WIEDEMANN-FRANZ LAW

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INTRODUCTION

- RESISTIVITY IS A MEASURE OF THE RESISTANCE OF A GIVEN SIZE OF A SPECIFIC MATERIAL TO ELECTRIC CONDUCTION.MATERIALS THAT CONDUCT ELECTRIC CURRENT EASILY ARE CALLED CONDUCTORS AND HAVE LOW RESISTIVITY.
- WE DECIDED TO DO OUR PROJECT ON THE TOPIC WIEDEMANN-FRANZ LAW AND TO FIND THE THERMAL AND ELECTRICAL CONDUCTIVITY OF FOUR DEFFERENT MATERIALS LIKE CONSTANTAN,LEAD,BRASS AND CAST IRON USING THE WIEDMANN- FRANZ LAW.
- AND WE USE TWO METHODS FOR THE CALCULATION OF THERMAL CONDUCTIVITY THAT ARE POTENTIOMETER METHOD AND CAREY FOSTER'S BRIDGE METHOD.

REASONING AND IMPORTANCE

- THE THERMAL CONDUCTIVITY OF METALS AND ALLOYS IS AN IMPORTANT PHYSICAL PROPERTY
- IT IS LIQUID STATE USUALLY HARD TO BE MEASURED BECAUSE TO EXCLUDE THE EFFECT OF CONVECTION
- WIEDEMANN FRANZ LAW HAS BEEN USED FOR THE ESTIMATION OF THERMAL CONDUCTIVITY OF METALS AND ALLOYS IN THE LIQUID STATE
- PURE SN AND SN BASED METALS SHOW THE LIQUID STATE

- MEASURING THE THERMAL CONDUCTIVITY OF VARIOUS SN BASED ALLOYS IN THE LIQUID STATE OF SIGNIFICANCE IMPORTANCE TO IDENTIFY HEAT TRANSFER IN TERMS OF WHETHER THE DEVIATION FROM WEIDEMANN FRANZ LAW IS OBSERVED.
- FIELDS METAL IS FOCUSED ON AS ONE OF THE SN BASED ALLOYS .
- THERMAL CONDUCTIVITY IN THE SOLID AND LIQUID STATE WITH VARIOUS TEMPERATURE RANGES BY EMPLOYING THE TRANSIENT HOT WIRE METHOD.
- WIEDEMANN FRANZ LAW IS ANALYSED BY USING THE OBTAINED THERMAL CONDUCTIVITY AND ELECTRICAL CONDUCTIVITY DATA

THEORETICAL OVERVIEW

- THE LAW DEFINES THE RATIO OF THE ELECTRONIC ROLE OF THE THERMAL CONDUCTIVITY OF A MATERIAL OF THE ELECTRICAL CONDUCTIVITY OF A MATERIAL IS DIRECTLY RELATIVE TO THE TEMPERATURE

$$\frac{\kappa}{\sigma} = LT$$

L → LORENZ NUMBER = 2.44×10^{-8} $W^{-2}K^{-2}$

T → TEMPERATURE

DERIVATION OF THE LAW

Wiedemann-Franz law

$$\sigma = \frac{ne^2\tau}{m_e} \qquad K = \frac{\pi^2 n k_B^2 T \tau}{3m_e}$$

The ratio of the electrical and thermal conductivities is independent of the electron gas parameters;

Lorentz number

$$\frac{K}{\sigma T} = \frac{\pi^2}{3}\left(\frac{k_B}{e}\right)^2 = 2.45x10^{-8} W\Omega K^{-2}$$

$$L = \frac{K}{\sigma T} = 2.23x10^{-8} W\Omega K^{-2}$$

For copper at 0 C

Wiedemann-Franz Law and Lorenz Number

Now the thermal conductivity per unit volume is:

$$\kappa' = \frac{1}{3}\frac{\pi^2}{2}k^2 n \frac{T}{E_F} v_F^2 \tau = \frac{1}{3}\frac{\pi^2}{2}k^2 n \frac{T}{\frac{1}{2}mv_F^2} v_F^2 \tau$$

Finally…

$$\kappa' = \frac{\pi^2 k^2 n \tau}{3m} T$$

Now long before Drude's time, Gustav Wiedemann and Rudolf Franz published a paper in 1853 claiming that the ratio of thermal and electrical conductivities of all metals has nearly the same value at a given T:

