Experiment #: 02

Experiment Title: Electrical conductivity of metals

Objectives:

1. To determine the electrical conductivity of aluminum and copper by plotting a current-voltage characteristic curve.

2. To verify the Wiedmann-Franz law and find out the Lorenz number.

Theory:

Historically, “The Wiedemann-Franz Law states that for metals at not too low temperatures the ratio of the thermal conductivity to the electrical conductivity is directly proportional to the temperature with the value of the constant of proportionality independent of the particular metal.” [1]. Kittel writes the Wiedemann-Franz (WF) Law as [1]

$$\frac{\kappa_e}{\sigma} = L_0 T = \frac{\pi^2}{3}\left(\frac{k_B}{q}\right)^2 T,$$

where L_0 is the Lorenz number (which is actually a ratio, not a number). As Kittel notes, the fact that (1) can be derived from the electron gas theory of metals and that it applies to a wide range of metals under a wide range of conditions, was a major success in the early history of the theory of metals.

Both Kittel and Ziman point out, however, that the Lorenz number (which Ziman calls the Lorenz ratio) can change for metals at low temperature. This is usually attributed to a breakdown of the Relaxation Time Approximation (RTA). It is sometimes stated that the scattering times in the electrical and thermal conductivities may be different [1]. As summarized in eqns. (6), below, however, when solving the BTE in the RTA, there is only a single scattering time that determines the electrical and thermal conductivity (it appears in the mean-free-path, $\lambda(E)$ in (6e)). As discussed by Ashcroft and Merman, the breakdown of the WF law at low temperatures is not the result of different scattering times for the electrical and thermal conductivities, but, rather, the due to the fact that the same scattering has different effects on the electrical and thermal conductivities ([3] footnote on p. 323).

The Wiedemann–Franz law describes the relationship between the electrical conductivity and the electrical component of the thermal conductivity of a metal. It quantifies the idea that metals that are good electrical conductors are also good thermal conductors. The usual statement of the Wiedemann–Franz law is,

$$\frac{K}{\sigma} = LT.$$

is the electrical component of the thermal conductivity,

is the thermal conductivity,

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

is the absolute temperature, and is the Lorentz number. For the free-electron model, the electrical and thermal conductivities are, The Lorentz number for free electrons is,

$$L = \frac{\pi^2 k_B^2}{3e^2} = 2.44 \times 10^{-8}\,\mathrm{W\,\Omega\,K^{-2}}.$$

The law defines the ratio of the electronic role of the thermal conductivity of a material to the electrical conductivity of a material (metal) is directly relative to the temperature.

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

$$L \rightarrow Lorenz\ number = 2.44 \times 10^{-8} W\Omega K^{-2}$$

$$T \rightarrow Temperature$$

This law is named after Gustav Wiedemann and Rudolph Franz in 1853 reported that the ratio has more or less the similar value for dissimilar metal at the same temperature.

List of Equipment:

Apparatus

1. Measure voltage (V)

2. Heat conductivity rod, Cu

3. Heat conductivity rod, Al

4. Heat conductivity rod, Cu

5. Digital Multimeter

6. Temperature Probe

7. Stopwatch

9. Glass beaker

10. Immersion heater

11. Rheostat

12. Gauze bag

13. Connecting cord,

14. Magnetic stirrer

15. Multitap transformer

8. Supporting block **16.** Calorimeter vessel

Circuit Diagram:

