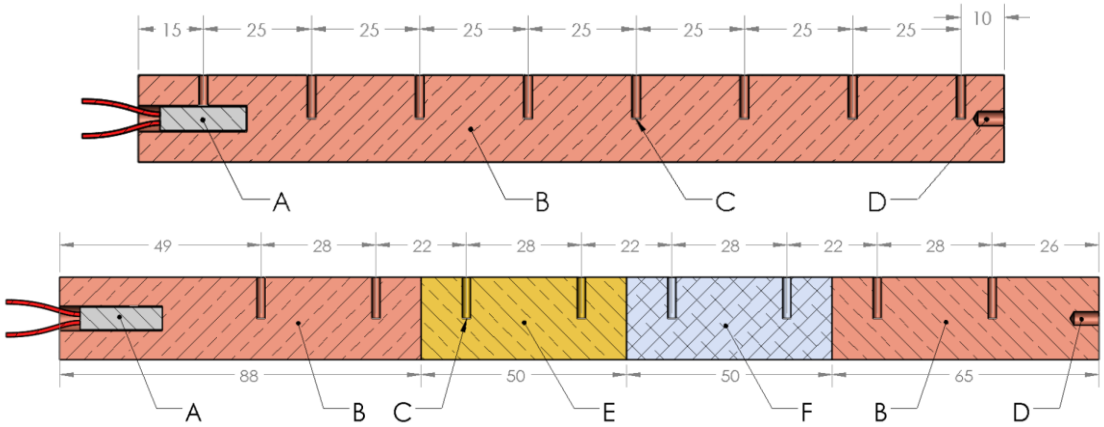




Crossno, J., Shi, J. K., Wang, K., Liu, X., Harzheim, A., Lucas, A., ... & Ohki, T. A. (2016). Observation of the Dirac fluid and **the breakdown of the Wiedemann-Franz law** in graphene. ***Science***, *351*(6277), 1058-1061.

Parts Of The Experiment

- Part A – Electric conductivity (σ) of various metals.
- Part B – Thermal conductivity (κ) of Copper.
- Part C – Measure heat capacity (c_p) and heat loss.
- Part D – Measure the relative κ of different metals.
- Part E – Discover the Wiedemann-Franz law.

