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#4 Simplified Vertical Rebound Testing

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I. INTRODUCTION

Description

This activity involves rebound testing of elastomers. Students will produce rebound data and determine the kinetic energy transformed by the impact of a free falling ball.

Student Audience

These activities can be used in high school basic science classes through university chemistry and physics classes.

Goals for the Experiment

The student will:

- describe energy transformation systems,
- relate kinetic and potential energy to the rebound system,
- relate materials and construction of balls to resulting energy transformation,
- collect data and calculate percent rebound and percent energy transformed, and
- discuss the implications of rebound and resiliency to applications and material choice.

Recommended Placement in the Curriculum

These tests are recommended for use in the discussion of any of the following topics:

- energy transformation systems,
- kinetic and potential energy,
- material structures and applications,
- physical properties of polymeric materials, and
- conservation of energy.

II. STUDENT HANDOUT

Simplified Vertical Rebound Testing

Scenario

When choosing a material for an application, the designer must take into consideration the inherent physical properties of the material in comparison to the service requirements. Think what athletic shoes would be like if the materials used for soles and inside linings did not have good rebound characteristics. Consider if the foam in upholstered furniture did not rebound after someone sat in it. Consider if all play balls had the same rebound characteristics how different soccer, basketball, or simply bouncing a ball would be. Not only does the designer take into consideration the material used, but also the type of construction needed to maximize desired characteristics.

As a technician for a major manufacturer of polymer based products, you have been assigned the task of evaluating the properties of several polymeric materials. Samples of these materials have been sent to your company in the form of spheres (balls). As one part of your evaluation, you will determine the vertical rebound characteristics of the samples.

Background

Resilience or rebound is an inherent property of rubber materials. This type of testing is based on the principle of conservation of energy within a closed system. The ball when dropped from a standard height, has a total potential energy before being released and this energy transforms into kinetic during the free fall. The balls has full kinetic energy immediately before impact which, in a perfectly elastic system, would result in the ball rebounding to the starting height. In actuality, some of the kinetic energy is transformed on impact into sound, heat, and vibrational energy with the ball rebound returning it to less than the original height. The molecular structure and physical properties of various polymers, as well as the construction of the ball, will cause the rebound to differ. For example, Happy and Sad balls (Decision balls, Choosit balls, Smart and Stupid Balls) appear to be identical in color, size, and density. However, the different molecular structures of these two elastomers will result in dramatic differences in rebound.

Safety, Handling, and Disposal

Wear your safety goggles at all times.

Materials

- meter stick or metric tape measure
- Happy and Sad balls
- various balls made of polymeric materials including a golf ball, a cotton ball, a Nerf ball, a croquet ball, a billiard ball, etc.
- masking tape
- (optional) wooden or tile platform for carpeted areas

Procedure

1. Tape the meter stick or tape measure to a wall such that the zero mark touches the floor. (The floor must be of a firm material or a board or large tile must be placed on the floor for the rebound surface.)
2. Hold the first ball to be tested so the bottom of the ball is level with the 100 cm mark.
3. Release the ball, and note the rebound height, recording to 0.1 cm. (Take all measurements from the underside of the ball.) Note that it may take some practice to be able to read the rebound height accurately.
4. Repeat with the same ball four more times for averaging in Step 6.
5. Assuming a close to perfectly elastic system, the loss in height of the rebound is due to the energy which is dissipated and transformed. Derive an equation for the percent of the original energy which is transformed.
6. Create and complete a data chart to display the rebound heights, % energy transformed, and the averages and standard deviations for each ball to be tested.

Questions

1. Into what various forms of energy did the kinetic energy transform on impact?
2. How did the characteristics of each ball affect the rebound?
3. Describe a product that could be made from the same material as one of the balls you tested. Explain the product's service requirements and relate the rebound data to this. Explain your logic.
4. List and explain various products (other than balls) which would require good resilience and rebound.
5. Discuss potential errors in the measurements.
6. Did some balls show a greater standard deviation than others? If so, why do you think this was the case?
7. What are the molecular structures of the materials in the Happy and Sad balls?

References

1986 Annual Book of American Society for Testing and Materials Standards, Volume 9.01 "D-2632-79 Standard Test Method for Rubber Property-Resilience by Vertical Rebound"; ASTM: Philadelphia, PA, 1986; pp. 612-613.

Kauffman, G.B.; Mason, S.W.; Seymour, R.B. "Happy and Unhappy Balls: Neoprene and Polynorbornene," *J.Chem.Educ.* 1990, *67.* 198.

Shah, V. *Handbook of Plastics Testing Technology*; John Wiley and Sons: New York, 1984.

III. INSTRUCTOR'S NOTES

Simplified Vertical Rebound Testing

Purpose

This activity provides a simple energy transformation system for you to study and calculate percent energy transformed. The results can also be used to determine applicable conditions for use.

Time Required

This activity can be completed in approximately 1 hour using 3-4 different samples.

Group Size

This activity is best completed with students working in pairs. Any size group can do this as long as there is wall and floor space available.