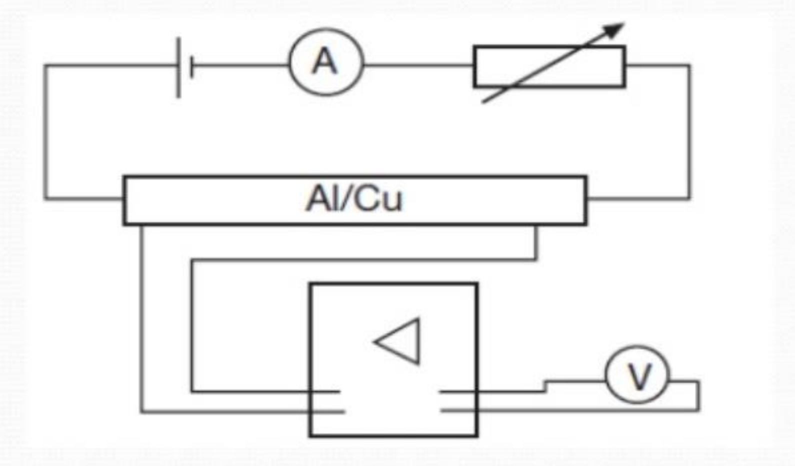


Fig.2. Circuit diagram for the measurement of electrical conductivity

Procedure:

Measurement of the electrical conductivity.

• Perform the experimental set-up according to the circuit diagram in Fig. 2 (set-up in accordance with a 4-conductor measuring method).

• Set the voltage on the variable transformer to 6 V.

• The amplifier must calibrated to 0 in a voltage-free state to avoid a collapse of the output voltage.

• Select the amplifier settings as follows:

Input: Low Drift

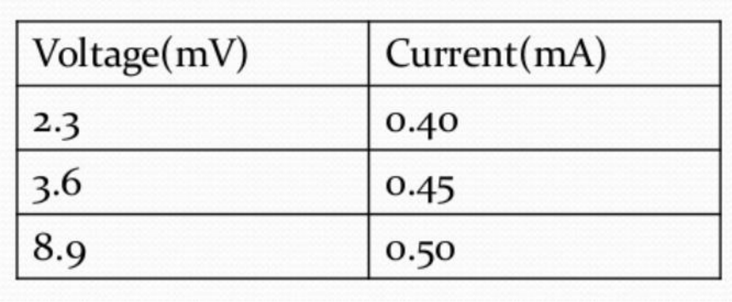
Amplification: 104

Time Constant: 0

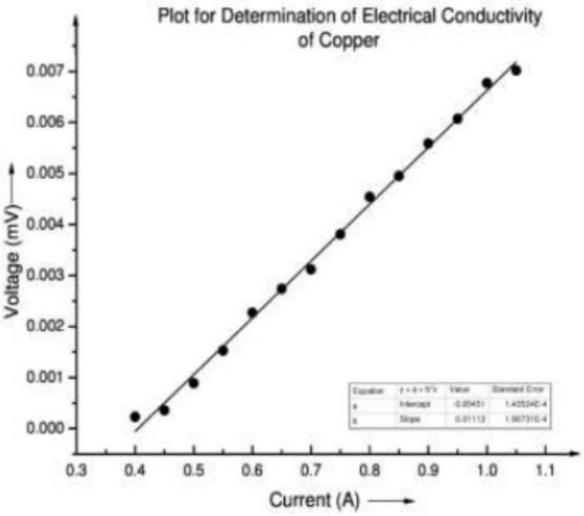
- Set the rheostat to its maximum value and slowly decrease the value during the experiment.
- Read and note the values for current and voltage
- The resistance, and thus the electrical conductivity, can be determined from the measured values.

Data Collection:

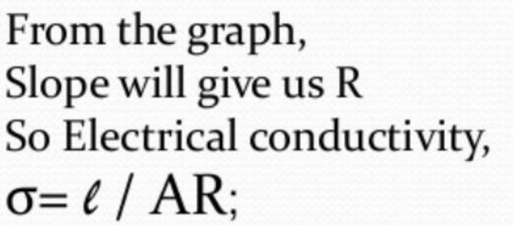
For copper;



Voltage(mV)	Current(mA)
2.3	0.40
3.6	0.45
8.9	0.50



Calculation:



From the graph,
Slope will give us R
So Electrical conductivity,
$\sigma = \ell / AR$;

Electrical concuctivity;

$\sigma = 1/\rho$

ρ= Resistivity

Result:

Benefits
- Easy and precise measurement of the electrical conductivity

Compact, easily transportable setup