 Name Hayden Fuller Section 6

25E – Experiment: Temperature Dependence of Resistance

The resistivity of metals can be experimentally represented with the relation: $\rho(T) = \rho_0(1 + \alpha(T - T_0))$ where ρ_0 is the resistivity at a reference temperature (T_0 usually 0° C) and α is the coefficient of resistivity. The resistivity of metals varies from 1.47x10^{-8} $\Omega \cdot$ m for pure silver to 100x10^{-8} for an alloy such as nichrome. The temperature coefficient of resistivity for metals is small, varying from 4x10^{-3} for pure silver to 4x10^{-4} for nichrome.

The resistance of semiconductors and insulators can vary tremendously with temperature, depending on doping levels and device configuration. For the experimental configuration we will have you measure, the resistance is expected to vary exponentially with temperature ($R \propto e^{E_a/kT}$).

Equipment: DMM; DC Power Supply; Wire Wound Resistor (~70 ohms); Diode; 3 Banana Wires; 2 Alligator Clips; Cup with Ice-Water (made by adding ice to room temperature water); Cup with hot water; Cup with Liquid Nitrogen

RESISTOR

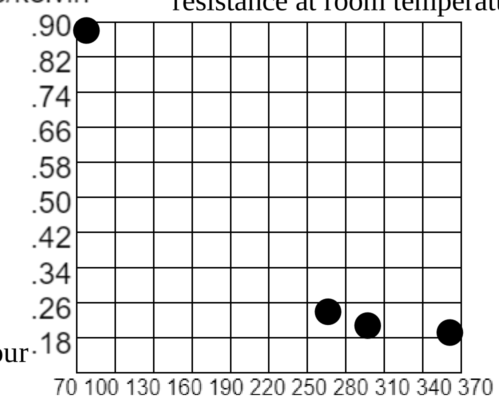
RESISTOR MEASUREMENT

- Clip the alligator connectors to the two ends of the resistor and wire it to the DMM with banana wires. Use the Ohmmeter setting on the Digital Multimeter to directly measure the resistance of the resistor. Make sure you have plugged the banana wires into the correct inputs on the DMM. This is your room temperature measurement. Enter it into the table on the next page.
- Dip the resistor in hot water (~360K) and record the resistance in the table below.
- Dip the resistor in ice water (~273K) and record the resistance.
- Dip the resistor in liquid nitrogen (77K) and record the new voltage and current.
- Turn the voltage down to zero and allow the resistor and clips to warm to room temperature.
- Plot the ratio of the resistor resistance at each temperature to the resistor resistance at room temperature here.

T(K)	Resistor Resistance
293 (Room T)	69.5
360 K (Hot water)	69.5
273 (Icewater)	69.4
77 (Liquid N_2)	67.9

0.237
0.193
0.254
0.882

Ratio ohms/kelvin



Temperature Kelvin

Estimate the coefficient of resistivity for the metal in your resistor from your plot. $\alpha =$__________

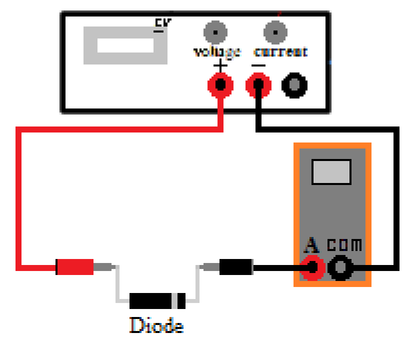
Is your estimate of α consistent with approximate values given in Table 25.2 of your textbook?

SEMICONDUCTOR DIODE MEASUREMENT

NOTE THAT THE DIODE HAS A NONLINEAR RELATIONSHIP BETWEEN VOLTAGE AND CURRENT. FOR THIS EXPERIMENT, KEEP THE DIODE VOLTAGE CONSTANT ONCE YOU HAVE CHOSEN IT.

Wire the power source, ammeter, and diode in series.

