# Beam Bending and Self Sensing CNT Thread

Michael Day: Group #3

## Lesson Information

### Grade Level

11, 12

### Subject areas

Pre-Calculus

### Duration

3, 50 minute periods

### Setting

Regular room

### Materials

See Lesson Plan

### Background Knowledge

### Lesson Plan(s) for the Activity

### Additional Resources

## Summary

This lesson asks the students: Can we find a way to self-sensor composite materials to determine if there will be damage or even failure. We will start with an experiment to show displacement. After talking about RET project, the students will make their own composite material with a wire embedded so they can test the resistance while the material is being stressed.

## Objectives

- Students will solve for variables given a formula from composite materials and other scientific concepts.
- Students will take data and infer if it will be linear or some other function. If linear, is it direct variation, or not.
- Students will be able to have several variables occur in an experiment and infer whether they are inverse or direct.
- Students will be able to graph the data and make a scatterplot.

**Patterns, Functions and Algebra**

- D 3. Solve equations and formulas for a specified variable; e.g., express the base of a triangle in terms of the area and height.
- F 10. Solve real-world problems that can be modeled using linear, quadratic, exponential or square root functions.
- I 13. Model and solve problems involving direct and inverse variation using proportional reasoning.

**Dtata Analysis and Probability**

- A 6. Interpret the relationship between two variables using multiple graphical displays and statistical measures; e.g., scatterplots, parallel box-and-whisker plots, and measures of center and spread.

# Self-sensing Carbon Nanotube Threads in Composite Materials

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| **Grade Level:** | **11, 12** | **Subject:** | **Advanced Pre-Calculus** | **Prepared By:** | **Michael Day** |
| **Duration:** | **3 Days** | | | | |

**Materials Needed**

**Wood trim pieces, glues, pvc pipes, copper pipes, any other long bendable things, string, weights, wire, paper, pencil, calculators, and excel spreadsheets.**

**Analyze Learners**

**What is this lesson about?**

**For three days students will learn about stress, strain, resistance, displacement, and formulas that apply to these and more. They will also learn about carbon nanotube threads and their impact on composite materials. (If you teach Pre-calculus or Algebra I suggest you get the physics teacher to help with the formulas!)**

**What will students be able to do at the end of this lesson?**

**Most important, students will be able to understand how experimentation works when there is no right or wrong data. Students will be able to define terms, manipulate equations, relate experimental data with graphs, and learn to read data for a better understanding of what research is all about. They will be able to do scientific inquiry with the data.**

Overview:

A: Students develop skills for solving equations, gather and analyze information. They will be using excel to draw graphs, analyze data, and then use mathematics and scientific analysis to come to a conclusion.

C: Students identify the skills needed for a career in research and engineering. Understanding that

**Education Standards Addressed**

**Patterns, Functions and Algebra**

D 3. Solve equations and formulas for a specified variable; e.g., express the base of a triangle in terms of the area and height.
F 10. Solve real-world problems that can be modeled using linear, quadratic, exponential or square root functions.
I 13. Model and solve problems involving direct and inverse variation using proportional reasoning.

**Data Analysis and Probability**

A 6. Interpret the relationship between two variables using multiple graphical displays and statistical measures; e.g., scatterplots, parallel box-and-whisker plots, and measures of center and spread.

**Measurement.**

A 1. Explain how a small error in measurement may lead to a large error in calculated results.

2. Calculate relative error.

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| sometimes answers are not known. It is the unexpected that makes it interesting.<br><br>S: Students are able to communicate findings and analysis to others. They shall see what it takes to make a difference in their global society. | |

| **Select Goals and Objectives** | **Teacher Guide** | **Student Guide** | **Assessment (Evaluate)** |
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| **Objectives**<br><br>(Specify skills/information that will be learned.)<br>• Students will solve for variables given a formula from composite materials.<br>• Students will take data and see if it will be linear or some other function. If linear, is it direct variation, or not.<br>• Students will be able to graph the data and make a scatterplot.<br>• Students will be able to determine the error, real and theoretical. | **Goals:** Teacher will present techniques for statistical analysis and graphic representations; and discuss real-world application of the techniques to engineering problems. | **Goals:** Students will see data in a new light. They will learn many scientific ideas | |
| **Select Instructional Strategies –**<br><br>**Information:**.<br><br>This is inquiry based learning at its finest. Be careful not to give too much away at the beginning. Their measurements do not have to be tremendously accurate. The whole idea is to get data and analyze it. | Day 1:<br>***Engage:***<br>Teacher will perform an experiment using PVC pipe, and weights which should peak their interest about variables that correlate. I will use the weights (I used a cup held on by string and quarters as weights) to bend the pipe. This will show a correlation between the weight and the amount of bend.<br><br>***Explore:***<br>Is it linear? This leads to questions about what variation in the experiment will change the outcome.<br><br>***Explain:***<br>Looking at those variations, I will lead the class into a discussion of creating a function with an | Day 1:<br><br>Students will observe experiment with PVC pipes<br><br>After writing down data from the experiment, students will discuss variations within the experiment that could affect the bending.<br><br>Students will try to describe the data with an equation.<br><br>Using excel or a calculator, they will test their equations. | Day 1:<br><br>Given a set of data, estimate a function that fits the data. Using a spreadsheet or calculator, test the function for best fit. There will be 5 of these problems. |

