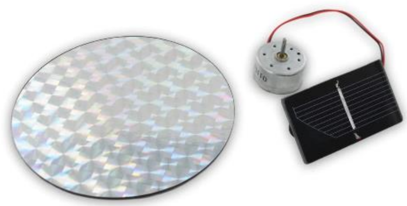
# Energy Discovery Bundle

**P6-6060**

## Contents

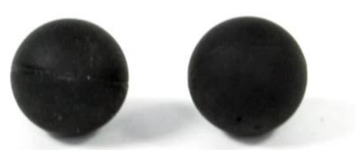
Radiometer



Solar Energy Science Kit

Newtonian Demonstrator

UV Beads 250 Pack



Happy/Unhappy Balls

Dropper Popper

Ice Melting Blocks

Colliding Steel Spheres

| Item | Topic | Instructions |
| --- | --- | --- |
| Radiometer (P3-8105) | Heat to Kinetic | Instructional Guide Included |
| Solar Energy Science Kit (P6-7000) | Light to Potential | Instructions Included in Packaging |
| Newtonian Demonstrator (P1-6001) | Potential to Kinetic | Instructional Guide Included |
| UV Beads 250 Pack (P3-6500) | Light to Chemical | Instructional Guide Included |
| Happy/Unhappy Balls (P6-1000) | Potential to Kinetic (to Potential) | Instructional Guide Included |
| Dropper Popper (P6-6075) | Deformational potential to Kinetic | Instructional Guide Included |
| Ice Melting Blocks (P6-7060) | Thermal transfer | Instructional Guide Included |
| Colliding Steel Spheres (P6-6070) | Kinetic to Thermal/Sound | Instructional Guide Included |

## Related Products

**Converting Gravitational Potential Energy to Kinetic Energy Kit (P6-7930)** This kit introduces students to the concepts of kinetic and gravitational potential energy and the conversion of one form of energy into another.

**Dye Sensitized Solar Cell Kit (P6-2150)** Caltech scientists, working with local high school science teachers, have created a self-contained kit for their Juice from Juice project that demonstrates how you can use blackberry and other fruit juices to generate power from sunlight.

**Conceptual Physics Alive: Energy (99-0080)** In this video, Paul Hewitt teaches Energy: Mechanical energy in its potential and kinetic forms is illustrated with demonstrations that include a bouncing dart, a pendulum, and a simple pulley system. The conservation of energy is illuminated using everyday examples and a hand-cranked electric generator.

ARBOR SCIENTIFIC

# Radiometer

P3-8105

## INSTRUCTIONAL GUIDE

## Contents

- Radiometer
- Instructional Guide

## Background

The Radiometer is a means of showing the relation between heat and molecular activity of a gas in a visible way. It also shows that light is a form of energy and that it can be converted into other forms of energy.

The Kinetic Theory of Gases states that the atoms and molecules in a gas or a mixture of gases are in constant random motion. This energy of movement (kinetic energy) depends only on the temperature of the gas. As the gas is heated, the molecules respond by moving faster and faster. This movement, when the gas in a contained system, give rise to gas pressure as the individual molecules strike the containing walls. As the temperature increases, the molecules move with ever increasing energy, striking the walls of the container more frequently and with greater force. Thus, it can be seen that the pressure exerted by a gas is related to the temperature of the gas. (It should be noted that the volume of the container is also relevant in this relationship-see *Boyle's Law* in any physics text).

## How it works

**Caution:** Handle the Radiometer carefully – its delicacy is about that of an ordinary light bulb. Should the bulb break, glass fragments will be sharp! Cautiously dispose of the glass but retain the pivot and vanes for some optional experiments (number 5 and 6)

The Radiometer consists of a rotating shaft with four vanes, sealed in a glass container which has had over 99% of the air removed. The vanes are painted black on one side, silver on the other. In the presence of light with an infrared (heat) component, the remaining molecules inside the bulb begin to move faster. At the same time, the light is striking the surface of the vanes. The silver surface reflects much of this radiation, but the non-reflective black surface absorbs it and becomes warmer.

As the randomly-moving molecules strike the vanes from all sides, the ones striking the dark surface absorb some of this heat and bounce away with more kinetic energy. This results in a slightly greater "kick" being delivered to the dark side of the vane; the accumulation of thousands of these slightly greater "kick" to the dark side of the vanes cause the vanes to spin. Because the movement of the gas molecules depend on the amount of heat in the system, and because increasing the light level results in additional heat delivery, it follows that the speed of vane rotation is dependent on the intensity of the light.

