

Battle of the Beams Activity Worksheet

Part 1 — Fabrication Introduction

Composite structures are a general class of materials that include two or more materials combined into one. One example is the use of straw and clay to make tougher bricks. Other typical composites are concrete, asphalt, plywood, fiber glass-reinforced polyester, carbon fiber-reinforced plastics and steel- or Kevlar®-belted tires. Of course we know all of these fairly well, but what about more advanced materials? In general, functional engineering materials for specific applications involve making composites out of metal and ceramic, ceramic and ceramic, polymer-metal and polymer-polymer combinations. Depending on the application and properties needed, different types of composite are selected.

Composites allow for engineers and scientists to achieve unique property combinations that individual material cannot provide. For instance, ceramic particles embedded in aluminum or copper matrix improve both flexural strength and wear resistance while maintaining a particular degree of toughening. However, aluminum by itself is not very wear resistant and the ceramic has poor toughness. Material scientists and engineers find composites of great interest because they provide unique property combinations that conventional materials are usually unable to provide.

Today you are going to make your very own composite beams. Each group has a choice of three reinforcement phases for their composites: Nerds® candies, rice and spaghetti noodles. If groups choose to use spaghetti noodles as reinforcement phases, then they have the option to make a continuous fiber composite or a discontinuous fiber composite. All composite beams will be bonded with a sugar matrix comprised of Laffy Taffy® and water. However, as mentioned, fabrication and matrix phase can alter the properties. In the spirit of scientific exploration, each group has the option to process its matrix phase at one of two temperature regions. Each temperature region corresponds to a different matrix behavior and can be understood with a little candy sense and solubility knowledge. The temperature regions are:

270 - 290°F: soft crack stage

300 - 310°F: hard crack stage

Composite fabrication, namely mixing of both phases, is very important and also a factor in beam performance. Groups must decide how they want to approach mixing in their reinforcement phases to yield the most well-bonded and homogenous distribution of reinforcement phases.

****NOTE: think about reinforcement composition prior to mixing.
Nerds® are made of sugar that may dissolve.****

Once fabrication is complete, each group tests its beam to determine the strongest one in the class. Understanding the following guidelines may influence each group's choice of fabrication method and composite type:

- Beam must conform to specified dimensions (the aluminum foil mold dimensions)
- Reinforcement phase weight should be within specified limits
- No other reinforcements may be used outside the specified list
- During testing, beam deflection (vertical distance moved) shall not exceed one-quarter inch. If a beam deforms this much without breaking, it is considered failed.

Let's get to work!

Name: _____ Date: _____

Part 1 — Fabrication Materials

- 1 aluminum foil mold (0.5 x 0.5 x 5 inch)
- 4 party-sized Laffy Taffy® candies
- 515 ml tap water
- 1 glass stir rod
- 1 hot plate
- 2 beakers
- 1 graduated cylinder
- 1 thermometer
- 1 oven mitt, lab apron and safety glasses
- 1 metal or plastic tray ~ 1-inch deep

To share with the entire class:

- 1 balance
- container of spaghetti noodles
- container of Nerds® candies
- container of rice

Part 1 — Fabrication Procedure

1. Begin by selecting your resin fabrication temperature and record in the data table (below).
2. As a group, choose which reinforcement phase to use for the competition; record on the data table.
3. Briefly discuss how your group plans on mixing in the reinforcement phase. Write your procedure on the data table as a reminder. *HINT: To produce the best beam, the more reinforcement the better, and the more the resin coats your reinforcement the better.*
4. Place a beaker on the hot plate and turn the hot plate to the highest setting.
5. Measure 15 ml tap water in a graduated cylinder and pour it into the beaker.
6. Unwrap four Laffy Taffy® candies and place them in the beaker.
7. Place the thermometer into the beaker with the water and taffy; monitor the temperature.
8. Using the glass rod, continuously stir the boiling mixture to speed up the resin process.
9. Depending on your selected cooking temperature, boil contents until solution has reached your specified temperature.
10. Place the aluminum foil mold into the tray.
11. Into a second beaker, add approximately 500 ml cold tap water.
12. Using an oven mitt, pour the resin into the aluminum foil mold. *Make sure that all of the reinforcements are in the mold with the resin.*
13. After the resin and reinforcement have settled in the mold, immediately pour water in the tray to accelerate its cooling.
14. Let the mold cool down for 5 minutes. If necessary, add more water to accelerate the cool down.
15. Strip the aluminum foil away from the beam and set the beam aside.
16. Clean up the lab station including all used glassware (place them back into the tray).
17. Dispose of solid waste in a trash can and liquids down the sink. Caution! Cool any hot waste product to room temperature before placing it in a trash can.
18. Complete Part 1 of the worksheet including the questions and filling in the first half of the data table.
19. Label your beam with a group name and give it to the instructor to store in a cool place until test day.

Part 1 — Fabrication Questions

1. Explain in 2-3 sentences why your group chose the resin temperature used for beam fabrication. Your explanation should include sugar solubility changes and water phase change.

2. Explain in 2-3 sentences why your group chose the reinforcement phase and shape used for beam fabrication. Your explanation should include how reinforcement material and shape may influence composite properties.

