Happy and Sad Balls

Grades: 9-12

Science Standards: Content Standard A: Science as Inquiry; Content Standard B: Physical Science;

Background: A product commonly known as "Happy and Sad" balls is marketed by many scientific supply wholesalers through various names. While certainly some minor differences may occur in the composition of the balls, they are generally thought to be composed of the two polymers called Neoprene® and Norborene.

Neoprene® (the Happy ball) is the trade name for polychloroprene. It is the softer of the two balls and bounces well like a superball. It has high resilience and dissipates little of its kinetic energy as heat or sound when bounced. In Physics terms, we say it has a high coefficient of restitution or a good bounce. An important use for this product is that it is used for swimwear. If you are a swimmer, scuba diver, or water skier, it is used for wet suits because it tends to hold heat.

Norsorex® (the Sad ball) is the trade name for polynorbornene. It also is known as Noene®, Sorbothene®, and Astrasorb®. It has low resilience and tends to absorb or dampen the kinetic energy of the bounce. In Physics terms we call this a very low coefficient of restitution or no bounce. It produces a small increase in its temperature and the characteristic "thud" sound upon impact. It too is used as clothing in the form of artificial leather as well as sound insulation, damping, and seals and gaskets. Elastomeric and viscoelastic solid polymers are soft rubbery solids which maintain their shock absorbing properties at higher impact speeds than foam. Because they are 100% solid, they are far stiffer than foams and a large fraction of the peak impact force is still transmitted through the material. The only material suitable for making body armor is polynorbornene more commonly called by its trade name Norsorex®. This is a dense, closed cell foam that has the ability to spread impact forces over a wide area. The most common "Happy / Sad" balls currently being marketed are:

"Happy / Unhappy"Balls:

The "Happy/Unhappy" balls are available from Science Kit & Boreal Laboratories. They currently cost $3.25 per pair. The Happy ball is common neoprene and rebounds very well. The Unhappy ball is norborene polymer rubber and possesses excellent impact absorption properties which allow it to hit the floor like a rock. Although both balls are identical in shape, the Unhappy ball has a bounce of almost zero while the Happy ball rebounds very well under standard 10-30°C conditions.

"Smart / Stupid" Balls:

The "Smart/Stupid" balls available through Flinn Scientific (item #AP1971) consist of a pair of rubber balls each exhibiting a different cross-linking effect. They currently cost $6.10 per pair. The Smart ball is a polybutadiene rubber that actually contains an unusually high amount of sulfur content. Because the polymer chains in this ball are extensively cross-linked, it dissipates very little heat energy when it bounces. This makes it very resilient and has good bounce energy when it comes in contact with the floor. The Stupid ball is a styrene-butadiene copolymer that has less cross-linking. This ball hits the floor as a thud when dropped. While we call this ball Stupid, it actually has some desirable energy-absorbing effects apparent in such things as automobile tires.

"Choositz Decision" Balls:

"Choositz Decision" balls are available through Educational Innovations (item #SS-3) and consist of two black rubber balls around 1.25 inches in diameter. They currently cost $6.50 per pair.

Safety:

No safety considerations are necessary. If you are using hot water for the optional activity, be aware of the temperature of the water. If you are using liquid Nitrogen or dry ice for the optional activity, be aware of the extreme cold temperatures these materials have and take necessary precautions.

Part 1: Classroom activity

Materials:

One pair of the Neoprene® and Norsorex® balls. These balls are available from a number of scientific supply companies listed above.
Kosher salt or canning salt can also be used as it is pure salt.
Beaker or 9-oz Polystyrene cup
Chemical splash goggles

Purpose:

For this activity, the student will be comparing the densities of the two balls. The densities of the balls will vary slightly with whatever brand you use, but essentially the Neoprene® ball has a density close to that of water while the Norsorex® ball is a little more dense. To show this minor difference between the two balls, Kosher salt is added to the water to raise the density of the aqueous solution so the balls will float. Using Kosher salt tends to produce a clear solution and not cloud the solution when free running or iodized salt is used. This is a good activity to show the structure-property relationship of polymers.

Procedure:

1. Place both balls in a dish of distilled water sufficient to hold both and note that both balls sink. It should be noted that the density of water is 1.00 g/mL so since the balls sink, the density of the two balls must be equal to or greater than 1.00 g/mL.
2. Slowly dissolve some Kosher salt in the dish by stirring. The addition of the salt raises the density of the water level so that one of the two balls will float.
3. If the teacher so desires, the density of the balls could also be calculated by the Archimedes or water displacement method. The following densities of the different balls were calculated to be as follows.

Density Table:

	Neoprene®	**Norsorex®**
Happy / Unhappy		
Smart /Stupid		
Choositz	**1.216 g/mL**	**1.166 g/mL**
Tenneco	**1.115 g/mL**	**1.097 g/mL**

Part 2: Classroom activity or take home assignment.

