Composites for Racing: Understanding Structure-Property Relationships

Created by Maliha Syed
2012-13 GK-12 Program, "Connections in the Classroom: Molecules to Muscles, Award #0947944" National Science Foundation

Note: This file contains the 5 E formatted lesson plan for instructors as well as a student handout version of the lesson plan.

Total time: 215 minutes

Engage (20 minutes) & Elaborate (20 minutes)

Introduce "the Blade Runner," Oscar Pistorius and his use of composite prosthetics for Olympic Racing.

Ask the students:

- Do you remember "the Blade Runner" from the Summer 2012 Olympics? What specifically do you remember about him?
- Discuss and introduce in detail the J-shape prosthetics he used in a PowerPoint. How does this composite work in terms of energy storage, strength and flexibility?
- What muscles and parts of the body are involved in running?
- Have the students try running or moving without using their legs.
- Introduce the idea of "molecules to muscles." What microscale components results in macroscale properties?—This will be explained more in more detailed during the "Explain" portion.

Explore (45 minutes-split into two days)

The students will be split into 4 groups for each section.

Each group's task is to create two different composites and perform tests on them to assess their strength.

Method for composite preparation: Hand-Layup (see p. 3 for procedure)
Materials

- Fillers
  1. Carbon Fiber
  2. Fiber Glass
- Matrix = Epoxy Resin (Part A and Part B)
- Wax paper or parchment paper
- Sponge brushes
- Plastic cups
- Weights

Allow 24 hours for composites to be cured before testing.

Explain (30 minutes)

The following concepts and ideas will be discussed:

- What is a composite?
- Where are they used?
- Molecules to Muscles
    - What components made up our composites? (Discuss the properties of carbon fiber and fiberglass)
    - What properties did the composite display?
    - Understanding structure-property relationships

Evaluate (Preparation: 50-60 minutes, Presentation: 30-40 minutes)

The students will prepare an 8-10 minute PowerPoint Presentation to answer the following questions:

1. Give two examples of composites that you find interesting and cool. Tell us what they are made from and what their applications are.
2. What is a composite made out of? (Hint: Two components)
3. What is the main goal of a composite material?
4. What two composites did you make in this lab? (Name the matrix and filler)
5. How did you make them?
6. What were the results of your tests?
7. Which composite was better and why?
8. Would Oscar Pistorius have an unfair advantage with his carbon fiber prosthetic legs? Why or why not?

Grading Rubric

Category	**4**	**3**	**2**	**1**	**Total**
Organization	Great flow! Makes perfect sense.	Good flow but you can work on it a little.	I was barely able to follow the presentation.	I was lost a lot during your presentation.	
Creativity	Very creative and pleasing to the eye.	Looks good.	The format is decent.	Need to work on visual design.	
Assessment Questions	Answered ALL questions very thoroughly	Answered most questions well	Answered most questions but not well	Did not answer many questions.	
Critical Thinking	You're an expert and think outside the box!	Understand the material well.	Understand some of the concepts.	You are struggling with the big picture.	
Group Participation	All members equally contributed & understand the information	All members contributed but not equally.	Everyone contributed but 1-2 people knew much more.	Only 1-2 people did most of the presentation.	
				Grand Total	

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Student Handout

The final task in this experiment will be to perform a group PowerPoint presentation. Please see below for guidelines and a grading rubric. You will perform peer reviews.

Answer the following questions before beginning the experimental portion.

1. What two composites will you create in this lab? (Clearly state matrix and filler)

2. Which method will you use to create your composites?

3. What two properties will you be assessing for your composites?

Composite Preparation Procedure

1. Lay a sheet of wax paper (approximately 2 feet long) on the tabletop.
2. Use a scissors to cut 3 glass fiber strips about 5 cm x 30 cm from the mat or fabric. Then use the balance to determine their total mass. Record the appearance of the glass fiber material, your observations when cutting the glass fiber strips, and their total mass on your worksheet.
3. Create the epoxy resin:
    a. To create the epoxy resin you will mix Part A and Part B. You can pick which ratio to mix them. Here are your options:
        i. 1:1 ratio
        ii. 2:1 ratio
        iii. 1:2 ratio
    b. Record which ratio you use on your worksheet!
4. Pour a **very small amount** of epoxy resin onto the wax paper. Use a brush to spread the resin to cover an area the size of the glass fiber strip you cut out.
5. Place one of the glass fiber strips onto the resin. Then dip the brush into the resin in the cup and paint resin into the glass fiver strip. Begin brushing in the middle and stroke toward the outer edges. Apply only enough resin with the brush to saturate the glass fibers.
6. Place a second glass fiber strip onto the first layer. Once again use the brush to apply resin. Work from the center out to help prevent air bubbles. Use just enough resin to saturate the glass fiber.
7. Repeat this process with each of the remaining glass fiber strips.
8. Cover the glass fiber laminate with a second piece of wax paper about the same size as the one upon which it is sitting.
9. Transfer your composite to the area designated by your instructor. Then apply a flat weight on top of it. Let the composite cure in this position overnight. Record in your worksheet the type of weight placed on the composite for curing.
10. After the composite has cured overnight, find the total mass of the composite so that you can compare it to the mass of the glass fibers used. Also note how it has changed. Record in your worksheet the total mass and how the composite has changed.

11. Repeat this procedure for the carbon fiber composite.

Composite Testing

You will perform two tests on each composite that you prepared tomorrow:

- Stress-to-Break Test—qualitative test
- Young's Modulus

Stress-to-Break Test

These composites are not easy to break. Thus, to acquire a qualitative understanding of their strength try and tear, rip or break each composite with your bare hands. Discuss which one was more difficult to break in your final presentation.

Young's Modulus Procedure

This test allows you to determine the stiffness of your composite.

1. Use a ruler to measure the width of your composite and a vernier caliper to measure its thickness. Record these in your worksheet.
2. Obtain a clamp and meter stick. Clamp the composite to the desktop. Have 20 cm of the composite sticking out over the table top unsupported (cantilevered). Record the length of the beam that is cantilevered in your journal.
3. Use the meter stick to record the height of the end of the composite. Ad a 50 gram mass to the very end of the composite. Then use the meter sick to determine the amount of deflection. If the deflection is too small to measure, add more weight to the end until you get a measureable deflection. Record these values in your journal.
4. Use the formula for Young's Modulus to determine the modulus of elasticity for the composite beam. Record this information in the Calculations section of your worksheet.

Calculate Young's Modulus:

$$\text{Young's Modulus (E)} = \frac{3 \times 98 \times m \times L^3}{D \times B \times H^3}$$

Where:

m = mass (g) of the weights added to the end of the beam

L = Unsupported length of the beam (cm)

D = Deflection of the beam (cm)

B = Width of the beam (cm)

H = Thickness or height of the beam (cm)

98 = A conversion factor with units of $N \cdot cm^2/g \cdot m^2$ that allows for the value to be obtained in Pascals (the SI unit for the elastic modulus)

PowerPoint Presentation Guidelines

Assessment Questions

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