Title: Mechanical properties of Gummi Worms

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Subject: Physics
Grade Level: High School
Standards:
- State standards met by this module
  - 1 - Scientific inquiry
    - What are the material properties that may be measured?
    - Why are tests of these types useful?
    - Mathematical analysis
    - Graphing
  - 4 - Understand and apply scientific concepts and recognize the historical development of ideas.
    - Key Idea 3: Explaining material properties
    - Key Idea 4: Elastic properties
  - 6 - Understand relationships and common themes and application to areas of learning
    - Key Idea 1: Interconnectedness
    - Key Idea 2: Use of models
    - Key Idea 4: Stability
    - Key Idea 5: Making predictions

Schedule: Three to four class/lab periods and some work to be done by the student at home

Description:

1. Do Gummi Worms obey Hooke's Law?
2. Plot a stress vs. strain curve and identify the yield point of the Gummi Worm.
3. Measure the creep of a Gummi Worm
4. How do Gummi Worms respond to compression?

Objectives:

- The student shall improve upon the following skills: measuring and data collection, graphing, calculating slope, producing a graph with Excel, graph analysis
- The student will make predictions based on prior knowledge/experience then compare with experimental results.
- The student will interpret and analyze laboratory results

Vocabulary:

- Force
- Spring Constant
- Deformation (plastic and elastic)
- Resiliency
- Compression
- Stress
- Strain
- Yield point
- Fracture
- Modulus
- Creep

Materials:

- Gummi Worms
- Binder clips
- Ruler
- Lab masses
- Ice
- Computer with Excel

Safety:

Take appropriate precautions with ice water.

Be careful when handling masses

Inspect for mechanical failure during tests.

Science Content for the Teacher:

Basic understanding of the elastic and plastic behavior of pliable materials as observed during the included activities. (Hooke's Law, stress-strain curves, resiliency, and creep)

Classroom Procedure:

The activity procedure is attached.

Assessment:

Questions are included with each activity to evaluate the level of understanding of the students.

It may also be helpful to have students write a formal laboratory or research report after completing the activities.

Acknowledgements:

Special thank you to research support specialist Phil Carubia for suggestions while developing these activities.

MECHANICAL PROPERTIES OF GUMMI WORMS

5. Do Gummi Worms obey Hooke's Law?
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HOOKE'S LAW

Hooke's Law states that the stretch of an elastic material is directly proportional to the applied force. Hooke's Law is valid for a material as long as the material returns to its original shape when the force is removed.

In mathematical terms, Hooke's Law is written as:

$F = kx$ Where: F = force (N)
x = stretch (m)
k = spring constant (N/m)

In this activity, the spring constant of the Gummi Worm will be determined

1. Set up equipment as shown in figure (right)
2. Record the relaxed length of the worm
3. Hang mass from the bottom binding clip and slowly lower it. Record the value of the mass used.
4. Record the new length of the worm
5. Remove the hanging mass and allow the worm to return to its relaxed length.
6. Repeat steps 3, 4, and 5 for five different values of mass.
7. Graph the stretch of the worm as a function of the hanging weight
8. Make the best fit line to represent the data.

DATA TABLE (with example data)

Relaxed length = 0.08m

Mass (kg)	Force (N)	Length (m)	Change in Length (m)

QUESTIONS:

1. Based on the graph, does the Gummi Worm obey Hooke's Law for this activity? If so, calculate the slope of the graph and discuss its physical significance. If it does not, discuss where and how the behavior deviates from the law.
2. What physical factors could be changed to alter the spring constant of the worm?
3. What is the physical significance of the area under the curve for this activity?

GOING FURTHER:

Select three worms with different colors. Trace the worms in the space below. Label the thicker end "head" and the other end "tail"

ONE	COLOR

TWO	COLOR

THREE	COLOR

Measure the length, width and thickness of each worm. (Note: measure the width and thickness at the same location approximately half way along the worm)

WORM	COLOR	LENGTH (cm)	WIDTH (cm)	THICKNESS (cm)
1				
2				
3				

TEST ONE

TEMPERATURE AND COMPRESSION/RESILIENCY

(THIS ACTIVITY MAY BE BETTER DONE AS A CLASS DEMONSTRATION)

1. Clamp the “heads” of three different worms with binder clips and place them in zip lock bags.
2. Place one in ice water, another in warm tap water (take care to prevent melting the worm) and leave the third at room temperature. Leave the worms in these temperatures for twenty minutes.
3. During the temperature change, make predictions for the order with which each worm will return to its original shape when the clip is removed. Provide a reason for your ranking. If you predict that any or all of the worms will remain deformed, state that and give a reason.
   PREDICTION OF ORDER: FIRST _______ SECOND ________ THIRD _________

   REASON:

   ACTUAL ORDER: FIRST _______ SECOND ________ THIRD _________
   DISCUSS ANY DIFFERENCES:

QUESTIONS

1. Watch the following youtube video - http://youtu.be/UCLgRyKvfp0 and discuss how it applies to this activity.
   a. What does Feynman mean by saying at the end of his report, “For a successful technology, reality must take precedence over public relations, for nature cannot be fooled.”?
2. Investigate other applications where the behavior of material under stress in various temperature conditions is important.