3. Predict how many pounds (or kg) your beam will hold before breaking. (The closest group may get a prize!) Predict that when your beam fails, it will either break, deform, or a combination of the two?

<p align="center">Prediction:</p> <p align="center">How many pounds the beam will hold:</p>	<p align="center">Prediction:</p> <p align="center">Beam failure will be:</p> <p><input type="checkbox"/> break</p> <p><input type="checkbox"/> deform</p> <p><input type="checkbox"/> combination</p>
<p align="center">Actual:</p> <p align="center">How many pounds the beam held:</p>	<p align="center">Actual:</p> <p align="center">Beam failure was:</p> <p><input type="checkbox"/> break</p> <p><input type="checkbox"/> deform</p> <p><input type="checkbox"/> combination</p>

Name: _____ Date: _____

Parts 1 & 2 — Data Table

Composite beam fabrication	Group #:	
	Name:	
Fabrication Specifications		
Reinforcement material	Reinforcement type (whisker/rod, fiber, particle)	Resin fabrication temperature (°F) & description
Mixing Procedure:		
Final Beam Specifications		
Beam width (in, mm)	Beam length (in, mm)	Beam thickness (in, mm)
Beam Testing Parameters		
Failure mass (kg, lb, g, oz)	Failure force (N, lbf, kgf)	Calculated failure stress (Pa, Psi)

Part 2 — Testing Competition Introduction

Today is beam breaking day and the group with the strongest, best engineered composite beam wins. Of course, subtle differences in beam geometry will influence the failure load. This can be solved by using the concept of stress to define a failure criterion. Stress is simply the load normalized by the subjected cross sectional area. This allows for every group’s beam to be treated equally. Since beam bending is too complicated to get into specifics, a formula will be provided so you can calculate stress based on your beam dimensions and applied force. Good luck and let the bending force be with you!!!

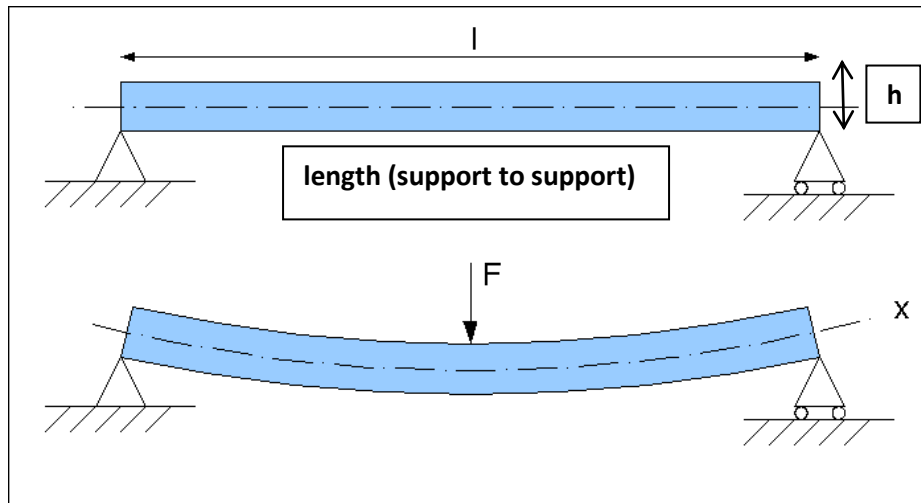
Part 2 — Testing Competition Materials

- 2 flat tables spaced ~3 inches apart (alternative: 2 ring stands with horizontal extensions)
- spring scale or other device for containing weight
- assorted weights that can be hung by a string or placed on/in a weight container/pan
- fishing line (or string)
- scissors, to cut fishing line/string

Part 2 — Testing Competition Procedure

1. Have one person from your group write the group’s beam fabrication specifications and final beam specifications on the classroom board.
2. Cut 6-8 inches of fishing line (or string) and begin tying a loop around the middle span of your beam. Tie an addition loop on the other end to accommodate spring scale and weights.
3. Select one person from your group to monitor the beam deflection (distance) during testing.
4. Place beam on supports with the string placed in the middle span (three-point bending).
5. The teacher begins to add weights to the spring scale.
6. Observe carefully to make sure any beam deflection is within the competition guidelines.
7. Continue to add weight until the beam breaks. Record the failure force (load) on the data table and on classroom the board.
8. Once your testing is done, calculate your beam stress using the equation, below. Remember that stress is material and geometry dependent (which essentially normalizes the data for comparison).
9. Complete the rest of the worksheet, including all questions and the data table.

Part 2 — Data: Beam Nomenclature



Stress Calculation

$$\sigma = \frac{3FL}{bh^2}$$

Where:

F = force (N, lbf, kgf)

L = lower support distance (see diagram) (in, mm)

b = beam thickness (in, mm)

h = beam height (in, mm)

Part 2 — Testing Competition Questions

1. How did your group's beam compare to other groups?

2. Explain in 2-3 sentences the differences between your group's composite beam and other beams. Why did yours perform the way it did?

3. In 3-5 sentences, explain what changes you would make to improve your beam's strength. Include a discussion about the role of reinforcements and fabrication techniques.