LAB NUMBER 3

ELECTRICAL RESISTANCE AND RESISTIVITY

INSTRUCTIONS FOR EXPERIMENTS

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DISCUSSION ON ELECTRICAL PROPERTIES OF MATERIALS

DEFINITIONS AND RELATIONSHIPS

CONDUCTIVITY, σ, AND RESISTIVITY, ρ, ARE RELATED AS

$$\sigma := \frac{1}{\rho}$$

RELATIONSHIP BETWEEN RESISTANCE (R), VOLATAGE (V), AND CURRENT (i) IS

```
R =V/i
```

WE HAVE THE RELATIONSHIP BETWEEN THE RESISTIVITY, ρ, RESISTANCE, R, CROSS SECTION AREA, A, AND LENGTH, L, AS

$$\rho \text{ =R*A/L}$$

SUBSTITUTING FOR R FROM ABOVE, WE GET

$$\rho := \frac{V\,A}{i\,L}$$

VARIATION OF RESISTIVITY WITH TEMPERATURE - TWO TEMPERATURES T1 AND T0

$$\rho 1 := \rho 0 + \alpha\,(T1 - T0)$$

CROSS SECTIONAL AREA , A , OF A WIRE IS GIVEN BY

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A =Pi*d^2 /4
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U_A = **2 x Ud**

where d is the diameter of the wire. Suppose `d =0.000394`

Res_d (Resolution of d in meters)
= 0.002 in mm (the smallest Vernier Reading in mm) /1000

$$Res\_d := 0.200000000\,10^{-5}$$

Then,

Ud =Res_d/d

$$Ud := 0.005076142132$$

Coming back to the equation

$$\rho = R*A/L$$

we can write in terms of associated uncertainties

$$\rho \angle U\rho = (R \angle U_R)\ (A \angle U_A)\ /(\ L \angle U_L)$$

$$= (R\ A\ /L\ ) \angle (U_R + U_A + U_L)$$

We can also write

$$U_A = 2x\ Ud$$

$$U_L = Res\_L/L$$

$$U_R = Res\_R/R$$

In the TABLE 2A we have

Res_d = 2x10^(-6)

Res_L =5x10^(-5)

Res_R = 0.1

$$U\rho = (U_R + 2U_d - + U_L)$$

If we use R = 3.1 ; d = 1.98 x 10^ (-4) , and L = 6.04 then We get

$$\rho = (\ 3.1416*d^2*R\ )/(4*L)$$

$$\rho := 0.158031993\,0\,10^{-7}$$

then we will get

U_R =Res_R/R; Ud = Res_d/d; UL = Res_L /L;

$$UR := 0.03225806452$$

$$Ud := 0.01010101010$$

$$UL := 0.827814569\,5\,10^{-5}$$

Now, we can calculate

$$U\rho = (U_R + 2U_d + U_L)$$

$$Urho := 0.05246836287$$

$$\rho\_max = \rho + (\rho * U_\rho) = 0.166323673010^{-7}$$

$$\rho\_min = \rho - (\rho * U\rho) = 0.149740313010^{-7}$$

In Lab 3 , the formulas are given in the Tables, and you are asked to perform one set of sample calculations for copper only