TEST TWO
CREEP TEST

According to Wikipedia: http://en.wikipedia.org/wiki/Creep_(deformation)

In materials science, **creep** (sometimes called **cold flow**) is the tendency of a solid material to move slowly or deform permanently under the influence of mechanical stresses. It can occur as a result of long-term exposure to high levels of stress that are still below the yield strength of the material. Creep is more severe in materials that are subjected to heat for long periods, and generally increases as they near their melting point. Creep always increases with temperature.[*citation needed*]

The rate of deformation is a function of the material properties, exposure time, exposure temperature and the applied structural load. Depending on the magnitude of the applied stress and its duration, the deformation may become so large that a component can no longer perform its function — for example creep of a turbine blade will cause the blade to contact the casing, resulting in the failure of the blade. Creep is usually of concern to engineers and metallurgists when evaluating components that operate under high stresses or high temperatures. Creep is a deformation mechanism that may or may not constitute a failure mode. For example, moderate creep in concrete is sometimes welcomed because it relieves tensile stresses that might otherwise lead to cracking.

PROCEDURE

1. Set up equipment as shown in figure (right)
2. Record the relaxed length of the worm
3. Hang mass from the bottom binding clip and slowly lower it. Record the value of the mass used.
4. Record the new length of the worm
5. Record the length of the worm at regular intervals (may have to relieve the tension by lowering the worm and mass over-night)
6. Plot length as a function of time

QUESTIONS

1. What does the slope of the graph represent? What about its inverse?
2. Why is it important to study the creep of materials?
3. List three factors that influence the creep of a material.
4. How is creep related to plate tectonics? Why do seismologists consider creep a 'good thing'?

GOING FURTHER

1. Investigate the industrial uses of creep tests. List and describe three different materials where this test applies.
2. Locate and duplicate photographs where creep has been observed. (properly cite all pictures)

TEST THREE
STRESS – STRAIN

STRESS (σ, in Pascals) is determined by dividing the force (F, in Newtons) exerted on a material by the cross sectional area (a, in square meters) of the material.

$\sigma = \frac{F}{a}$

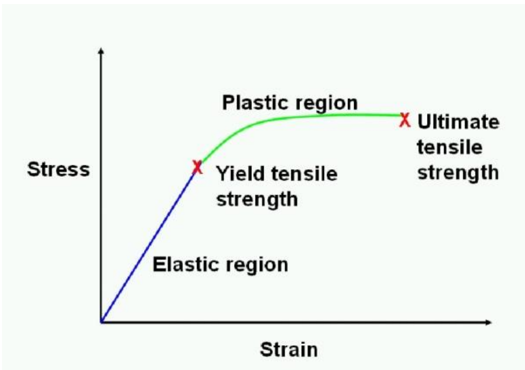
STRAIN (ε, dimensionless) is the displacement of a material determined by dividing the change in length (ΔL, in meters) by the initial length (L, in meters).

$\epsilon = \frac{\Delta L}{L}$

TENSILE MODULUS (E, in Pascals) is the ratio of the stress to the strain. $\mathrm{E} = \frac{\sigma}{\varepsilon}$

STRESS – STRAIN CURVE – Typically broken down into two regions. The first is where Hooke's Law is obeyed and the second is after the elastic limit is exceeded.

EXAMPLE OF A STRESS-STRAIN CURVE



http://www.theraffettogroup.com/wordpress3/wp-content/uploads/2013/05/stress-curve.jpg

PROCEDURE:

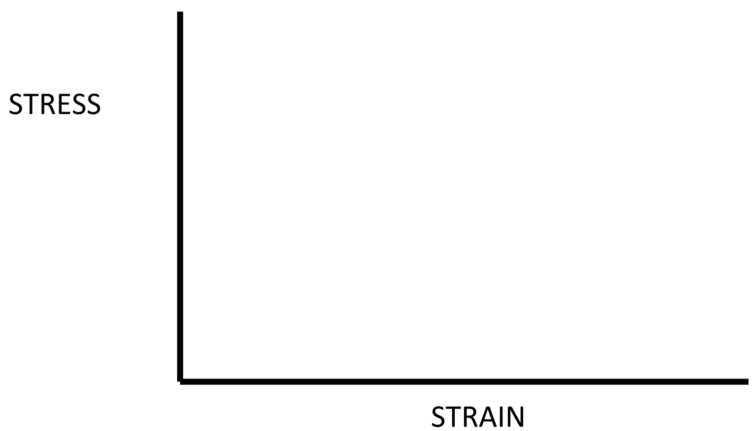
1. Use the width and thickness measurements to calculate the cross sectional area of the worm. Record this value.
2. Record the relaxed length of the worm
3. Set up equipment as shown in figure (right)
4. Hang mass from the bottom binding clip and slowly lower it. Record the value of the mass used.
5. Calculate the force exerted by the mass.
6. Calculate the stress
7. Record the new length of the worm
8. Calculate the strain
9. Repeat steps 4 - 8 for ten different values of mass. (Unless the worm breaks. If not, continue until failure)
10. Enter the data in an Excel spreadsheet and produce a graph of the results.

MASS (kg)	FORCE (N)	AREA (m^2)	STRESS (Pa)	LENGTH (m)	ΔLENGTH (m)	STRAIN

	(A2*9.81)		(B2/C2)		(E2-Lo)	(F2/E2)

ANALYSIS

1. Define the following terms and identify them on the graph
    a. ELASTIC DEFORMATION –
    b. PLASTIC DEFORMATION –
    c. YIELD POINT –
    d. FRACTURE POINT –
2. Return the worm to the original outline (in pieces) and identify changes.
3. On the axes below, sketch your graph then sketch and label two other graphs: one for a material that is more brittle than the worm, and another for a material that is more ductile than the worm. List two materials that would demonstrate those properties.



4. List at least three factors that would influence the shape of a stress-strain curve.