Materials

Per group

- meter stick or metric tape measurc
- Happy and Sad balls (One supplier for 1.5-inch balls is Hawkeye Rubber of Cedar Rapids, IA; (319) 363-2679. The balls are also sold as Smart/Stupid Balls (AP 1971) by Flinn Scientific Inc., P.O. Box 219, Batavia, IL 60510-0219; (800) 452-1261.)
- various balls made of polymeric materials including a golf ball, a cotton ball, a Nerf ball, a croquet ball, a billiard ball, etc.
- masking tape
- (optional) wooden or tile platform for carpeted areas

Safety, Handling, and Disposal

- Students should wear safety goggles.

Points to Cover in Pre-Lab

1. Use this activity as an introduction to or lab activity on energy transformation.
2. Discuss current knowledge or misconceptions related to energy transfer, kinetic and potential energy.
3. Remind students to use metric measurements and 100.0 cm as initial height. This will simplify their calculations.
4. If you do not want your students to derive the equation for the percent of the energy transformed, provide it.

% Energy Transformed = [(100.0 cm - average rebound height in cm)/100.0 cm] x 100%

5. One student will need to drop the ball and the other student will need to sit on the floor to make readings from under the ball. Students generally have great fun doing this activity. Encourage them to take as accurate readings as possible, since the drop and rebound occur very quickly. More than five drops may be needed to get the data.

Procedural Tips and Suggestions

1. Have students tape the meter stick or tape measure to a wall where the floor is flat and free of obvious imperfections or cracks. Surfaces which are not smooth may cause balls to rebound everywhere but straight up.
2. Discussion or observations may be made as to what keeps this from being a perfectly elastic system.
3. Have the students predict which balls will have the greatest rebound and why they think their answer is correct.
4. Follow this investigation with the "Glass Transition in a Rubber Ball" lab.

Sample Results

The following is a sample data chart that could be created from data collected.

Rebound Lab Data (sample)

Rebound Lab Data		
Happy ball made of Neoprene		
Trial	Rebound height (cm)	% Energy transferred
1	57.8	42.2
2	55.6	44.4
3	58.1	41.9
4	57.5	42.5
5	57.0	43.0
Average	57.2±.98	42.8±.98

Sample description: Happy ball made of Neoprene

Plausible Answers to Questions

1. Into what various forms of energy did the kinetic energy transform on impact?

A: Heat, vibration, sound are common answers. Energy was also transforming back to potential as the ball rebounds.

2. How did the characteristics of each ball effect the rebound?

A: Answers will vary based on whether they are discussing structural or material concerns. In the Happy/Sad balls it is the difference between Norbornene (or Norsorex) and Neoprene that alters the properties. The base elastomers have very different characteristics. Compounding can create very different rebounds as well. If a local compounder is willing to make balls for you, have them vary the loading of carbon black to obtain different rebound heights. It is suggested to compare similar structures to limit the confounding variables (e.g. only solid balls, only compressed air, only foam) for beginning students. Other students may be able to speculate and discuss the difference of structure and relate it to rebound.

3. Describe a product that could be made from the same material as one of the balls you tested. Explain the product's service requirements and relate the rebound data to this. Explain your logic.

A: Answers will vary. Make certain rebound data is correctly used and score on logic and expression.

4. List and explain various products (other than balls) which would require good resilience and rebound.

A: Answers will vary. For example: a tire needs good rebound to provide a smooth ride, recover from road imperfections, etc.

5. Discuss potential errors in the measurements.

A: The value for the rebound height depends on how accurately one can eyeball the point at which the ball reaches its maximum height. If the eye is not level with the underside of the ball at its maximum height, there will be an error in the measurement. If the ball is not perfectly round, there may be different rebound heights. An uneven floor or angled meter stick are other potential sources of error.

6. Did some balls show a greater standard deviation than others? If so, why do you think this was the case?

A: Answers will vary. It might be expected that slightly irregularly shaped balls or balls with low rebound heights would have greater relative standard deviations.

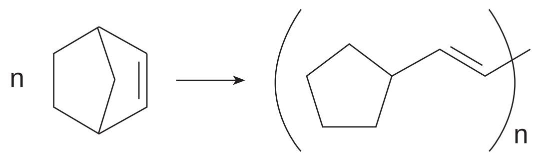
7. What are the molecular structures of the materials in the Happy and Sad balls?

A: The Happy Ball is made out of polychloroprene (neoprene) rubber. Neoprene is the product of the polymerization of chloroprene (2-chloro-1,3-butadiene):

$$CH_2 = CCl - CH = CH_2 \longrightarrow -(CH_2 - CCl = CH - CH_2)_n-$$

"n" is the number of monomers present in the reactants and the number of repeat units in the polymer. In neoprene, "n" is equal to about 100. The polymer is cross-linked by heating with zinc oxide or magnesium oxide. Neoprene has low cross-link density and a reversible elongation of 500%.

The Sad Ball is made of polynorbornene. Norbornene (bicyclo[2,2,1]hept-2-ene) is polymerized with the opening of one ring and the remaining five-membered ring and double bond becoming part of the repeat unit.



References

1986 Annual Book of American Society for Testing and Materials Standards, Volume 9.01 "D-2632-79 Standard Test Method for Rubber Property- Resilience by Vertical Rebound"; ASTM: Philadelphia, PA, 1986; pp. 612-613.

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