EXPERIMENTAL MEASUREMENTS

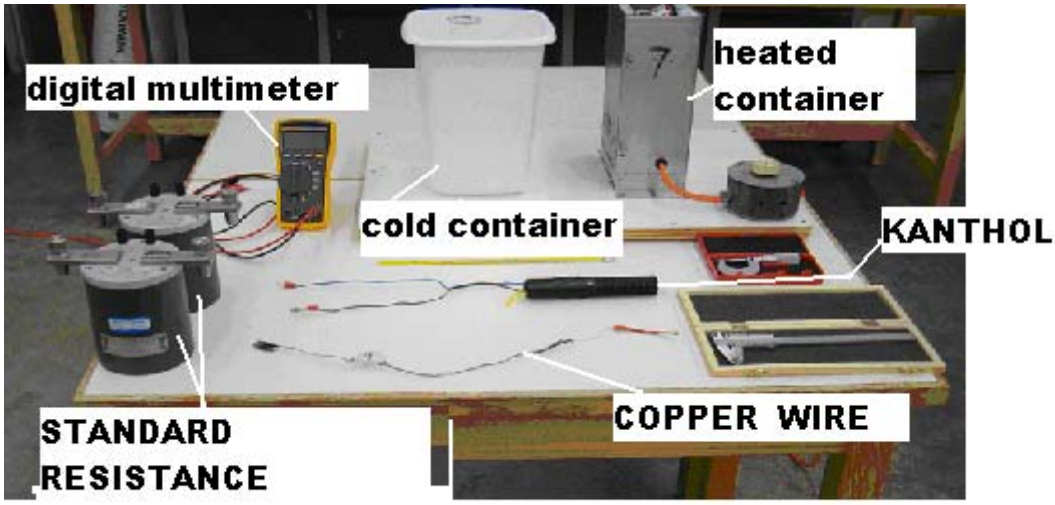


FIG. 1 VARIOUS ITEMS USED IN THE EXPERIMENT

NO 1

CALIBRATION OF DIGITAL MULTIMETER

Fig. 1 shows various items used in the experiment. The digital multi meter is calibrated by measuring the resistances of two standard resistances having value of 10 ohms and 1 ohm . Suppose the 10 ohms resistance is shown as 10.2 ohms then the offset is 0.2 ohms, and it has to be subtracted FROM 10.2 .

TABLE 1
CALIBRATION CORRECTION OF MEASURED RESISTANCES

RESISTOR	MEASURED VALUE	CORRECTION	CORRECTED VALUE TO BE ENTERED IN THE SPREADSHEETS
1 OHM	1.1	-0.1	1
10 OHMS	10.1	-0.1	10
KANTHAL (T1)			
KANTHAL (T2)			
KANTHAL (T3)			
COPPER (T1)			
COPPER (T2)			
COPPER (T3)			

NO 2

COPPER WIRE MEASUREMENTS

The details about the copper wire are shown in Fig. 2.

(A) The portion having copper winding is immersed in a tube containing paraffin (shown in Fig. 3) which is immersed in the hot container shown in Fig. 1.

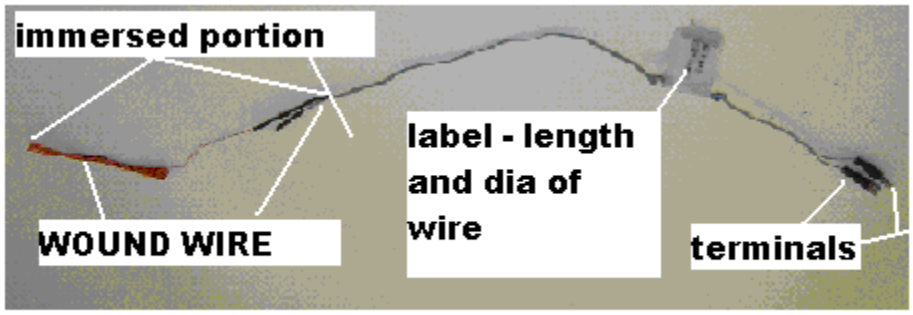


FIG. 2 COPPER WIRE

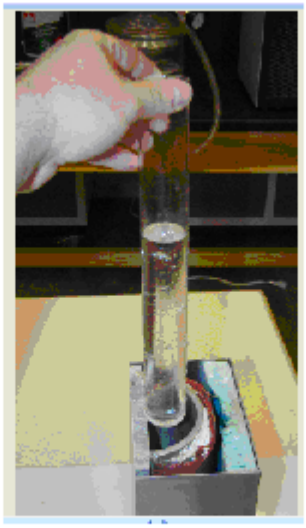


FIG. 3 THE TUBE CONTAINING PARAFFIN BEING IMMERSED IN THE HOT CONTAINER

(B) The steady state temperature of the paraffin bath is measured with a thermometer which has smallest reading of 1 degree C.

(C) The resistance of the copper at **Room Temperature** is measured, and calibration correction is applied **AS DONE IN TABLE 1**

(D) The resistance of the copper in the heated state is measured, and calibration correction is applied.