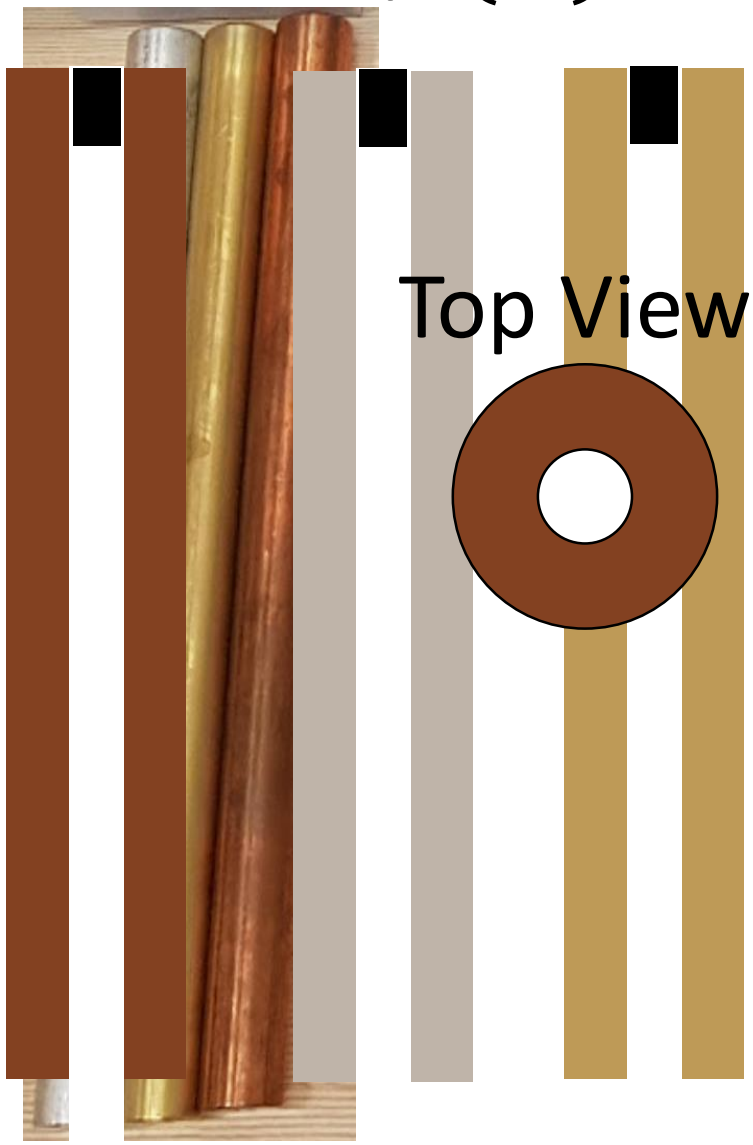


Equipment

Part A – Electrical conductivy (σ)

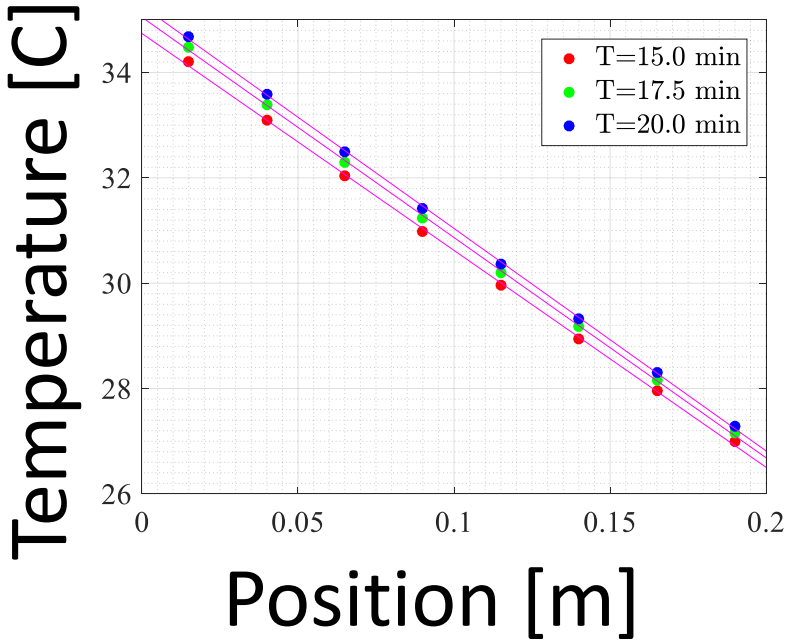
- Aluminum, Brass and Copper tubes
- Small magnet falls at a constant speed

