Beam Modulus of Elasticity

Learning Objectives

* The student will engage in an activity to develop a model based on observations (of their own devising) from the physical world.
* Understand the factors that affect the deflection of a rectangular cross-sectioned center-loaded beam, supported on both ends.
* Conduct experiments to confirm the published values of the Modulus of Elasticity for various materials.

Recommended Grades/ Subjects

Grades 9-12, or College: Physical Science, Physics, or Engineering

Time needed

The project should be able to be completed in one 45 minute period.

related EXPERIMENTS

This Activity can be conducted as part of a series related to deflection of a center-loaded beam supported on both ends. Related Activities include:

1. Inquiry Activity-Deflection of a Rectangular Center-Loaded Beam
2. Inquiry Activity-Beam Shape and Deflection

Related Next Generation Science Standards

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| --- | --- | --- |
| Disciplinary Core Ideas | Crosscutting Concepts | Science and Engineering Practices |
| ETS1.A. Defining and Delimiting Engineering ProblemsETS1.B. Developing Possible SolutionsETS1.C. Optimizing the Design Solution | PatternsCause and effectScale, proportion, and quantitySystems and system models | Asking questions and defining problemsDeveloping and using modelsPlanning and carrying out investigationsAnalyzing and interpreting dataUsing mathematics and computational thinkingConstructing explanations and designing solutionsEngaging in argument from evidenceObtaining, evaluating, and communicating information |

Information for the Instructor

Introduction

This series of activities explores the equation for a center-loaded beam that is supported at both ends:

$∆ = \frac{FL3}{48EI}$

Where *∆* is the beam’s elastic, vertical displacement at mid-span, *F* is the load, *L* is the span length, *E* is the modulus of elasticity, and *I* is the area moment of inertia. If we consider a solid rectangular beam of length *L*, base *b* and height *h*, then the area moment of inertia is *bh3/12* and the equation becomes

$$∆ = \frac{FL3}{4Ebh3}$$

Investigation of the Modulus of Elasticity

Most materials have an observable elastic region where the force applied is proportional to the deformation of the material and when the force is removed the object regains its original shape. In this investigation, students will start with the dimensions of rectangular beams with the intent of determining the modulus of elasticity for various materials in this elastic region. The slope of a force *vs.* displacement graph through its elastic region will provide the other necessary information for this calculation. The obtained values can be compared to published values.

Students can be prompted in advance to consider various materials and predict their relative slopes, causing them to consider previous knowledge and engage in understanding the link between data and graphical displays.

General Considerations

There are a number of things that are useful to keep in mind when doing the beam experiments discussed here:

1. The experiment file *Elastic Modulus Rectangular Beam* or *VSMT Basic* can be used for this investigation. Both can be found by clicking on File>Open>Experiments>Probes & Sensors>Structures & Materials Tester.
2. The prediction exercise may be most effectively accomplished without having the materials in the students’ hands; or perhaps with one material in hand so they can flex it while considering other materials from a list.
3. You will want to choose materials that are readily available and with elastic properties that match with the VSMT load cell limit (1000 N). Blades of metals such as aluminum, steel, and brass are generally available from hobby stores or hardware stores. Wood species can have a high degree of variability, but samples are readily available. Plastics may also be good materials for testing.
4. A caliper is useful for more accurate measurement of beam dimensions. Ideally, beam samples dimensions would be close to identical.
5. There is no need to apply forces that will bend the beams to the breaking point; however, you may find it interesting to explore the region beyond the elastic limit. Refer to the Challenge Activities.
6. The experiments described here make use of a U-bolt and quick link to securely connect the beams to the VSMT. The weight of this tackle may be included in the calculations of force (and is incorporated into the experiment files). This is not required to determine the general relationships for this activity.
7. Follow the safety recommendations found in the VSMT *User Manual*:

Wear safety glasses.

Tackle using threaded parts should be attached so that a sufficient amount of the threaded component is engaged.

Quick links should be secured and not left open.

Follow Up Questions

1. Summarize your findings.
2. Were any of your findings contrary to your predictions? If so, discuss potential reasons or misconceptions. If not, summarize your predictions and comment on your results.
3. Compare your values to the values listed in resources. Reference your resources appropriately.

Challenge Activities

Challenge activities may be appropriate for the entire class or for students who complete the initial assignment early.

* Provide students with an unknown material for them to try to identify by determining the modulus of elasticity and other physical characteristics (e.g. density, and color).
* After an evaluation of the elastic region of several materials apply an additional force to permanently deform the material. Students can compare the elastic limit of various materials. Students can determine if trends exist. For example, do stiffer materials (higher modulus of elasticity) have higher elastic limits?

Supplemental Student Instructions

We feel that the student sheets present engaging challenges. However, depending on your emphasis for this project and the level of your students, you may wish to provide them with more detailed instructions on various aspects of the software and logic setup as included below.

Equipment Setup

* For measuring force and displacement of rectangular beams a U-bolt connected to the load cell using two quick links and a threaded eye-bolt is recommended.
* Select your material samples so that you can use the same tackle for each test.

troubleshooting

The most common confusion related to using the VSMT is that the Displacement Sensor will not auto-ID. Be sure to select the Displacement Sensor as explained in the VSMT *User Manual.*