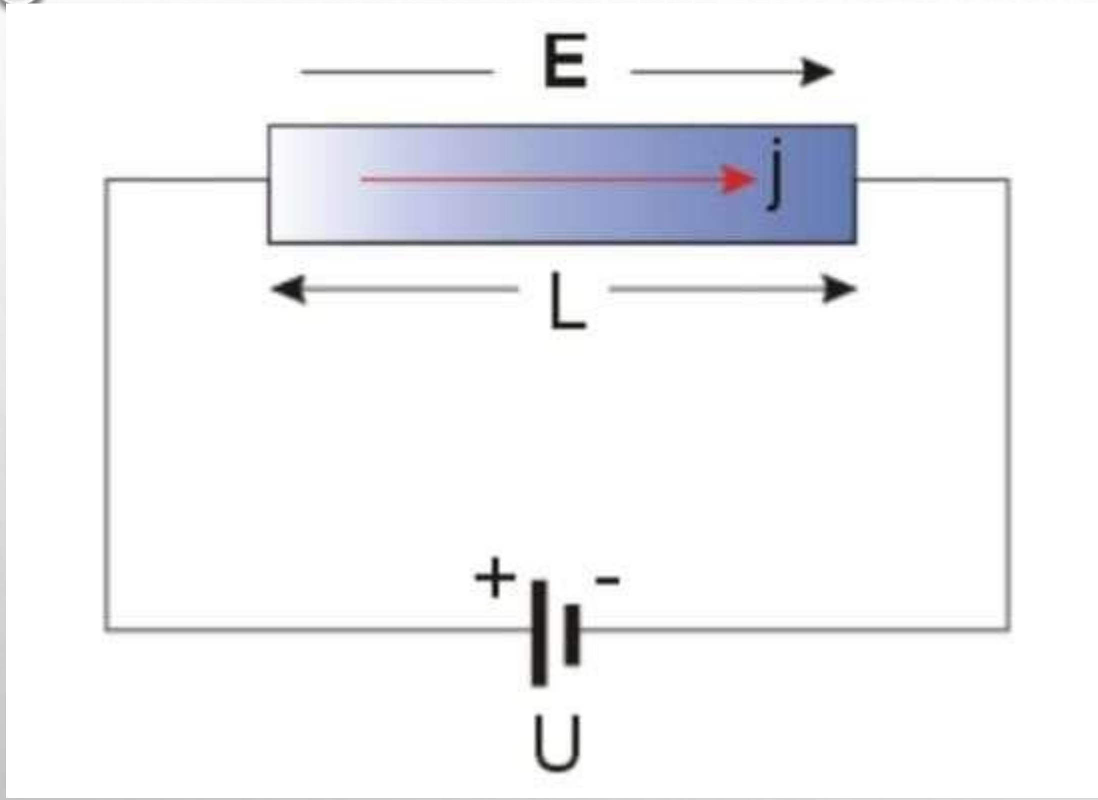
$$\frac{\kappa}{\sigma} = constant$$

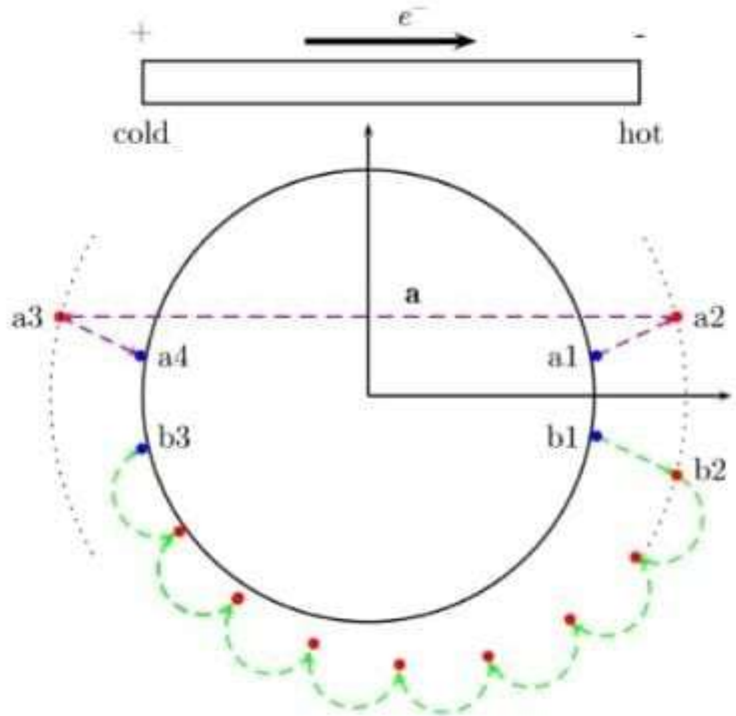
Gustav Wiedemann

Not long after (1872) Ludwig Lorenz (not Lorentz!) realized that this ratio scaled linearly with temperature, and thus a Lorenz number L can be defined:

$$\frac{\kappa}{\sigma T} \equiv L$$

very nearly constant for all metals (at room T and above)





Sketch of the various scattering process important for the Wiedemann–Franz law.

WIEDEMANN-FRANZ LAW FOR MOLECULES

- IN 2020, GALEN CRAVEN AND ABRAHAM NITZAN DERIVED A WIEDEMANN-FRANZ LAW FOR MOLECULAR SYSTEMS IN WHICH ELECTRONIC CONDUCTION IS DOMINATED NOT BY FREE ELECTRON MOTION AS IN METALS, BUT INSTEAD BY ELECTRON TRANSFER BETWEEN MOLECULAR SITES.

LIMITATIONS OF WIEDEMANN- FRANZ LAW

- THE VALUE OF 'L' IS NOT THE SAME FOR AS THE MATERIALS
- THIS LAW IS NOT VALID FOR INFORMATIVE TEMPERATURE
- IN THE PURE METALS BOTH(Σ) AND K INCREASES AS TEMPERATURE

DECREASES

METHODOLOGY

- TO FIND ELECTRICAL CONDUCTIVITIES OF DIFFERENT MATERIALS. FIRST WE HAVE TO FINDRESISTIVITY OR ELECTRICAL RESISTIVITY FOR THAT MATERIAL

  WE HAVE TWO METHODS OF EXPERIMENTS

  1. TO FIND THE RESISTIVITY OF THE MATERIAL BY USING POTENTIOMETER APPARATUS