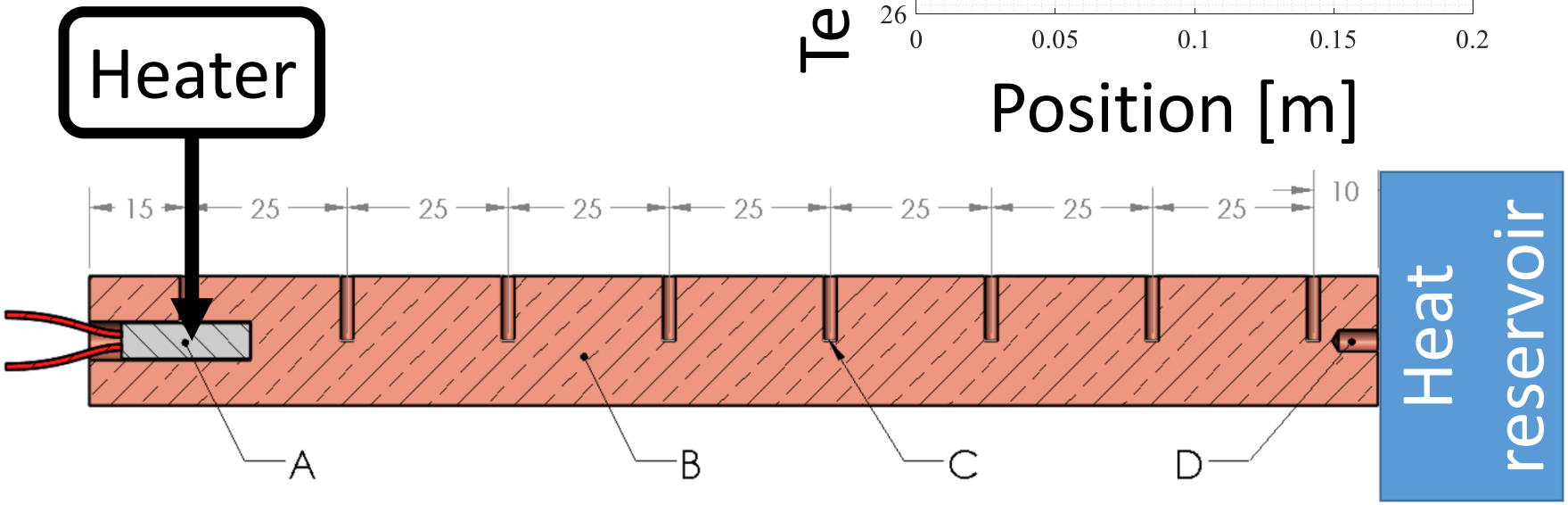
$$t = 0.22 \frac{\pi r_m^2 (\mu_0 M)^2 w L_0}{mg} \sigma$$



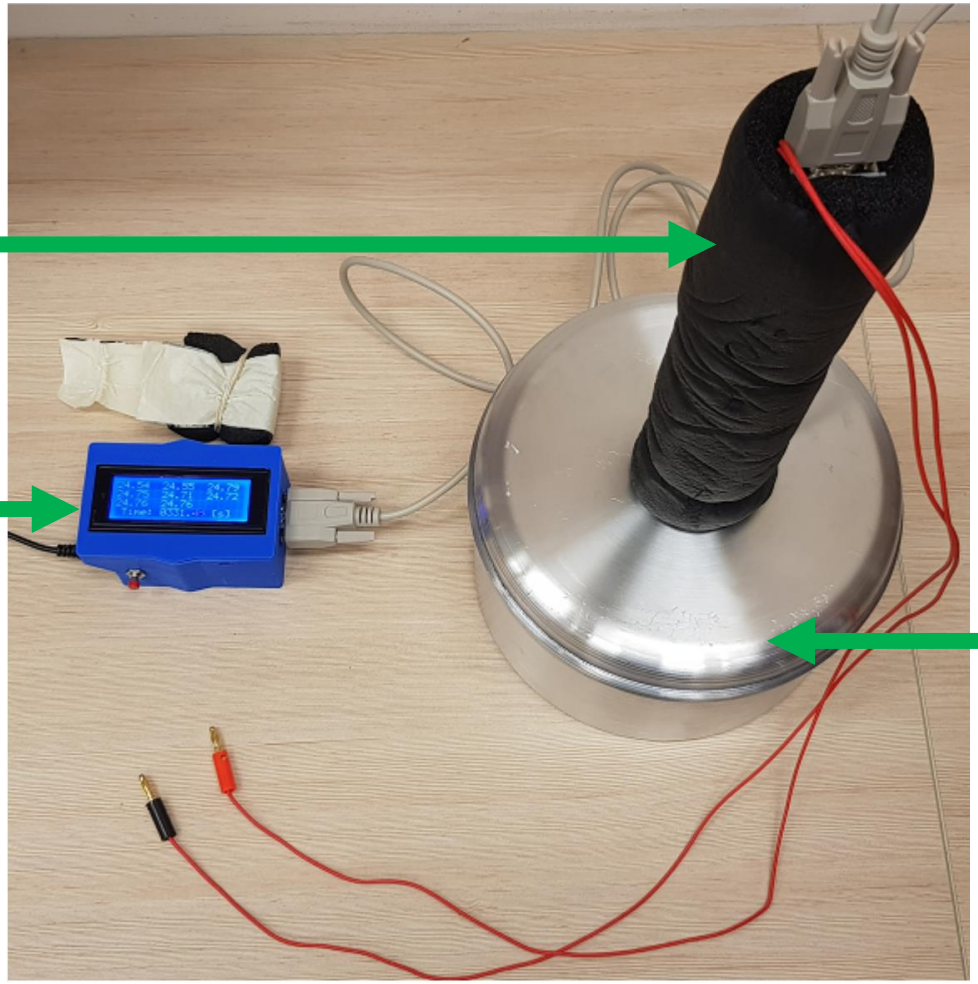
Part B – Thermal conductivity (κ)