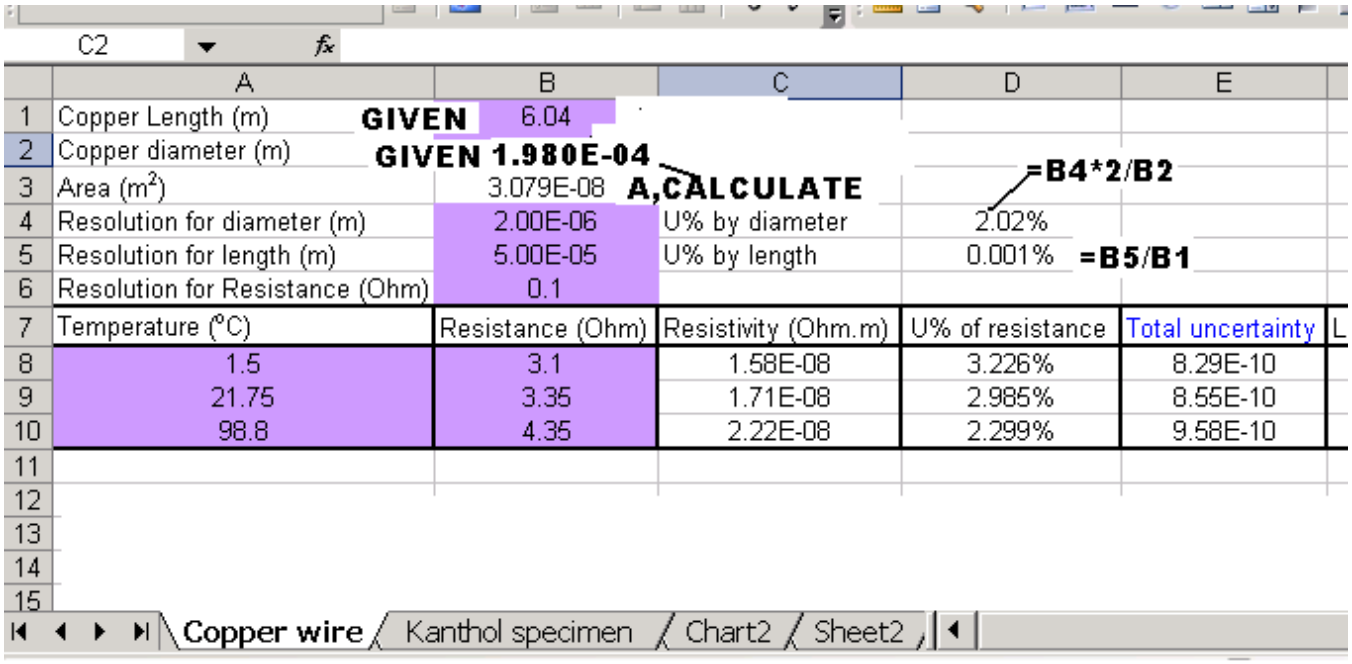
(E) The resistance of the copper in the cold state is measured, and calibration correction is applied.

All the temperatures as well as three values of resistances , after applying the calibration corrections, are entered in A8, A9, and A10 as well as B8, B9, and B10 respectively (see the Figure below).

(F) The length and diameter of the copper wire is noted from the label shown in Fig. 2. The values of length and diameter are entered in B1and B2 respectively.

(G) Fill in the resolution values in B4 (micro meter resolution) , B5 (Vernier Caliper resolution) , and B6 (thermometer resolution) .