## Activities

Some of your students may accept the previous as gospel. The more inquiring mind, however, usually demands a little more in the way of proof. Below are some suggested exercises for more advanced understanding.

1. **Place the bulb in sunlight on a partly cloudy day.** Note that the rate of spin is greatest in sunlight, less as a cloud blocks the sun.
2. **Apply heat alone to the bulb.** Do the vanes spin? Heat will cause an increase in molecular motion, but without radiated heat to differentially warm the vanes, the collision on each side of the vanes will occur with the same energy. The vanes will not spin.
3. **Use various filters (dark glass, clear glass of varying thickness, cardboard, paper) to block the light and note how the rate of spin is affected.** Can you determine what effective component of the light is being blocked?
4. **Will the radiometer spin backwards?** Because the dark side also radiates heat away faster than the silver side, if you put a piece of ice on the radiometer, it will spin the opposite direction, because now the dark side is cooler.
5. **Will the radiometer work if the vanes are not in a vacuum?** You will need to be "lucky" enough to break your radiometer bulb to determine this. In a normal atmosphere, the differential warming of the vanes and increased kinetic energy of the gas molecules will still occur. But there are so many gas molecules in air compared to the evacuated bulb that the molecules will be hitting each other constantly and not be able to affect any movement of the vanes. Even if they did, the vanes would not be able to spin through the milling throngs of molecules-the resistance would be too great to overcome.
6. **Definitive proof.** Set up the vanes and pivot from a broken Radiometer (secured in a bit of clay) in a bell jar connected to a vacuum pump. Apply a constant source of light and see what happens. Turn on the pump and begin to evacuate the chamber. The vanes should begin spinning. If perfect vacuum could be reached, the vanes would once again fail to turn. Why? In this experiment, do you ever reach a point where enough air is removed to notice a decrease in peak spin?

## Related Products

**Radiation Cans, Set of 3 (PX-2084)** Radiation Cans are perfect for experiment with the Laws of thermodynamics. Just add water and a thermometer or temperature sensor to each of these three cans, place in near a light source, and watch the temperature rise.

**Ice Melting Blocks (P6-7060)** Cool experiment kit! Touch these two black blocks, and one feels cooler. This discrepant event introduces many concepts, including heat transfer, change of state, and thermal conductivity.

**Solar Furnace (96-7280)** Ideal for classroom demonstrations on solar energy! The Solar Furnace effectively showcases the transfer of energy between solar radiation and thermal energy.

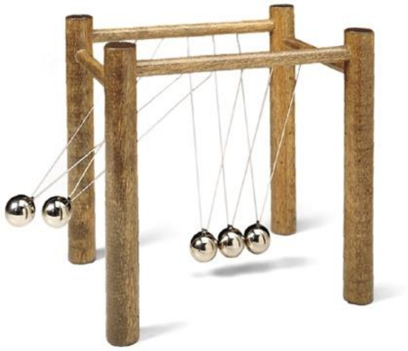
# Newtonian Demonstrator – Newton's Cradle

P1-6001

INSTRUCTIONAL GUIDE

## Contents

- Newtonian Demonstrator
- Instructional Guide



## Introduction

This classic apparatus provides a dramatic demonstration of several fundamental physical principles, but is by no means a simple device. Since the historic seventeenth century demonstration of the effects of two colliding pendulums, there has been considerable debate over exactly what the demonstration was showing. Primarily, the Newtonian Demonstrator illustrates Newton's Third Law—for every action, there is an equal and opposite reaction. Thus, when one ball is swung out and released, one is "kicked" out the other side, two when two balls are released, and so on.

## Background

The apparatus also is used to demonstrate the conservation of linear momentum: when two or more bodies collide, their total momentum (mass x velocity) is the same before and after the collision. An example of this principle is seen in the firing of a gun, the "collision" being provided by the discharge of gunpowder. When the gun is fired, the velocity of the bullet times its mass equals the mass of the gun times its recoil velocity. Since these two measures are equal and opposite (Newton's Third Law), their sum will be zero. Since their momentum before firing was also zero, it can be seen that linear momentum has been conserved. Momentum will be conserved in any colliding system, whether the colliding objects move opposite from one another, in the same direction, or at some angle after the collision.

Lifting one or more balls gives them energy of position, also known as potential energy. Releasing them to the forces of gravity gives them energy of movement, or kinetic energy. When the balls collide, the total momentum of the system is unchanged, that is, the sum of [mass x velocity] of each component is the same before and after collision. Thus, the momentum of the system is conserved.