- Power on one side, Reservoir on the other





Part B – Thermal conductivity (κ)

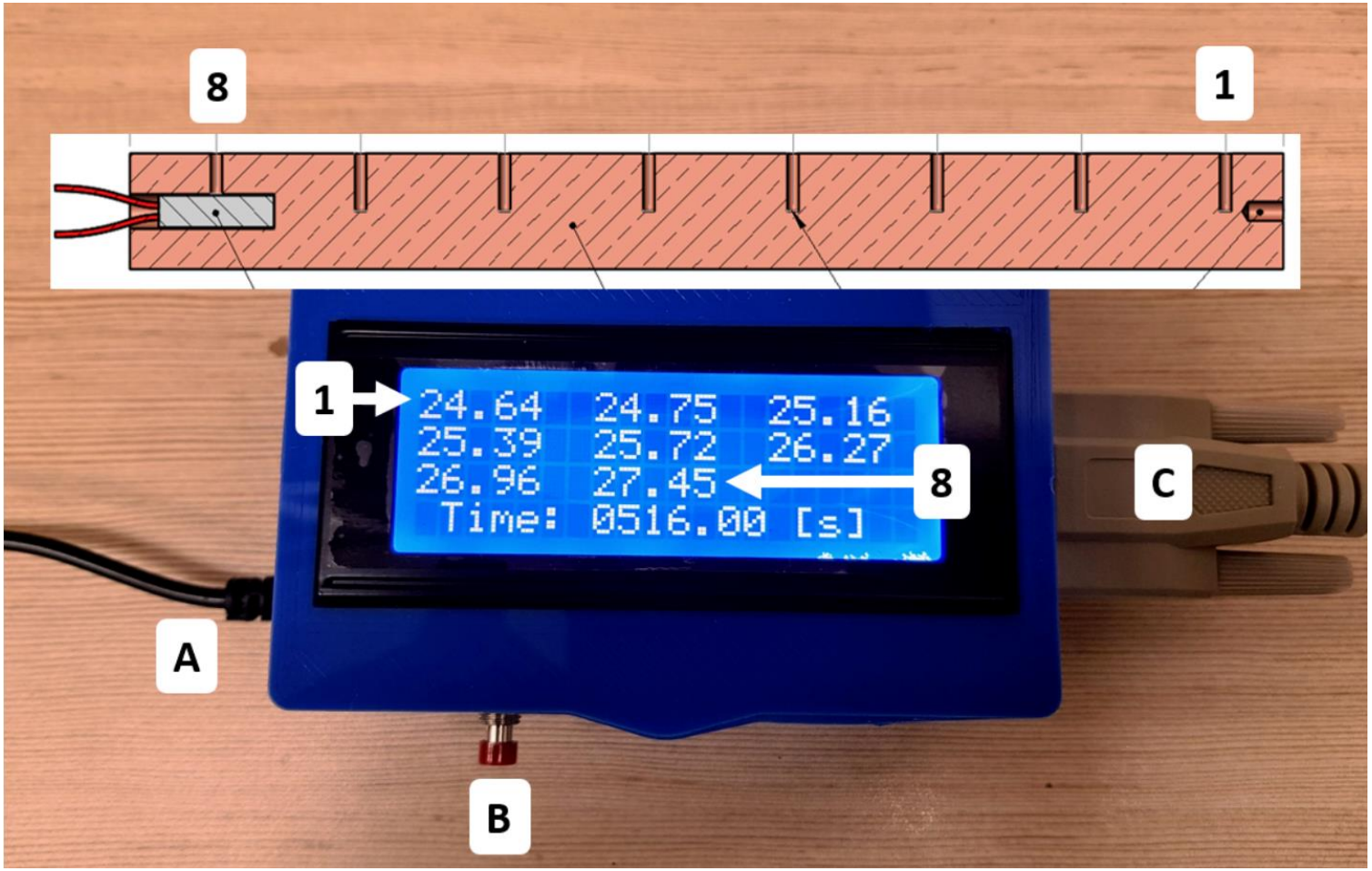


Isolated Rod

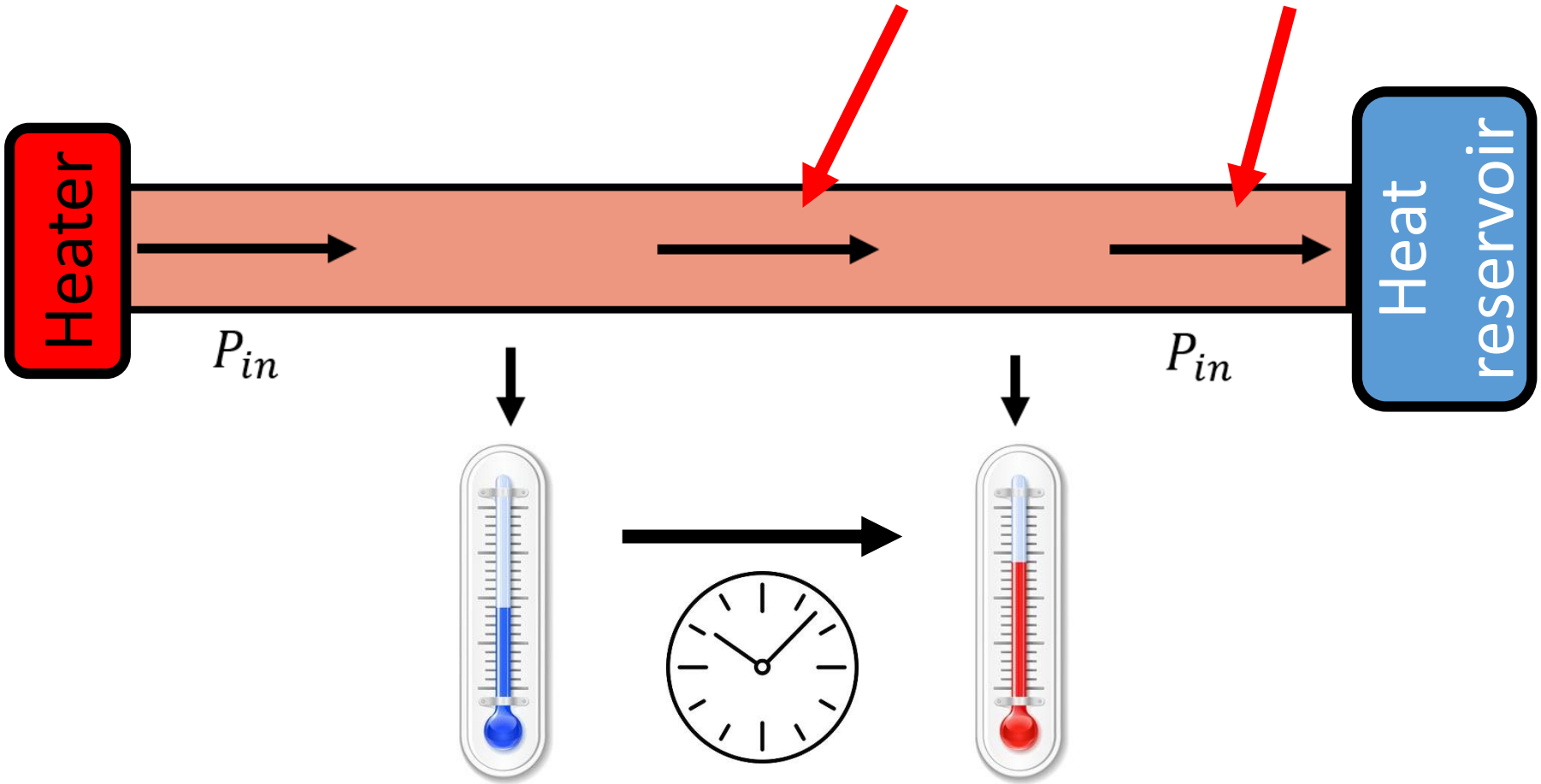
Readout Box