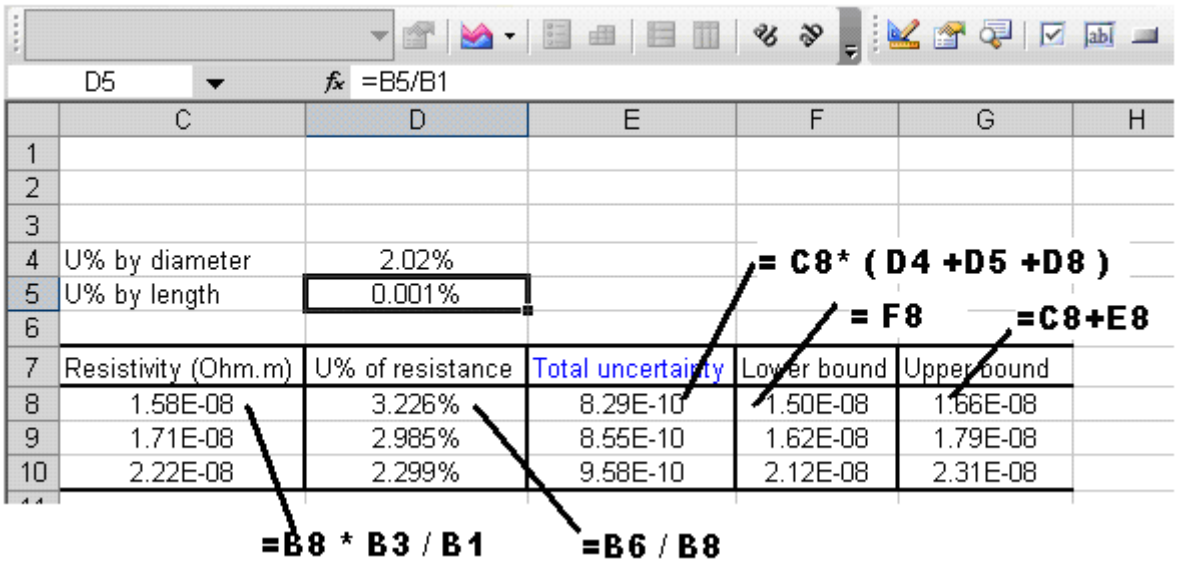
TABLE 2A



	A	B	C	D	E
1	Copper Length (m)	GIVEN 6.04			
2	Copper diameter (m)	GIVEN 1.980E-04			
3	Area (m^2)	3.079E-08	A,CALCULATE	=B4*2/B2	
4	Resolution for diameter (m)	2.00E-06	U% by diameter	2.02%	
5	Resolution for length (m)	5.00E-05	U% by length	0.001%	=B5/B1
6	Resolution for Resistance (Ohm)	0.1			
7	Temperature (°C)	Resistance (Ohm)	Resistivity (Ohm.m)	U% of resistance	Total uncertainty
8	1.5	3.1	1.58E-08	3.226%	8.29E-10
9	21.75	3.35	1.71E-08	2.985%	8.55E-10
10	98.8	4.35	2.22E-08	2.299%	9.58E-10

Copper wire | Kanthol specimen | Chart2 | Sheet2

TABLE 2B



	C	D	E	F	G	H
1						
2						
3						
4	U% by diameter	2.02%				
5	U% by length	0.001%				
6						
7	Resistivity (Ohm.m)	U% of resistance	Total uncertainty	Lower bound	Upper bound	
8	1.58E-08	3.226%	8.29E-10	1.50E-08	1.66E-08	
9	1.71E-08	2.985%	8.55E-10	1.62E-08	1.79E-08	
10	2.22E-08	2.299%	9.58E-10	2.12E-08	2.31E-08	

= C8* (D4 +D5 +D8)

= F8

=C8+E8

=B8 * B3 / B1

=B6 / B8

(H) Check the plots

SAMPLE CALCULATIONS

Perform sample calculations

(1) D4, D5 , C9, D9, E9 , F9, and G9 based on the formulas shown in Tables

NO 3

KANTHAL WIRE MEASUREMENTS

The details about the Kanthal wire are shown in Fig. 4

(A) Measure d_h and pitch p using Vernier Caliper and compute d_c using formula in Fig. 4

