Experiment No. 5
Resistivity And Temperature Coefficient of Resistivity

by Dr. E. M. Levin

Objective:

(a) To determine the resistivity of tungsten and to verify that resistivity is an intrinsic property of a material.

(b) To determine the temperature coefficient of resistivity of tungsten.

Apparatus:

25-, 40-, 60-, 75- and 100-watt incandescent lamps, a variable transformer (variac), 2 multimeters, lamp socket and connecting wires.

The filament of an incandescent lamp appears to be a simple coil to the naked eye. However, a closer look at reveals that the filament is a coiled coil. The thin filament is wound into the form of a thin coil and then a wider coil is made from the thinly coiled filament.

Theory:

The resistance R of a metal wire of length L and area of cross section A is given by

$$R = \rho \frac{L}{A} \qquad (1)$$

Here r is the resistivity of the material of the wire.

It should be noted that resistivity does not depend on the geometry (length or diameter of the wire). It only depends on the material of which the wire is made. Thus resistivity is called an intrinsic property of the material. As opposed to an intrinsic property, there are extrinsic properties which depend on the geometry of the sample.

Eq. (1) gives $\rho = R \frac{A}{L}$. Thus MKS units of ρ are ohm-m.

The resistivity ρ of a material strongly depends on the temperature. In general, it increases with temperature. Let ρ and ρ_o be the resistivity of a material at temperatures T and T_o, respectively. Over a moderate range of temperature,

$$\rho = \rho_o [1 + \alpha (T - T_o)] \qquad (2)$$

Here α is defined as the temperature coefficient of resistivity.

It should be remarked that Eq. (2) holds for moderate ranges of temperature. If the temperature range is large, higher order terms have to be considered.

For a given wire, R is directly proportional to r. Thus, from Eq. (2), we get

$$R = R_o [1 + \alpha (T - T_o)] \qquad (3)$$

Here R and R_o are the resistances of the wire at temperature T and T_o, respectively.

Solving for the temperature coefficient of resistivity, we get

$$\alpha = \frac{[R - R_o]}{[R_o(T - T_o)]} \qquad (4)$$

The temperature coefficient of resistivity of tungsten near room temperature is 0.0045 per C^o.

Procedure:

Unit 1: Determination of the resistivity of the material of the lamps at room temperature:

(a) Use the multimeter to measure the resistances of the lamps directly (without connecting them into the circuit).

(b) Record the room temperature.

Unit 2: Determination of the temperature coefficient of resistivity:

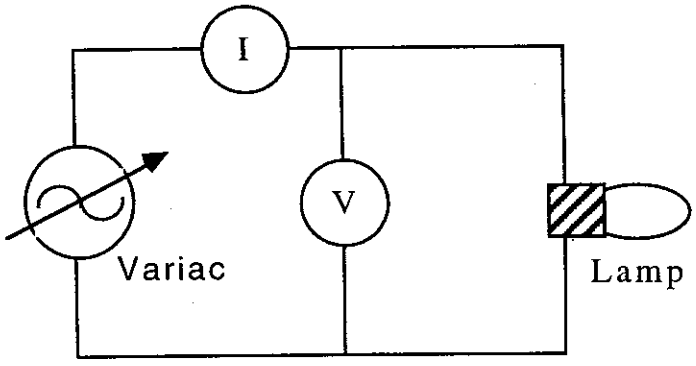

Fig. 6.1. An incandescent lamp powered by a variac.

(c) To measure the resistances of the filaments of the lamps at high temperatures (when they are connected in the circuit), we apply Ohm's law. Set up the circuit as shown in Fig. 1 including the 25-watt lamp in the circuit. Note that the multimeter measuring the current should be set to read AC current and that measuring the voltage, to read AC volts. Let your instructor check the circuit and then switch on the variac.

(d) Remember that the variac can supply voltage from 0 to 140 volts. The higher the voltage applied, the greater the power supplied which raises the temperature of the filament, and its brightness. Adjust the output voltage of the variac to 120 volts. Measure the current in the filament.

(e) Repeat the procedure with lamps of power 40, 60, 75 and 100 watts adjusting the output voltage of the variac to 120 V.

Follow the instructions contained in the data sheet for calculations and for plotting graphs.

York College of The City University of New York

Physics II Name:

Experiment No. 5: Pre-Lab Questionnaire

1. The resistivity depends on _____

   and _____ but it does not depend

   on _____.

2. Equation $\rho = \rho_o [1 + \alpha (T - To)]$ can be applied if

3. In this experiment, the resistances of the filaments of lamps at the operating temperatures are determined by

4. In this experiment, the variac is used for

Experiment No. 5

Name: Marks:

Partner: Remarks:

Section:

Date Submitted:

Title:

Objective:

Theory/Formulas:

Experiment No. 5
DATA SHEET

Observations:

Unit 1: Determination of resistivity at room temperature:

Room Temperature =

Filament Data Table

[R_o (MM) is the resistance measured by using the multimeter.]

Lamp Wattage	Operating Temperature (T in C^o)	Length of uncoiled filament (L in m)	Area of cross-section (A in m^2)	R_o(in ohm) (MM)
25	2290	0.56	7.00×10^{-10}	
40	2470	0.38	8.56×10^{-10}	
60	2550	0.53	1.60×10^{-9}	
75	2600	0.55	2.23×10^{-9}	
100	2650	0.58	3.17×10^{-9}	

Unit 2: Determination of current at operating temperature:

Lamp Wattage	Voltage Applied (V)	Current (A)
25	120	
40	120	
60	120	
75	120	
100	120	

Calculations:

Unit 1: Determination of resistivity at room temperature:

Lamp Wattage	Length of uncoiled filament (L in m)	Area of cross-section (A in m^2)	R_o(in ohm) (MM)	Resistivity ρ (in ohm-m)
25	0.56	7.00×10^{-10}		
40	0.38	8.56×10^{-10}		
60	0.53	1.60×10^{-9}		
75	0.55	2.23×10^{-9}		
100	0.58	3.17×10^{-9}		

Average, resistivity, ρ_m =

Percent error in ρ =

(The percent error is meaningful only if it is less than 20%)

Use the formula given on page Intro-4 of the Lab Manual to calculate the standard deviation.

No. (i)	ρ_i	$(\rho_i - \rho_m)$	$(\rho_i - \rho_m)^2$
1			
2			
3			
4			
5			

Standard Deviation in ρ =

Plot a graph of R against wattage on a linear graph paper.
Is resistance an intrinsic variable? Explain.

Plot a graph of ρ against wattage on a linear graph paper.
Is resistivity an intrinsic variable? Explain.

Unit 2: Determination of temperature coefficient of resistivity:
Use values of R_o from unit 1 to calculate α.

Lamp Wattage	V (volt)	I (amp)	Power V I (watt)	Resistance at operating temperature (R)	Temperature Coefficient (α) in $(C^o)^{-1}$
25					
40					
60					
75					
100					

Average value of α =

Percent error in α =

Questions:

1. What is meant by an intrinsic variable? An extrinsic variable?

2. Define resistivity. In some cases, the experimental value of resistivity differs from the standard value considerably. Why?

3. What is meant by temperature coefficient of resistivity?

4. Do the experimental values of power supplied agree with the rated wattage of the lamps? Explain your answer.