Heat Reservoir

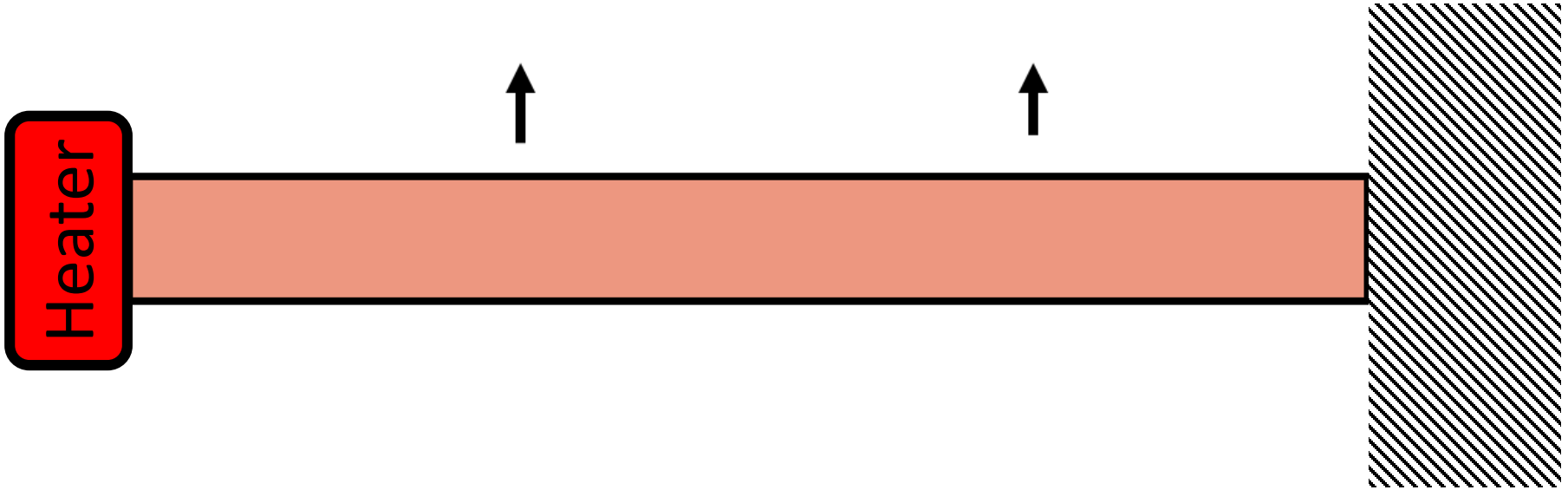
Part B – Thermal conductivity (κ)