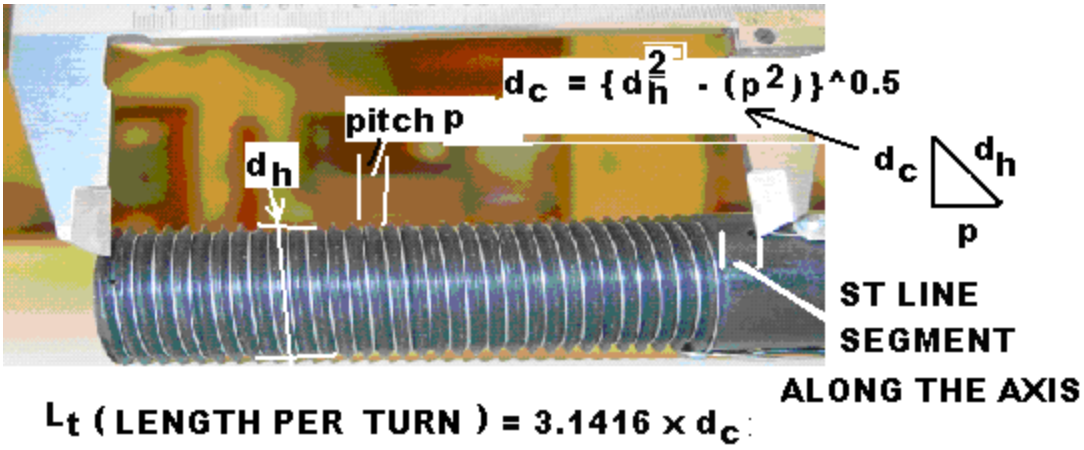


FIG. 4 MEASUREMENT OF TOTAL LENGTH OF KANTHAL

Length Per Turn is given by L_t above . This is just for interest, -- **Not entered in the calculations in the spreadsheet .**

Total Length L = N x Lt + Extra Length (Straight Line Segments) --- **Not for entering in the spreadsheet.**

(A) Count the number of Turns N

(B) Enter

N (B1),

d_c as per the formula given in Fig. 4 and enter as (B2), and

Straight Line Segment as shown in Fig. 4 as (B3)

(F) Make electrical measurements at the three temperatures and enter as A11, A12, and A13 as well as B11, B12, and B13.