Materials:

Styrofoam ice cooler chest
Ice from refrigerator-freezer. Dry ice (optional).
Liquid Nitrogen (optional).
Chemical splash goggles

Purpose:

For this activity students may either do this as a classroom activity or as a take home assignment. In this activity the Neoprene® and Norsorex® balls are placed in the freezer compartment of a school or home refrigerator-freezer unit and allowed to freeze overnight. The balls should be kept in a Styrofoam ice chest with ice or dry ice until it is time for the activity. The balls are then removed from the chest and a bounce test is performed on both to see if there is any effect of freezing upon the bounce of the balls. This activity can be extended by further cooling the balls in liquid Nitrogen (LN_2) and then bouncing them as they warm to room temperature. Be careful to not drop the balls until they warm to room temperature or they will shatter and cannot be repaired. At T_g (glass transition temperature), damping will be observed and the balls will not bounce. Does this mean the balls have the same glass transition temperature?

Part 3: Classroom Activity

Materials:

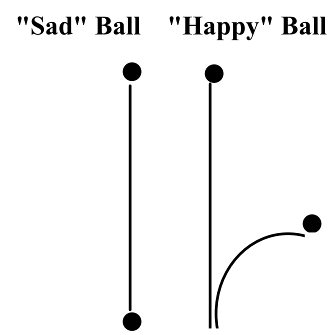
Balls from Activity 1
Hotplate
Pan or Pyrex glassware
Water
Tongs
Chemical splash goggles

Purpose:

For this activity both balls will be placed in a pan of simmering water for about 10 minutes. Using tongs, the student will remove one of the balls from the pan and the bounce test is performed to see if there is any effect of heat upon the balls. Because of the heat involved it is recommended that students use tongs exclusively when handling the heated balls for obvious safety reasons. What they will find is that heating the Sad ball in boiling water makes the ball considerably more elastic and will bounce to perhaps one-third that of the Happy balls bounce. While the Happy ball is also affected by the heat, the bounce from this ball has no appreciable effect as it basically bounces the same as it did at room temperature.

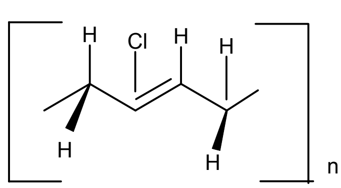
General Questions For All of The Activities:

1. What is the difference in behavior of the two balls when dropped?
2. Before the balls were dropped, how did their energies compare?
3. How did the energy compare after they hit the floor?
4. Which ball lost more energy?
5. Where did the energy go?
6. Explain how this effect would be different on the moon.

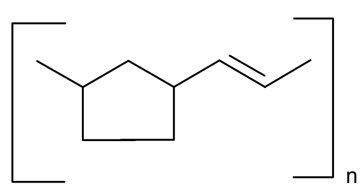


More Chemistry:

The chemical structures for the two elastomers are shown below:



Neoprene rubber



Polynorbornene

Polymers such as elastomers have a rather unique property referred to as the glass transition temperature or T_g. This property is the temperature in which the material changes from a hard, glassy crystalline material to a soft, rubbery, amorphous material. The two balls have different glass transition temperatures and that partially accounts for the reason they bounce at different levels. With the so-called Happy ball, its glass transition temperature of -42°C makes it highly elastic at temperatures above its glass transition temperature and therefore has a higher level of rebound vs bounce rate. (The glass transition temperature for the Sad ball is 35°C.) Upon cooling the Happy ball below its glass transition temperature with liquid Nitrogen (LN_2), the ball becomes less elastic and the bounce rate is also less. Heating this ball in boiling water has no appreciable effect as it basically bounces the same as it did at room temperature.

The so-called Sad ball has a glass transition temperature of 35°C and this makes it very non-elastic and therefore does not bounce very high. It actually is sometimes characterized as falling "like a rock" or making a thud-like sound. Upon cooling it with either ice cubes in a Styrofoam chest, dry ice,or LN_2, the ball bounces even less than at room temperature. Heating the ball in boiling water makes the ball considerably more elastic and will bounce to perhaps one-third that of the Happy ball bounce.

The following chart illustrates the bounce rate of the two balls in relation to what your students should find with temperature. If liquid Nitrogen is not available, it is suggested you use dry ice if possible to see the effect as illustrated below. The use of ice cubes or freezing the night before in the freezer really does not produce the noticeable effects listed below.

Bounce of Balls vs.Temperature

	"Happy" Ball	**"Sad" Ball**
Room Temperature	**Bounces**	**Small Bounce**
Cool with LN_2	**No Bounce**	**Bounces even less**
Boil in Water	**Bounces the same as it did at Room Temperature**	**Will Bounce 1/3 as high as the "Happy" Ball**

References:

Harris, Mary. Macromolecules: A Workshop for Middle Level and High School Teachers. 1996.

"That's The Way the Ball Bounces" Sports Issue of Exploring Magazine. 1991.

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