DC power supply: Connect red to + and black to -

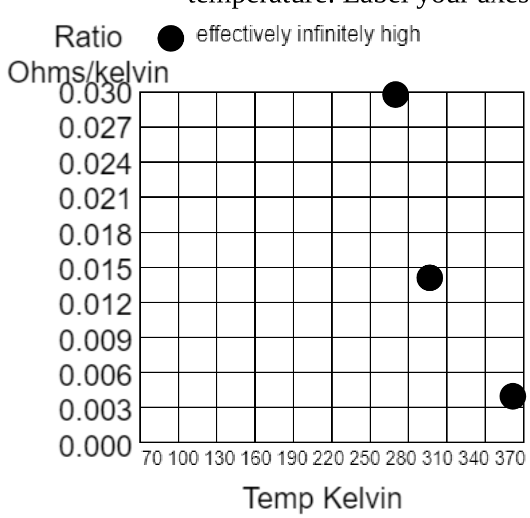


- Dial the potential up to about 0.7 V. If there is no current, then switch the direction of the diode in the circuit. (Diodes conduct well when the potential is applied in one direction and poorly in the other.)
- Vary the applied voltage until the current is about 0.1A – read this from the ammeter (three decimal places) at ROOM temperature. You should not have to exceed 1 V to get this current.
- Record the current and voltage. <u>Keeping the voltage "*constant*"</u>, dip the diode first in HOT water and then in ICE water and finally in liquid nitrogen. Record the current and voltage for each temperature.

1) Place measurements in the table below.

TEMPERATURE	**DIODE**			
T(K)	Diode Voltage	Diode Current	Diode Resistance	
293 (Room T)	.73	.171	4.269	.01457
360 K (Hot water)	.73	.513	1.423	.00395
273 (Icewater)	.73	.090	8.111	.02971
77 (Liquid N_2)	.73	.000	undefined effectively infinite	Infinite

2) Plot the ratio of the resistance of the diode at each temperature to the resistance of the diode at room temperature. Label your axes appropriately.



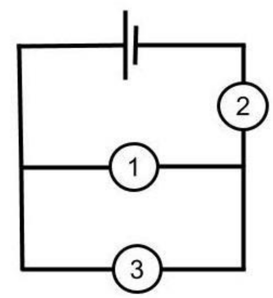
3) Is your observation consistent with the sketch in Figure 25.6b of your textbook? (Answer with an explanatory sentence, not just a yes or no.)

Yes, they both show resistance decreasing as temp increases

25F – Experiment: Ohmic and Non-Ohmic Resistors

Objective: Quantitatively observe ohmic and non-ohmic behavior in various devices.

You will work through two video demonstration experiments in Mastering Physics Chapter 25. Their links are:
1) Direct Measurement Video: Current Voltage Relationship in a Copper Wire,
https://mediaplayer.pearsoncmg.com/assets/_frames.true/secs-iv-copper-wire .
2) Direct Measurement Video: Current Voltage Relationship in a Light Bulb Filament,
https://mediaplayer.pearsoncmg.com/assets/_frames.true/secs-iv-filament .



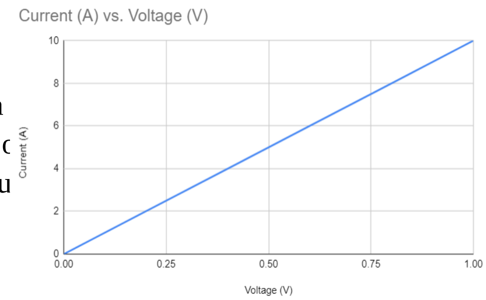
1) You have a battery, a resistor, an ammeter, and a voltmeter and want to arrange them in a circuit to measure the resistance of the resistor. How should the resistor, ammeter, and voltmeter components be arranged in the circuit to the right? Note there is more than one way to do this. Just give us one.
   - Resistor = #_3_
   - Ammeter = #_2_
   - Voltmeter = #_1_
2) View the video "Current Voltage Relationship in a Copper Wire" (see box above). Is the electrical circuit shown in the video of the experiment consistent with your answer to question 1?

3) From the video, record the current and voltage for five different voltage-current pairs, with the voltage ranging from 0.1 V to 1 V. Transcribe that data into the table below.
4) View the video "Current Voltage Relationship in a Light Bulb Filament" (see box above). Record the current and voltage for five different pairs with the voltage ranging from 0 to 10 V.