(G) Compute Cross Sectional Area A of the Kanthal Wire

A = 3.1416 x d^2 / 4 ; Enter the value of A in B6

TABLE 3

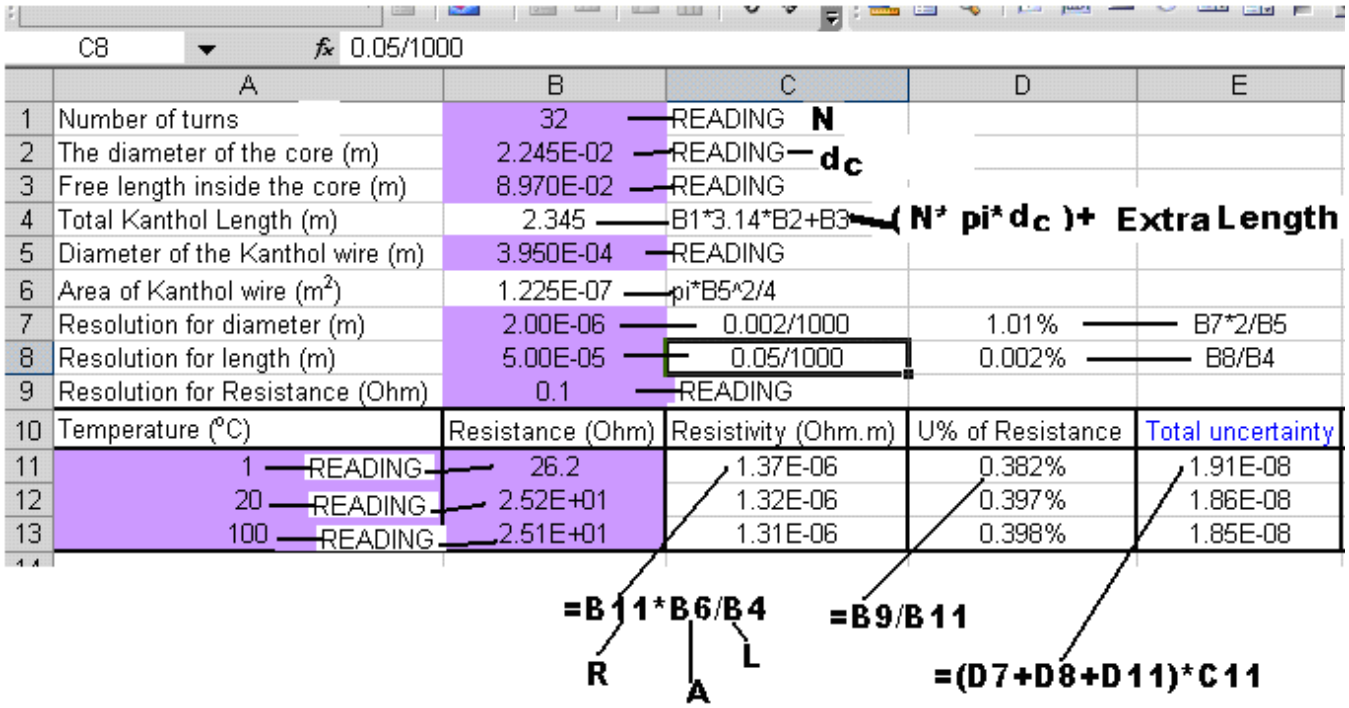
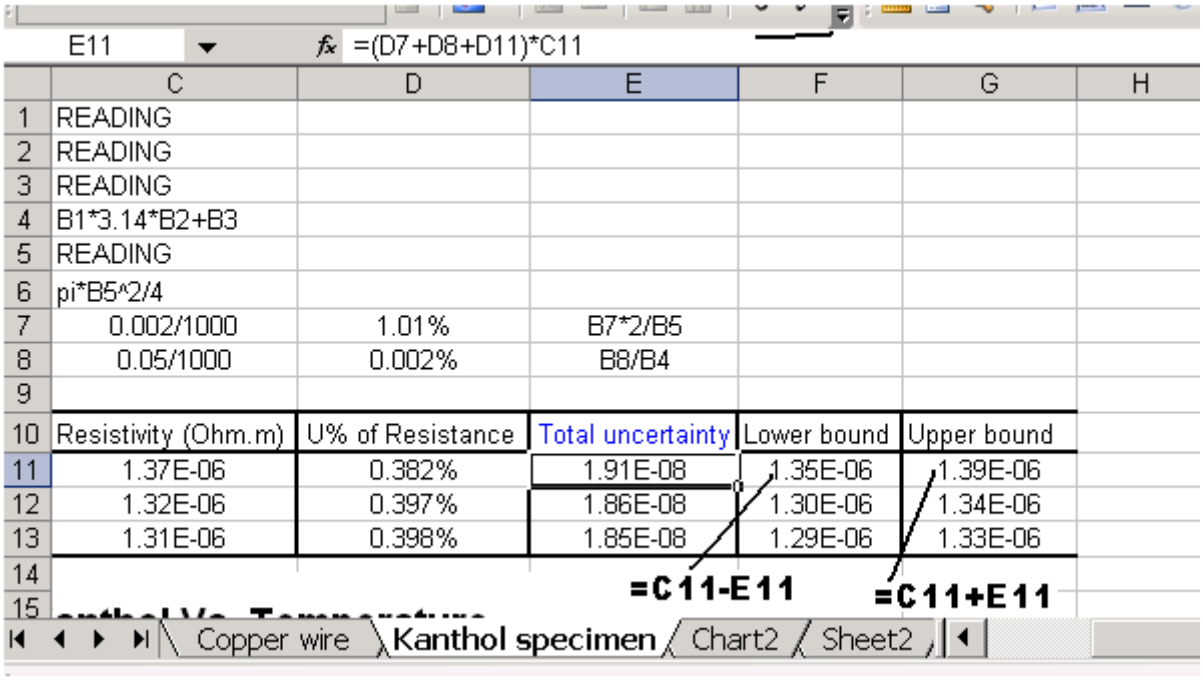


TABLE 4



NO 4

Plot the results for Kanthal just like Copper

NO 5

Discuss the results for the two resistors separately.

NO 6

Write Conclusions

NO 7

Write Sources of Errors.