MSE170 U. Washington

Fundamentals of Materials Science

LAB I

WHAT IS IN IT AND WHY?

Study (Pre-Lab) Questions (Complete these BEFORE coming to lab, there will be Study/Pre-Lab Questions for each lab this quarter):

1. Make a list of 3 examples for each of the following material properties:
    1. Mechanical properties
    2. Electrical properties
    3. Optical properties
    4. Magnetic properties
    5. Thermal properties

2. Define the five types of properties listed above in **engineering terms**, using descriptive text and/or equations. Use the glossary and the index in the text to help you.

3. Postulate the most important properties needed for the selection of a material for a stair railing. Consider railings that may be in the following environments:
    1. in your home
    2. in a place of business
    3. outside

   How does **usage** change your list of most important properties? Using this information, develop a list of materials that you would choose for your railing for each of the environments specified. If you are sent out to build or buy these railings, what additional factors might you consider? How would these factors influence your choice of materials?

I. Introduction

All engineers are involved with materials on a daily basis. We manufacture and process materials; design and construct components or structures using materials; select materials, analyze failures of materials, or simply hope the materials we are using perform adequately. Materials may be classified into several groups: metals, ceramics, polymers, semiconductors, and composite materials. Materials in each of these groups possess different structures and therefore properties.

The purpose of this laboratory is to get you thinking about How? What? and Why? different materials are selected when designing a particular object common to our everyday lives. In this laboratory, you will disassemble a light bulb in order to understand why particular materials were selected for its various components. Since we will be examining the light bulb components from an engineering standpoint, we will want to consider the materials employed as they relate to the design and function of a light bulb. No materials selection decisions can be made without thorough consideration of the particular application of the material.

Therefore, we will want to understand the overall design of the object itself as well as the various materials used to make the object. Here, our aim is towards a more complete understanding of the engineering decisions that are part of the design process. It is with this in mind that you should approach your analysis during this laboratory.

There are two parts to this laboratory. In the first part, you will be measuring a material property for light bulbs. In the second part you will be disassembling and examining your light bulb. You should work together in groups with one light bulb per group. You should work cooperatively in your team during this lab; doing so will enhance your enjoyment and learning. The work in your lab notebook, however, should be your own.

PART I – MATERIAL BEHAVIOR OF A LIGHT BULB

I. Background and Theory

Ohm's law states that the voltage across a piece of material (such as a wire) is proportional to the current through the material:

$$V = I * R \qquad \text{[Eq. 1]}$$

Where:

- V is the applied potential field – voltage (volts - V)
- I is the flow of electrons – current (Amps - A)
- R is the resistance of the piece of material (ohms – Ω).

R is a constant if the temperature of the conductor remains constant. If the temperature increases, the resistance increases for a metal and it decreases for a semiconductor. The increase in R for a metal is due to an increase in vibrations scattering the electrons which are the current carriers. For many metals R increases linearly with temperature.

In the case of a light bulb, the resistance of the tungsten (W) used for the filament varies with temperature according to the following relation:

$$\frac{T}{300} = \left[\frac{R(T)}{R(300)}\right]^{0.811} \qquad \text{[Eq. 2]}$$

In this equation T is the absolute temperature in Kelvin (K), and room temperature is assumed to be 300 K. R(T) is the resistance at the temperature T. R(300) represents the resistance at ambient room temperature. The absolute temperature in K is related to the temperature in C by the following relationship:

$$T(K) = T(C) + 273.15 \quad \text{[Eq. 3]}$$

Equation 1 holds very well over a wide range of temperatures from 300 K up to 3680 K (the melting point of tungsten) but it does not work for temperatures below 300 K. The maximum useful filament temperature is about 3000 K which is limited by the vaporization pressure of tungsten.

Household light bulbs are rated in power units of Watts. In general the electric power P delivered to a circuit can be expressed as:

$$P = I * V \quad \text{[Eq. 4]}$$

Where
- I is the current in the circuit (A)
- V is the potential difference across that circuit – voltage (V)

When the light bulb is in a steady state, the power furnished by electricity is radiated away according to the **Stefan-Boltzmann law**:

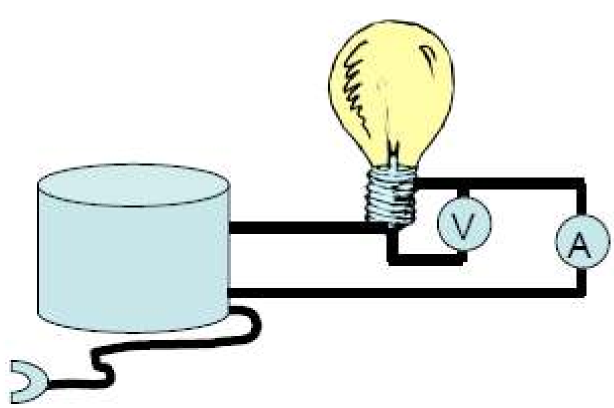
$$P_{in} = P_{out} = A * T^4 \quad \text{[Eq. 5]}$$

Where
- P_{in} is the power into the light bulb
- P_{out} is the power emitted from the light bulb
- A is a constant of proportionality
- T is the temperature (K)

The power is emitted as electromagnetic radiation by the vibrating electrons in the filament, and occurs in the visible and infrared part of the spectrum.

II. Experimental

Equipment:
We will manually create a circuit which duplicates the following sketch, using an AC-variac, an AC volt meter, an AC current meter, and mounted light bulb.



Procedure:

1. Using the digital multimeter (DMM) set to measure resistances, find the resistance of the cold (at room temperature) filament of the bulb.

2. Apply small voltage to the light bulb. Measure the voltage drop across the filament and measure the current passing through the filament. Compute the resistance using Eq. 1.

3. Compare the resistance values obtained from 1 and 2.

4. Gradually bring up the variac voltage, so that the light bulb starts to produce light. Measure the voltage and current at 20 different lighting conditions, spanning 20V to a maximum of 95V. Use the table below as a guide, but keep your data in your lab notebook.

Run #	Current (I)	Voltage (V)	Resistance (Ω)	r = R(T)/R(300)	T(K) = 300* $r^{0.811}$	P = I*V	$T(K)^4$

   a. Compute r = R(T)/R(300), then calculate T(K)
   b. Calculate power in the second to last column
   c. Calculate $T(K)^4$ in the last column
   d. Plot Power versus $T(K)^4$. Does the data follow a straight line or not?

PART II – DISASSEMBLY OF A LIGHT BULB

I. Introduction
In this part of the lab you will be disassembling and examining/documenting a light bulb. Over the course of this process, examine each component to determine its purpose, material, properties, and fabrication method.

II. Experimental Procedure:

1. **Always wear your safety glasses** when you or anyone near you is working to disassemble a light bulb.

2. First, make an engineering sketch of the assembled light bulb in your note book clearly numbering each component. Compose a table of each of the components: number, name, material, properties, and processing method. You should have a minimum of 10 components in this table.

3. If you are unclear about processing methods, discuss this in your group and use your text book for definitions such as rolling, forging, casting. You should be specific in your material descriptions, rather than "metal" is it stainless, or aluminum, or… Rather than "plastic" is it nylon, or rubber, or…Be specific about your material properties such as electrical, thermal and mechanical, each of those covers a very wide range of qualities. Again, work together, and your textbook may also be able to help you.

4. Begin to disassemble your team's light bulb to get a better look at the components on the inside of the light bulb. This may provide more insight of components' shape, type of material, and orientation to other components. **Wear gloves when breaking the glass portion of the light bulb and be careful not to cut yourself.** After inspecting the inside of the light bulb, make any changes to your drawing/table.

PART III – REPORT FORMAT AND GRADING CRITERIA

1. Your INFORMAL write-up for this lab should consist of ONLY these things:
   a. 1-2 paragraphs discussing the following (use these questions to form your paragraphs but do not simply number and answer the questions):
      i. Based on your measurements what was the temperature of the filament for a working light bulb?
      ii. Did the experiment confirm that the power radiated away from the light bulb is proportional to the fourth power of temperature? Be sure to include an excel plot to support your statement (and a raw data table in an Appendix if you wish)
      iii. Why do light bulbs have vacuums?
      iv. Make some general comments about what type of light bulb components utilize metals vs. ceramics/glass vs. polymers and what properties make these general classes of materials optimal for those components (less than 150 words)
   b. Drawing of the light bulb
      i. Copy/scan it from your lab notebook and tape or paste into your report
      ii. Neat and readable, does not need to be perfect
      iii. Contains numbers corresponding to table
   c. Table of light bulb components
      i. At least 10 components numbered, named, material stated, properties qualified and related to function, processing attempted

2. Point Breakdown (40 total pts)
   a. Paragraphs (20pts)
   b. Drawing (10pts)
   c. Table (10pts)