Copper Wire Potential Difference (V)	Current (A)	Resistance (ohm)
0	0	NA
.2	2	.1
.4	4	.1
.6	6	.1
.8	8	.1
1.0	10	.1

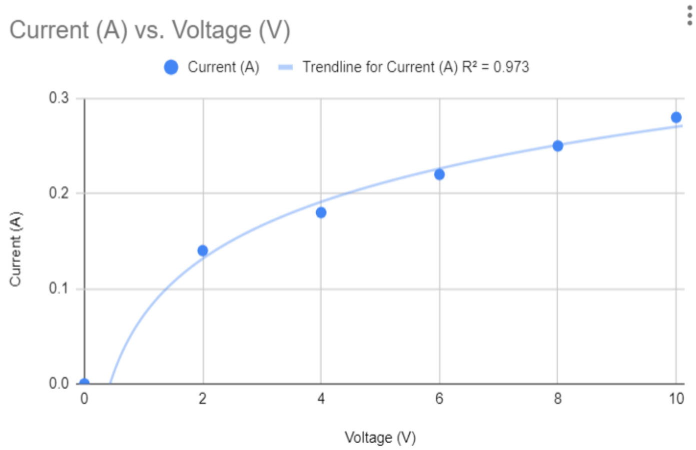
Light Bulb Potential Difference (V)	Current (A)	Resistance (ohm)
0	0	NA
2	.140	14.28
4	.180	22.22
6	.220	27.27
8	.250	32.00
10	.280	35.71

Name Hayden Fuller Section 6



5) Make a plot of your current-voltage data for the copper wire. (Excel or a a good tool for this. If you are unfamiliar with its use, refer to the Notes c the program to fit a line through your data. Paste your plot into this docu

6) Make a plot of your current-voltage data for the light bulb. (Excel or a similar online version is a good tool for this.) Allow the program to fit a line through your data. Paste your plot into this document here.



7) Do the measured data points vary by more than the larger of a measurement significant digit (0.01 V or 0.001 A) or few percent from the line? If not, your device is experimentally Ohmic. If your data vary systematically from the line, the device is not Ohmic. Wire is ohmic, bulb is not

a) Is the copper wire Ohmic over the range measured? Explain how you concluded this.

Yes, it has a linear relationship between V and I is linear with slope 1/R

b) Is the light bulb Ohmic over the range measured? Explain how you concluded this.

No, it is not a linear function.

c) It is likely that you have found that the light bulb is not Ohmic. Propose an explanation for why this is the case.

The filament heats up with increased voltage, leading to increased resistance, and decreased current

.250

8) **<u>Optional 3 extra credit points</u>**: perform actual resistor and light bulb voltage-current experiments, like the ones seen in the videos using actual lab room equipment: metal wound resistor, DC power supply, banana wires, alligator clips, and a digital multimeter (DMM). Using these items, set up two circuits like that shown in the figure on page 2 (Module 25E) of this lab activity. **Note: for both circuits, do not touch the resistor or the lightbulb when a current is flowing in the circuit. They will get hot while a current passes through them.**

a) In the first circuit, replace the diode with the metal wound resistor, and use the DMM to measure the current in the circuit for seven different power supply voltage settings between 0 and 15 V. Record your data in a table, like that shown on page 4, and plot the current vs voltage data for the metal wound resistor.

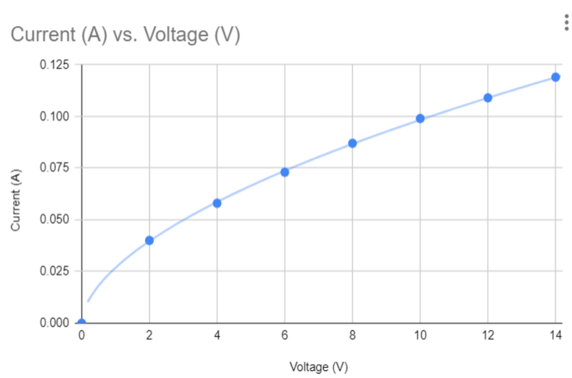
b) In the second circuit, replace the diode with the lightbulb and use the DMM to measure the current through the lightbulb for seven different power supply settings between 0 and 15 V. Record your data in a table, like that shown on page 4, and plot the current vs voltage data for the lightbulb.

c) How do your results in (a) and (b) compare to those of your video experiment analysis?

