Thoughts: You may use ONLY those materials you submitted to me (that I will return to you). You may NOT use any other material, including others in the class or their work. I typically deal very harshly with cheating. Use sunscreen. I am happy to clarify a question and to help you find some obscure fact (mass of the Earth) or obscure formula (area of a sphere) – but NOT things you should have learned from the class: (e.g., Ohm’s law). I won’t help you do the test (i.e., don’t ask me whether or not you need to know the area of a sphere - you’re supposed to know what you need). There are exam questions that involve working with the equipment - if everybody saves those for the end, then everybody will wind up waiting for the person before you. So don’t save them for the end. Do your own work. Relax. Trust me on the sunscreen.

1. Using the voltmeter and battery provided, find the potential difference provided by the two poles of the battery. Draw a simple sketch of the battery and indicate which side is at a higher potential. Indicate the direction and magnitude of the electric field created by the battery.

It’s easy enough to confirm that the Front \( \equiv \) Back are equipotential surfaces.

Potential DIFFERENCE is between front \& back (round) surfaces.

- \( \Delta V = 3.10 \text{V} \) (\( + \) side is at higher voltage)
- \( \Delta V = 2.92 \text{V} \) ( )

Thickness of battery is the distance between the equipotential surfaces:
- \( L: 3 \text{mm} \)
- \( R: 3 \text{mm} \)

\[
L: E = \frac{3.10 \text{V}}{3 \text{mm}} = 1.03 \text{V/mm}
\]

\[
R: E = \frac{2.92 \text{V}}{3 \text{mm}} = 0.97 \text{V/mm}
\]
2. The distance to the moon (from Earth) is 384 Mm \((M = 10^6)\) (about 2/3 the mileage on my truck). Suppose that the moon and the Earth each carried a charge of 1 Coulomb. Use Coulomb's law to calculate the electrostatic force between the two objects.

\[
F = \frac{kQ_1 Q_2}{r^2} = \frac{(9.1 \times 10^9 N \cdot m^2/C^2)(1C)(1C)}{(384 \times 10^6 m)^2}
\]

\[
= 6 \times 10^{-8} N
\]
3. An EEG or electroencephalograph is used to measure the electrical activity of the brain by placing electrodes on the scalp and measuring the voltage between the those places on the scalp (in precisely the same way you placed electrodes on the "magic" paper and measured the voltage between those points on the paper). An EEG operator is generally more interested in the timing of those voltage readings rather than the amplitude. But I will ask you about the amplitudes. The picture is a sketch of the TOP view of a human head, with the letters showing the positions that the electrodes are to be placed in an EEG measurement. Imagine that the difference in voltage between F3 and C3 is about 60 \( \mu \text{V} \) (EEG operators call this the "F3-C3 channel...").

A) If possible, estimate the value of the field on your scalp between point F3 and C3. If it's not possible, explain why.

\[
|\hat{E}| = \frac{\Delta V}{\Delta x} \approx \frac{60 \mu \text{V}}{5 \text{ cm}} = 12 \frac{\mu \text{V}}{\text{cm}} = 12 \times 10^{-4} \frac{\mu \text{V}}{\text{cm}}
\]

This is the component of \( \hat{E} \) between F3 and C3.

B) If you know that F3 is at a higher voltage than C3, is it possible to indicate the direction of the field? If so, do it (draw a vector showing the direction of the field). If it's not possible, explain why you can't.

\[\hat{E} \text{ points toward decreasing voltage}\]

So there is a component of \( \hat{E} \) from F3 to C3. But unless we know that is the maximum drop in that area, we don't know the direction of \( \hat{E} \).
4. You showed in class that a light bulb is not an ohmic resistor. Suppose you have two identical light bulbs and you measure the resistance of each to be 1.2 Ω.

If you arrange the two light bulbs in series, the simple formula you have from lecture class says the equivalent resistance will be 2.4 Ω (the sum of each). Knowing what you know about the I-V curve for a light bulb (shown), do you expect the ACTUAL equivalent resistance to be GREATER THAN, LESS THAN or the SAME AS what the simple formula predicts. Explain your answer.

From the graph, as you increase V, R increases.

A) If you apply the same voltage to the series combination, each bulb will have a lower voltage and so a lower resistance than the first measurement. So the combined resistance will be less than 2.4Ω.

B) If you deliver the same current to the combination, each bulb will have the same voltage drop as in the first measurement. So the total voltage drop is twice as much. Twice the voltage with the same current means twice the resistance:

\[ R_{eq} = 2.4 \, \Omega \]
5. At the front of the room is a multimeter set to read current, showing the current flowing through the resistor connected to a power supply.

A) From the front indication only (NOT looking at the power supply or how it’s connected), determine the direction the current flows through the resistor and indicate it here.  \[ \rightarrow \]

\[
\text{Reading: } 2.05 \text{ mA (i.e. positive)}
\]

Reading is positive, so current enters mA port and leaves com port.

So, passes Resistor Right to Left:  \[ \leftarrow \]

B) I will write the resistance of the resistor on the board. Use this information as well as what you see on the ammeter to find the voltage setting of the power supply.

\[
V = IR = (2.05 \text{ mA})(3.00 \text{ k}\Omega) = 6.15 \text{ mV} \text{ k}\Omega
\]

\[ = 6.15 \text{ V} \]