Part C – Measure Heat Capacity And Heat Loss To Correct κ

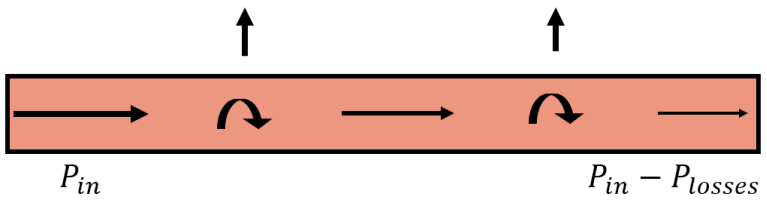


Part C – Measure Heat Capacity And Heat Loss To Correct κ



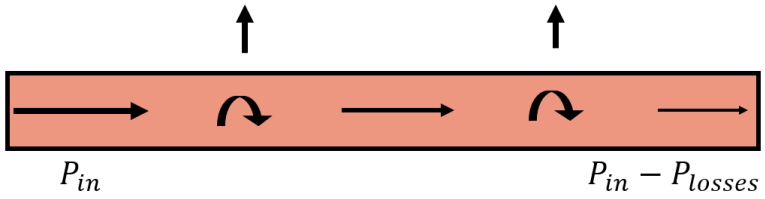
Part C – Measure Heat Capacity And Heat Loss To Correct κ

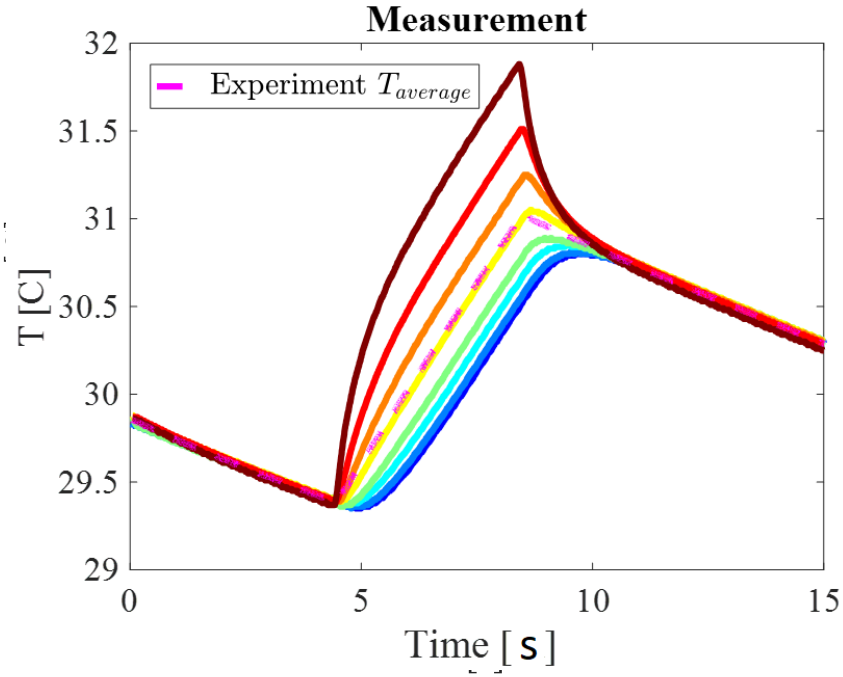
- The rod is not at steady state
- There is heat loss to the environment



