Subject Area(s)	**Physics, science & technology**
Associated Unit	**None**
Associated Lesson	**None**
Activity Title	**The Young's Modulus of Jell-O**

Yellow highlight = required component

Header

Image 1
ADA Description: jello layers backlit
Caption: none
Image file: jello_layers_backlit_thumb.jpg
Source/Rights: Copyright © House of Annie
http://www.houseofannie.com/jello-layers/

Grade Level	**11 (9-12)**
Activity Dependency	**None**
Time Required	**60 minutes**
Group Size	3
Expendable Cost per Group	US$5.00

Summary

Students learn about material properties testing, analysis of elastic properties of solids and graphical methods. They acquire basic familiarity with terminology used by mechanical engineers, materials scientists and bioengineers, all by working with familiar materials and contexts.

Engineering Connection

Materials Scientists, Mechanical Engineers, Bioengineers and Biomedical Materials Researchers are all concerned with the properties of materials. Recently it became possible to explore these properties in soft hydrated materials like agarose and hydrogels. This activity gives students the chance to gain deep insight into what engineers study and how their approaches have a clear connection to the life sciences.

Engineering Category = #1

Choose the category that best describes this activity's amount/depth of engineering content:

1. Relating science and/or math concept(s) to engineering
2. Engineering analysis or partial design
3. Engineering design process

Keywords

Jello, biomedical, bioengineering, materials science, mechanical engineering, Young's Modulus, physics, Hooke's Law, laboratory, springs, force

Educational Standards

ITEEA 2000, grades 9-12, **13.L**:

Standard 13. As part of learning how to assess the impact of products and systems, students should learn that:

L. Use assessment techniques, such as trend analysis and experimentation, to make decisions about the future development of technology.

ITEEA 2000, grades 9-12, **17.P**:

Standard 17. Students will develop an understanding of and be able to select and use information and communication technologies.

P. There are many ways to communicate information, such as graphic and electronic means.

ITEEA 2000, grades 9-12, **19.M**:

Standard 19. In order to select, use, and understand manufacturing technologies, students should learn that:

M. Materials have different qualities and may be classified as natural, synthetic, or mixed.

New York State Math Science & Technology Standards 2010

Standard 1—Analysis, Inquiry and Design

Scientific Inquiry:

1. The central purpose of scientific inquiry is to develop explanations of natural phenomena in a continuing, creative process.

Students elaborate on basic scientific and personal explanations of natural phenomena, and develop extended visual models and mathematical formulations to represent their thinking.

Pre-Requisite Knowledge

A basic understanding of graphing methods, be they on graph paper or more sophisticated regression/trend & correlation analysis from graphing calculators or spreadsheet programs. Exposure to Hooke's Law for spring force is helpful.

Learning Objectives

After this activity, students should be able to:

- Recognize the difference between the Spring Constant, k for a Hooke's Law spring and Young's Modulus, E for a solid member
- Develop a basic analytical methodology for testing elastic properties of any solid, pliable material
- Explain how the processes of analysis physicists perform inform those which engineers do

Materials List

Each group needs:

- One digital force meter (e.g. Pasco PS-2104 or Vernier DFS-BTA) with readout to handheld device or computer
- One Ping-Pong ball
- One Small ruler or calipers
- One or two paper towels
- One sample of an elastic hydrated material, such as Agarose or Jell-O, at least 2 inches thick, in a small clear container, refrigerated overnight

To share with the entire class:

- Blackboard/Smartboard to display various group results

Introduction / Motivation

This activity is meant to be done as an extension of a typical Hooke's Law lab most high school physics classes perform. When students get used to the idea that a spring's stretch is proportional to the load placed on it, the concept of elasticity may be extended to other areas.

It should come as no surprise to students that gelatinous substances like Jell-O have a "springiness" to them, but it may be surprising to most that not only can you study this "springiness" in a similar manner to Hooke's Law, but it is also being done by numerous scientists and engineers for biological applications!

Vocabulary / Definitions

Word	Definition
Pressure	Applied Force / Area of contact
Strain	Thickness of system due to Force / Thickness of system under zero Force

Procedure

Background

As an extension of a Hooke's Law activity, the data students will gather will be Force and Displacement data. The level of sophistication is left up to you, the instructor. Students will go about collecting their data by pushing down with an increasing force on a Ping-Pong ball which will sit atop your elastic substance. The reason for the Ping-Pong ball is to decrease the applied pressure and allow a higher maximum force before the substance ruptures.

The Jello-O can be prepared different ways. It is sold in individual containers for more money, so if the quick set-up time is worth the extra cost, this can be a great solution. Otherwise, glassware from a typical chemistry department works well. Filling up a few 100mL beakers to the 80mL level can be done fairly quickly, and many smaller beakers can accommodate a Ping-Pong ball. Additionally, with the clear walls of the container, the length measurement need not be done inside the container.

Students can generally collect between 5 and 8 pieces of data to graph. While the force measurement is fairly straightforward, the displacement measurement may be a bit challenging. Note that students will have to measure the depth to which the top layer of the Jell-O sinks, so just reading off values from the ruler won't do. Measuring the height of the bottom of the force probe may prove easier to do.

