

## WHAT IS THIS THING REALLY MADE OF?

This lesson primarily focuses on students' ability to use measurement techniques along with math techniques to accurately measure small objects as well as recognize patterns in materials to be able to relate these small scale measurements to large scale properties. The students will use microscopic pictures taken to scale or composite materials to measure different macroscopic and microscopic characteristics, then develop mathematical relationships between them to enable them to characterize their sample.

RET Project Connection: The effects of crack (damage) patterns on the vibration and mechanical properties of components

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School: Somerville High School

Town/District: Somerville, Massachusetts

Subject(s) Taught: Physics AP, Honors Physics, Standard Physics, Vocational Physics

Subjects Covered: Physics, Mechanics, Geometry, Measurement, Algebra

Grades Appropriate: 9, 10, 11, 12

Lesson Duration: 1 class period

Fundamental Topics:

- Geometric Analysis
- Large vs. Small Scale
- Reading drawings to scale
- Analysis of Patterns

Goals/Objectives:  
(Student will)

1. Be exposed to how different simple ideas can be used together to solve more complicated problems.
2. Analyze the structure of a microscopic picture to determine characteristics of the larger scale structure.
3. Use measurement and mathematical techniques to analyze and characterize materials and patterns.
4. Determine ratios of components of composite materials based on their area and volume.

Background Information: Traditionally students are taught math, science and engineering in vacuums, without much interaction between the three. Recent efforts have tried to integrate education that introduces these areas together, and have shown that cooperation and knowledge across the areas increases when the different topics are taught at the same time.

From my experience, students entering high school have a big lack of practical mathematics knowledge as well as hands on measurement. This lesson gives students a chance to use various measurement techniques (rulers and calipers) along with geometry, ratios and algebra to solve an engineering issue and then relate it to mechanics. Students use real life samples and accomplish something that real engineers do, and they can do it all with tools around the classroom and knowledge that they need to know for MCAS.

Misconceptions:

1. Small materials are different than large materials
2. Materials do not follow patterns from small to large scale
3. Math is not useful outside of itself and it not related to science

Links to Massachusetts SIS1. Make observations, raise questions, and formulate hypotheses.

Physics Frameworks: SIS2. Design and conduct scientific investigations.

SIS3. Analyze and interpret results of scientific investigations.

- ✓ Use appropriate metric/standard international (SI) units of measurement for mass (kg); length (m); time (s); force (N); speed (m/s); acceleration (m/s<sup>2</sup>); frequency (Hz); work and energy (J); power (W); momentum (kg•m/s); electric current (A); electric potential difference/voltage (V); and electric resistance ( $\Omega$ ).
- ✓ Solve simple algebraic expressions.

- ✓ Perform basic statistical procedures to analyze the center and spread of data.
- ✓ Measure with accuracy and precision (e.g., length, volume, mass, temperature, time)
- ✓ Convert within a unit (e.g., centimeters to meters).
- ✓ Use common prefixes such as milli-, centi-, and kilo-.
- ✓ Use scientific notation, where appropriate.
- ✓ Use ratio and proportion to solve problems.

Links to Massachusetts  
Math Frameworks:

8.M.1 Select, convert (within the same system of measurement), and use appropriate units of measurement or scale.

8.M.2 Given the formulas, convert from one system of measurement to another.

8.M.3 Demonstrate an understanding of the concepts and apply formulas and procedures for determining measures, including those of area and perimeter/ circumference of parallelograms, trapezoids, and circles. Given the formulas, determine the surface area and volume of rectangular prisms, cylinders, and spheres. Use technology as appropriate.

8.M.4 Use ratio and proportion (including scale factors) in the solution of problems, including problems involving similar plane figures and indirect measurement.

8.P.9 Use linear equations to model and analyze problems involving proportional relationships. Use technology as appropriate.

Understand measurable attributes of objects and the units, systems, and processes of measurement

Apply appropriate techniques, tools, and formulas to determine measurements

10.N.4 Use estimation to judge the reasonableness of results of computations and of solutions to problems involving real numbers.

10.M.1 Calculate perimeter, circumference, and area of common geometric figures such as parallelograms, trapezoids, circles, and triangles.

12.P.1 Describe, complete, extend, analyze, generalize, and create a wide variety of patterns, including iterative and recursive patterns such as Pascal's Triangle.

12.P.10 Use symbolic, numeric, and graphical methods to solve systems of equations and/or inequalities involving algebraic, exponential, and logarithmic expressions. Also use technology where appropriate. Describe the relationships among the methods.

12.M.2 Use dimensional analysis for unit conversion and to confirm that expressions and equations make sense.

Materials Required:

- Scrap samples of different MMC composite materials.
- Magnified photographs of the faces of the MMC composite materials with scales.
- Caliper
- Ruler
- Calculator

Lesson Development:

1. A general discussion of what a composite material is and why they are important will occur prior to the lesson. Students will be shown different types of composites and how they can be made different (i.e. changing number of fibers, orientation, etc)
2. Students first will be given a problem. This problem will consist of them having to determine what percentage of materials a certain unidirectional fiber reinforced composite is made of. They will only be given a piece of their composite, a few magnified with scale photographs of the materials, as the makeup of the material cannot be seen by the human eye, a caliper, a ruler and calculator. They will be told what materials the composite is made of, (i.e. Aluminum matrix with graphite fibers coated in Alumina) but not how much of each. Some groups may be told one piece of information, such as your sample has 8 rows of fibers total.

3. From this, the students will work in groups to create a way in which to find out what percentage of the volume of the composite is the matrix material, what percentage is fiber material and what percentage of that fiber material is from the coating, or in engineering terms find the volume ratio. They will also have to determine how many fibers their material contains.

They will have to accomplish this by using the photos that they have to make measurements and then relate those measurements to their actual sample. They will have to relate patterns in the microscopic scale to the macroscopic scale.

An example of how the students might accomplish this is included with the student materials, but in general they will have to

- Calculate the cross sectional area of one fiber by measuring it on a diagram and then use the included scale appropriately.
- Use one of the pictures to determine how many fibers there are in a given area of the material.
- Use this to create an overall fiber area in the given area.
- If applicable use those numbers to calculate an overall fiber volume ratio.
- Or if given the number of rows of fiber, calculate from photos how many fibers there are linearly and multiple by number of rows to get the number of fibers per area, and then calculate the fiber volume ratio the same way.
- They could then use these same numbers (fibers/area) along with the total area of the sample (measured with a caliper) to determine the total number of fibers.

This would all be done in groups without much interaction from the teacher.

Concerns: Some students may not know how to use a caliper. I would first, if time permitted, give them a known sized item and have them measure it and see if they can figure out how it works. Or send them to sites like <http://phoenix.phys.clemson.edu/labs/cupol/vernier/index.html> to go through an online tutorial of how a caliper works.

This assumes the students can figure out a lot for themselves. If this ends up not being the case, the lesson can be modified to give the students some more guided directions. They can be told what to measure just not how to use it yet. They could be told the whole process, and have it more of exercise if the students are having a lot of difficulty with it. I would probably give the students as little information as possible depending on what they can handle, and as they get stuck provide them with a little more and more.

Extension: If resources are available, students can create their own types of composites with clay and straws, foam and toothpicks or string, or any other materials. They could then use simple methods to try to break them and see if any strength is added.

Students could try to determine how strong their different composite materials would be relative to each other based on different volume ratios. They would research online to try to verify their hypotheses if there is no mechanism available to test this. This would help if the sample materials used came from known stock that had a known failure stress.

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