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| For Day 2, the instruction is more lecturing to start. This is where your friend, the physics teacher comes to help. Formulas abound and it helps if you know them fairly well. After teaching about cnt threads, resistance and more, the instruction is all about following directions. Can they create a composite material with a wire through it to try and gauge resistance? | emphasis on which variables are independent and dependent.<br><br>***Elaborate:***<br>I will help them find a function to fit the data, after they have attempted themselves. We will use calculators and excel spreadsheets to find a best fit model.<br><br>Day 2:<br>***Engage:***<br>Teacher will describe the self-sensing carbon nanotube threads in composite materials and how they affect any possible defects in the material. At this point, I will show the video on nanotubes.<br><br>***Explore:***<br>After handing out an equation sheet, I will reflect on some of the equations I used in the RET project. I will explain the project, showing the data and graphs that we obtained.<br><br>***Explain:***<br>I will re-teach how to solve for certain variables given equations.<br><br>***Elaborate:***<br>The experiment part of the lesson comes next. I will show students how they will be making their own self-sensing threads in a composite material. Taking tongue depressors, I will show them how to glue the TDs together with a wire between them. They will cure overnight. | Day 2:<br><br>Students will listen to a discussion of self-sensing carbon nanotube threads in composite materials and how they affect any possible defects in the material. After watching a video, the students will receive an equation sheet from the RET project.<br><br>The students will see data sheet after data sheet with graphs and explanations of the project.<br><br>After re-learning how to solve for variables given certain equations, they will have an opportunity to do these on their own.<br><br>Now, the fun begins. Students will be formed into 8 groups. Using tongue depressors and different forms of glue, each group will create a composite material with a conductive thread that simulates a carbon nanotube. This will take overnight to cure. Note to make sure each group finds the resistance of each conductor before they glue. | Day 2:<br><br>Part 1: Given equations, students will solve for a given variable. Trying to keep with the science concept, there will be problems from a science text.<br><br>Part 2:<br>Students fill out a lab report with the start of the experiment. |
| Day 3 is more data collecting. Using excel to help fit the data to a model. Anyone that | Day 3:<br>***Engage:***<br>Teacher will destroy a bridge from science to show how the weight | Day 3:<br>After watching the bridge be destroyed, students will discuss why this happened. | Day 3:<br><br>Sheet filled out by students with |

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| wants the data we collected from our project, please email us and we will be glad to help. There is a lot of it with graphs that never showed up anywhere on the presentations. The main instructional procedure here is to have the students use scientific inquiry to figure out what they learned from these experiments. | will cause fault.<br><br>***Explore:***<br>Teacher will use the bridge to analyze what went wrong? And could a sensor have helped detect when it was going to happen? Then, I will show what the students will be doing with their experiments.<br><br>***Explain:***<br>I will show samples from RET project and some data that was found in the project. I will show how the carbon nanotubes play a part in the self-sensing of the composite material. This will lead to them doing their experiment.<br><br>***Elaborate:***<br>After the experiment, I will show them how to transfer the data, and, in a discussion of that ever important question: what did they find? | Could a sensor in the building material of the bridge have signaled the time right before the bridge was collapsing?<br>Students will start their experiment. Taking the threaded composite material, placing it on the edges of the table, and then placing weights in the middle, they will take data after every weight is added. They need to remember they are looking for the displacement of the material. They also need to write down the resistance for each weight added. Taking the data to excel, students will analyze weight added versus resistance and displacement. They will answer: What happened? | experimental data will be collected. Since each group has different materials, they will compare data and find similarities. Using excel again, they will plot a graph of resistance versus time. |
| **U**tilize Technology:<br>Calculators<br>Smart board<br>Excel<br>Internet | Teacher will use smart board with schematics, tables and graphs. Calculator overhead and excel will also be explained. | Every day students will use calculators and excel to determine if the data fits a model. They will make graphs and calculate lines of best fit. | **Other Resources**<br><br>Internet to find the elastic modulus of certain types of materials. |
| **Require Learner Participation**<br><br>**Activity**<br><br>(Describe the independent activity to reinforce this lesson) | | Students have to be involved in this activity to get anything out of it. Have them bring materials from home. That gets the parents involved also! | Students should look up composite materials and summarize what they find. |
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Important Attachments:

1. Pre-Post Assessment See on web site
2. Worksheets See on web site

3. PowerPoint See on web site
4. Reflection after lesson