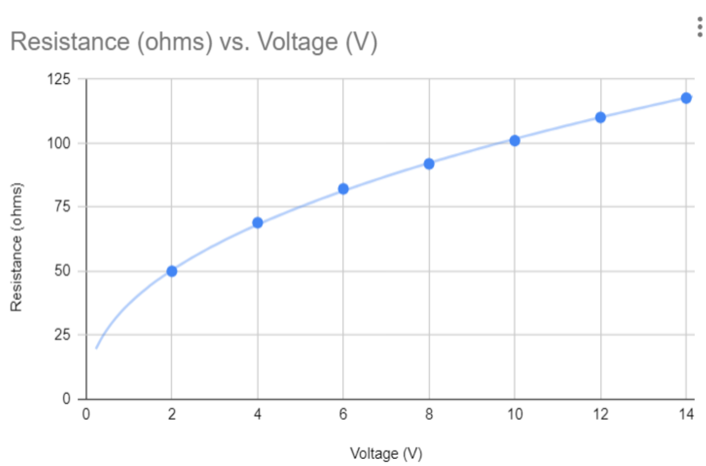
a) we don't have wire wound resistors and were told to skip this

b) light bulb

V=I * R
0 .000
2 .040
4 .058
6 .073
8 .087
10 .099
12 .109
14 .119



c) They give very similar results, non ohmic, resistance increases with voltage



 Name Hayden Fuller Section 6

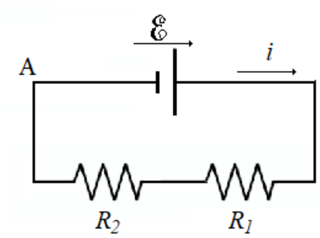
26A – Resistors in Circuits – Kirchhoff's Voltage Law and Ohm's Law

VOLTAGE RULE (LOOP RULE): The *algebraic* sum of changes in the electrical potential (ΔV_i) encountered in a complete traversal of any loop of a circuit must be zero (This rule follows from conservation of energy.)
Kirchhoff's Voltage Law is written as:

$$\sum_{i}^{n} \Delta V_i = 0$$

Ohm's law: $$\Delta V = i\,R$$

This activity will step you through the logic of why the resistance of two resistors in series is simply the sum of the resistances according to Kirchhoff's Rules.
Consider the circuit shown to the right.



1) Starting at point A (upper left corner of circuit) and going clockwise, one will use the loop equation (Kirchhoff's Voltage Law) for the sum of the potential changes, using V_1 for the potential change across R_1 and likewise for V_2 across R_2, in going around the loop. Assume that the conventional current flows clockwise as well.

   a) Write out Kirchhoff's voltage law for this circuit, starting at A and going clockwise. Use labels E, V_1, V_2

   -V(E)+V(R1)+V(R2) = -E+V1+V2 = 0

   b) Use Ohm's law to express the above voltages in terms of the current i and resistances R.

   -E+iR1+iR2 = 0

   c) Determine the current i in terms of the supply voltage $\mathcal{E}$, and resistors R_1, and R_2 by solving the potential *loop* equation.

   E=i(R1+R2) i = E/(R1+R2)

   d) Solve for the effective resistance of the two resistors together in terms of R_1 and R_2 by using $\mathcal{E}/i = R_{effective}$.

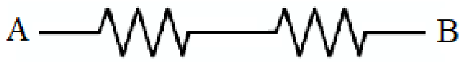
   $R_{effective}$ = R1+R2

A similar argument can be made to show that the effective resistance of resistors in parallel is given by $1/R_{eff} = 1/R_1 + 1/R_2$.

 Name Hayden Fuller Section 6

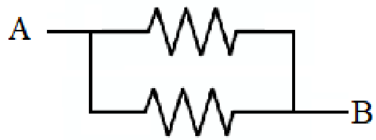
2) Solve for the equivalent resistance, R_{eq}, between points A and B in the following circuits. Assume all resistors have resistance of 100 ohms.

a)



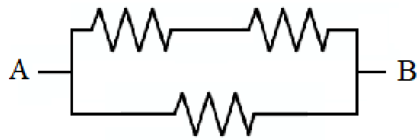
R_{eq} 200

b)



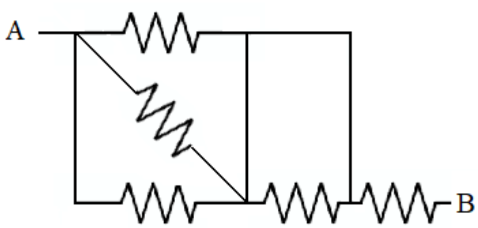
R_{eq} 50

c)



R_{eq} 75

d)



R_{eq} 133.33

e) Make a schematic for a circuit with resistance of 175 ohms using only 100 ohm resistors. Use fewer than 10 resistors if possible.