  2. TO FIND THE RESISTIVITY OF THE MATERIAL USING CAREY FOSTER'S BRIDGE APPARATUS

1. METHOD TO FIND RESISTIVITY OF THE MATERIAL USING POTENTIOMETER APPARATUS
   - WHEN A CURRENT 'I' FLOWS THROUGH THE COIL OF UNKNOWN RESISTANCE 'X' POTENTIOMETER DIFFERENCE ACROSS IT IS 'I X'. IF 'L' IS THE BALANCING LENGTH ON THE POTENTIOMETER FOR THIS POTENTIAL DIFFERENCE

$I \times \propto L^1$

ANALYSIS OF THE DATA

MATERIAL	ELECTRICAL RESISTIVITY in ohm	ELECTRICAL CONDUCTIVITY In s/m	THERMAL CONDUCTIVITY At 301 K or 28°c (k) In w/mk
Constantan (eureka)	42.22×10^-8	0.236×10^7	17.332
Brass	7.838×10^-8	1.275×10^7	93.641
Lead	17.297×10^-8	0.578×10^7	42.4506
Cast iron	11.9×10^-8	0.84×10^7	61.692

CONCLUSION

’WIEDEMANN- FRANZ LAW’ CAN BE APPLIED TO FIND THE THERMAL CONDUCTIVITY OF A MATERIAL. SINCE THE LAW RELATES THE THERMAL CONDUCTIVITY AND ELECTRICAL CONDUCTIVITY THROUGHOUT THIS PROJECT WE FOUND OUT THE RESISTIVITY FOR SOME SAMPLE MATERIALS LIKE BRASS, IRON ETC.. IN ORDER TO FIND THE ELECTRICAL CONDUCTIVITY AND THE THERMAL CONDUCTIVITY FROM ANALYSING THE DATAS OBTAINED FROM THE EXPERIMENTS, ITS CLEAR THAT THE MOST EXCELLENT ELECTRICAL CONDUCTOR WILL BE HEAT.