# Flexible Conductive Materials in High School Physics


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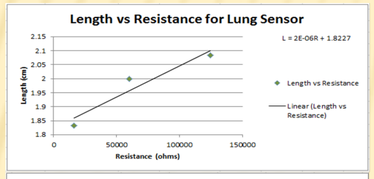
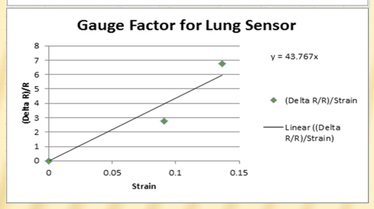
## Research Activities

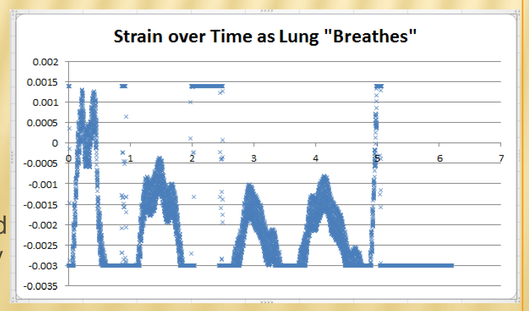
- Attended lectures on the properties of, history of, and production process of carbon nanotubes (CNT).
- Created CNT ink for use in an inkjet printer by using a CNT powder, distilled water, a surfactant, and sonication.
- Designed a sensor to be printed by instructing a 3D printer to print in two dimensions on a heated bed coated in an elastic poly substrate. The sensor consisted of a simple “U” shape.
- Calibrated sensor manually by stretching by hand and measuring change in resistance. These values of length and resistance change were used to graphically determine the strain and gauge factor. Asked for more precise measuring device due to frustrating nature of manual calibration. Told that our value was actually close to the known value for gauge factor.



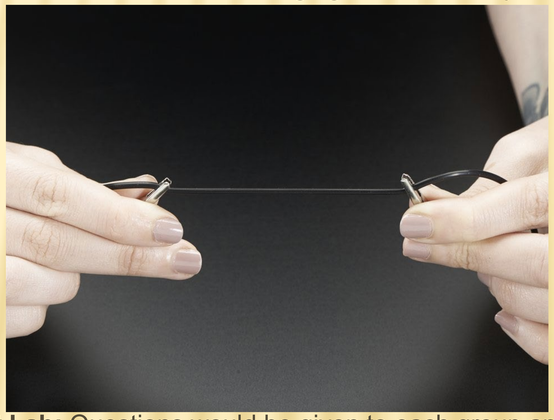

- Attached the sensor to a phantom lung that simulates the expansion and appearance of a human lung.

Using the gauge factor we determined during manual calibration we used the software available in the lab to determine the strain over time as we caused the lung to “breathe” by use of a pump.




## Lesson Plan

1. **Pre-assessment:** Students describe in words what factors affect electrical resistance and how they affect electrical resistance.
2. **Inquiry Based Lab:** The teacher asks two guiding questions for the lab: Why do some conductors conduct better than others? What factors affect conductivity and in what way? The main focus of the teacher demonstration should be lab safety, **not** how to complete the lab. It is up to the students to design the lab procedure and answer the guiding question.
3. **Possible Lab Approach:**
   - I would attach alligator clips to both ends of the conductive rubber cord and attach them to the multi-meter, which I would use to measure the resistance it has when it is at its equilibrium state.
   - Then I would attach the cord to a ring stand, stretching it a bit at a time by adding weights to the bottom causing it to stretch more and more. I would measure resistance after each weight is added.
   - I would then graph this data. The students’ should see that as the cord is stretched the resistance increases. They should also notice that the cord becomes thinner as it is stretched. Both of these factors increase resistance.
   - They should graph enough data points so they can see the relationship between length and resistance. They should see the relationship is nonlinear in this case, because both the length and the cross sectional area are changing simultaneously.



4. **Post Lab:** Questions would be given to each group and then they would be asked to prepare a small presentation. The presentation is done in front of the whole class as a lab group. The students defend their lab procedure and conclusion to the class.
   1. How does the changing length of the cord affect the resistance?
   2. How does changing length affect the cross sectional area of the cord?
   3. Create a general equation describing the resistance of an object based upon its length, cross sectional area, and resistivity. Explain your equation by using the data from your experiment.
   4. What is one possible application for a variable resistor such as this cord? Explain how it would work.

## Summary


In Physics and Physical Science students and teacher discuss resistance in detail. In particular students are expected to know the relationship between resistance, length, cross sectional area, and conductivity. In the research conducted this summer with Dr. Gou, a Carbon Nanotube (CNT) strain sensor was stretched increasing resistance, because the length increases and the cross sectional area decreases. This change in resistance can be very dramatic for CNT sensors and they stretch a noticeable amount unlike their metal counterparts. So they are ideal for students to “play” with as they can manually stretch it and measure the change with a multi-meter. Typical strain sensors do not noticeably stretch so students couldn’t feel the difference with their hands. In this educational application CNT sensors are actually preferable. As they are not readily available, carbon-black impregnated rubber is a viable and inexpensive substitute.

- Hands on approach to Electrical Resistance
- Inquiry-Based Lab
- Easily implemented with standards
- Inexpensive


## Implementation Strategy

### Lesson Objective(s)/Learning Goal(s)

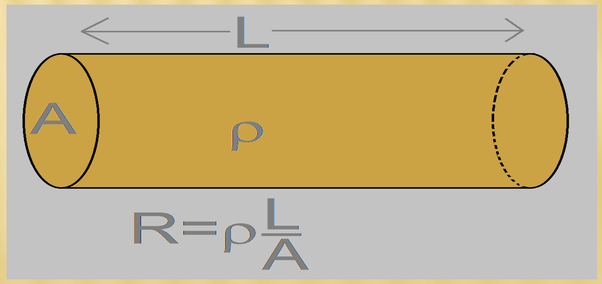
- Students know how resistance of a substance varies with length, resistivity, and cross-sectional area of the substance.

### Materials/Technology Needed

- “Conductive Rubber Cord Stretch Sensor + extras!”—(From Adafruit; $9.95 for a meter)
- Multi-meter
- Alligator clips and connectors
- meter stick or ruler

### Standards:

- SC.912.P.10.15 - Current, Voltage, Resistance, and Power
- SC.912.P.10.14 - Conductors, Semiconductors, and Insulators




## References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