A more advanced technique may be to give different groups samples with various concentrations of water-to-Jell-O (or water-to-agarose, or introduce an additional substance into the mixture like flour and vary the concentrations of it), and see if they arrive at different slopes, meaning different material properties.

Before the Activity

- Prepare the samples and refrigerate. (The elasticity is fairly temperature-dependent, so make sure to only remove from the refrigerator when ready to test.)
- Zero out all force sensors in the vertical position, since they will all be pushing down
- Run this experiment at least once on your own so that you know between what Force and Displacement values students should stick to

With the Students

1. Distribute materials and ensure all students understand how to use the force sensor and how they will be taking measurements using the ruler or calipers.
2. Explain the procedure for collecting data. At no point should the applied force of the Ping-Pong ball be large enough to rupture the surface of the material.
3. Once between 5 to 8 data points have been collected, plot a graph of Force *vs* Displacement (or, for more sophisticated students, Pressure *vs* Strain).
4. Have students report back the type of relationship they see and the confidence with which they see the relationship; also report the slope and equation.
5. Once students have completed their data write-up, they will share it with their peers, either on their own whiteboard or on a Blackboard/Smartboard table in the front of the room.

Figure: Insert Figure # 1 here, right

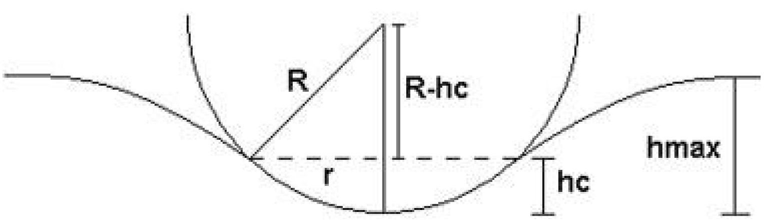

Figure 1

ADA Description: Schematic of spherical tip making indentation on sample substance

Caption: Figure 1: *R* = radius of curvature of the indenter tip, *h*c = contact depth, *h*max = maximum indent depth, and *r* = radius of the projected contact area of the tip with the substance.

Image file: Ebenstein_schematic.bmp

Source/Rights:

Image Insert Image # 3 here, centered

Image 2 **ADA Description:** Sample apparatus showing depression of Ping-Pong ball by force sensor, a ruler to measure Depth and a display for Force **Caption:** Image 2: The Force sensor is pushing on the Ping-Pong ball which in turn depresses some amount into the Jell-O. The ruler can measure the displacement which the Ping-Pong ball travels. **Image file:** apparatus.jpg

Attachments

None

Safety Issues

- The Jell-O is likely not safe to eat afterwards.

Troubleshooting Tips

It's probably a good idea to have more than enough samples on hand since a force of only 1 or 2 Newtons can break the surface (even spreading out the area over the Ping-Pong ball).

Investigating Questions

Some particularly inquisitive students can research what's special/unique about the structure of gelatin that gives it the properties they observe. Also, anyone who's actually prepared Jell-O has seen that the ratio of Jell-O mix to water is astoundingly in water's favor (and this ratio doesn't change much while the mixture cools). Students can mix Jell-O themselves at home and carefully measure what percentage (both by mass and by volume) of Jell-O product is actually just "trapped" water. (This further makes you appreciate why it's such a strange substance!)

Assessment

Pre-Activity Assessment

Descriptive Title: Hooke's Law [optional]

Have students practice with lab work on Hooke's Law. Given the data for a typical Hooke's Law spring lab, can students:

1) Graph the data, generating slope and equation?
2) Predict the amount of force the spring will apply for a given amount of stretch?
3) Explain how much stretching would be required for the spring to exert a given force?

Activity Embedded Assessment

Descriptive Title: Data collection and analysis

Students will collect data, draw graphical conclusions from the patterns they see and place it where the class as a whole can analyze the results.

Post-Activity Assessment

Descriptive Title: Whole-Class Discussion

After the experiment has been carried out, students will look over the results the class has generated and draw conclusions based on what they see changing (or staying consistent) among the experiments the class performed.

Activity Extensions

The same activity can be performed but using higher levels of complexity and different substances. Additionally, background research may be performed on this practice of indentation in order to get a “real world” connection.

Activity Scaling

- For lower grades, simply consider *F vs d*
- For upper grades, try to come up with a method for evaluating pressure and use strain instead of displacement

Additional Multimedia Support

None

References

Ebenstein and Pruitt, Nanoindentation of soft hydrated materials for application to vascular tissues, J Biomed Mater Res 69A: 222–232, 2004.

Other

Jell-O is a registered trademark of Kraft Foods.

Redirect URL

None

Contributors

Seth Guiñals-Kupperman and Mingyu Li, with the support of Dr. Remi Dingreville, Dr. Vittoria Flamini and Dr. Vikram Kapila

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Supporting Program

Science and Mechatronics Aided Research for Teachers (SMART): A Research Experience for Teachers Program, Department of Mechanical, Aerospace, and Manufacturing Engineering, NYU Poly

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