Part C – Measure Heat Capacity And Heat Loss To Correct κ

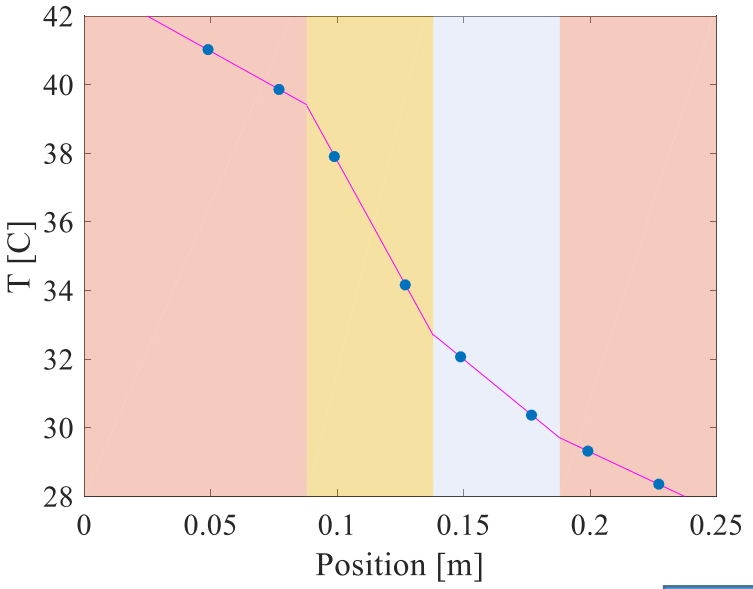
- The rod is not at steady state
- There is heat loss to the environment
- We use cooling-heating-cooling cycle

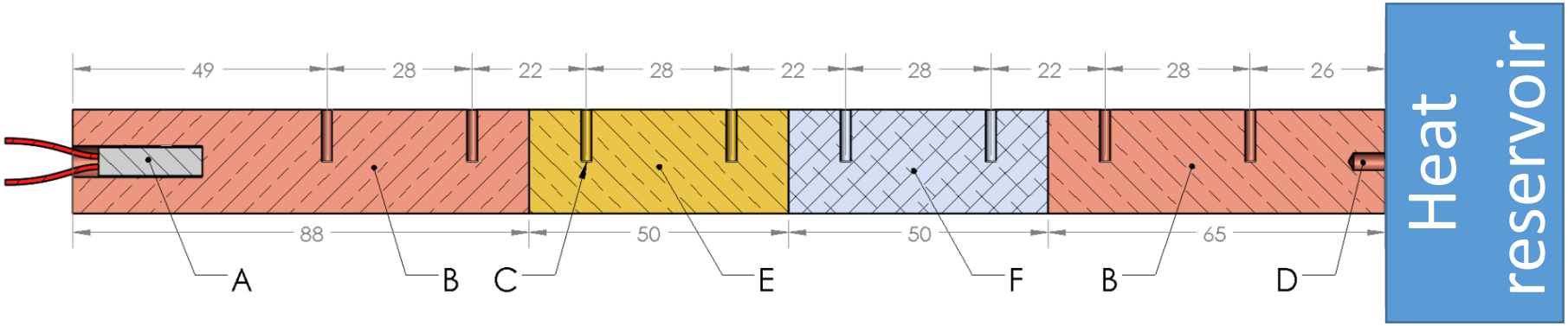




Part D – Measure The Relative κ Of Different Metals

- Using alternating material rod
- Get accurate relative thermal conductivity
- Using the knowledge from part C to correct results





Part E – Discover The Wiedemann-Franz Law

Material / Property	Copper	Aluminum	Brass
$\sigma\ [\Omega^{-1}m^{-1}]$ Electrical conductivity	5.97×10^{7}	2.89×10^{7}	1.60×10^{7}
$\kappa \left[\frac{W}{Km}\right]$ Heat conductivity	396	239	115
$L \left[\frac{W\Omega}{K^2}\right]$ Lorenz coefficient	2.23×10^{-8}	2.27×10^{-8}	2.42×10^{-8}

Acknowledgments – Roy Beck- Barkai, Yoram Dagan