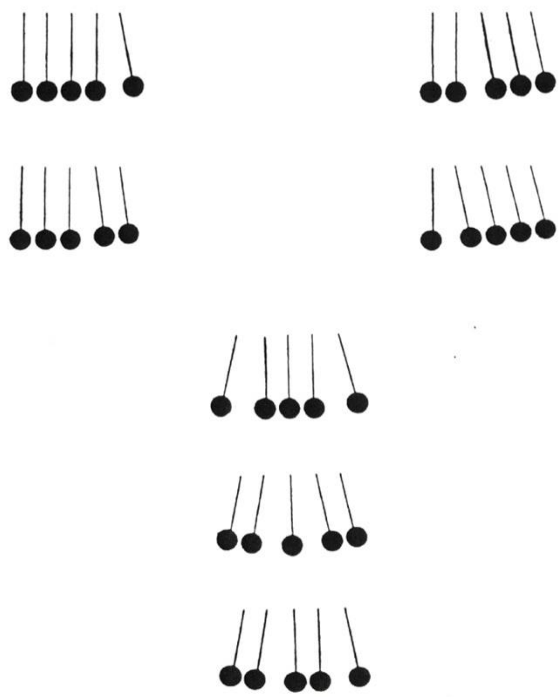
Great! But if momentum is truly conserved, why does the system eventually slow and stop? To answer this, one must consider the law of conservation of energy, which states that energy can neither be created nor destroyed, but can only change from one form to another. In this demonstration, we are not dealing with an "ideal" system isolated from all other forces. The balls are meeting resistance from the air, as are the supporting strings, and some energy is lost with each collision by being converted into heat, another form of energy. Though momentum is being conserved, energy is gradually "lost" (i.e.,

converted to other forms of energy), and the system eventually stops.
**CARE:**

Avoid magnetic fields: any magnetism in the balls will hamper performance. To prevent induced magnetism, let the balls swing in the East-West direction. If the balls appear to attract each other when hanging free, clean them. If the condition persists, store the unit in its original carton in a very warm, dry place. Use of electronic demagnetizers may hamper performance.

- Alignment of the balls may be adjusted by moving string gently through the ball.
- Clean the balls to keep them bright and free from surface dirt. Silver polish and a soft cloth are best.
- Rocking of the frame may occur during use. If adjustment is needed, try twisting the frame or shimming the short leg with a bit of clay or tape.

**STARTING PATTERNS:**



## Related Products

**Magnetic Accelerator (P4-1365)** Is energy conserved in a magnetic field? Watch as students try to figure out this amazing demo.

**Collision in Two Dimensions Apparatus (P2-8450)** The Collision in Two Dimensions Apparatus allows students to experience the conservation of momentum and kinetic energy by investigating the difference between elastic, inelastic, and partially elastic collisions.

**Bouncing Dart (PX-1204)** The Bouncing Dart demonstrates the energy transfer that occurs in elastic and inelastic collisions. The dart has an elastic end and an inelastic end.

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# UV Beads

P3-6500, P3-6505

INSTRUCTIONAL GUIDE

## Contents

- 250 multi-colored UV Beads (P3-6500)
  **OR**
- 1000 multi-colored UV Beads (P3-6505)

**Recommended for activities:**

- UV Flashlight and Holder (P2-9045)
- Sunglasses
- Different types of bulbs

## Background

UV Beads contain a chemical that changes color when exposed to ultraviolet light and will fade back to white without UV exposure. The beads can cycle back and forth over 50,000 times. The sun emits ultraviolet light, so exposing the beads to sunlight will cause their color to change. Students can experiment with different conditions and see which cause a color change. The ultraviolet wavelengths in sunlight cause skin to tan and burn. Students can relate the results of their experiments to the likelihood of getting sunburned in different conditions.

The electromagnetic radiation needed to affect change is between 360 and 300 nm in wavelength. This includes the high-energy part of UV light Type A (400-320 nm) and the low energy part of UV light Type B (320-280 nm). Long fluorescent type black lights work well; incandescent black lights and UV-C lamps will not change the color of the beads.

## Introduction

The dye molecules in the UV Beads consist of two large, planar, conjugated systems orthogonal to one another. No resonance occurs between two orthogonal parts of a molecule. When high energy UV light excites the central carbon atom, the two smaller planar conjugated parts form one large conjugated planar molecule. Initially neither of the two planar conjugated parts of the molecule is large enough to absorb visible light and the dye remains colorless. When excited with UV radiation, the resulting larger planar conjugated molecule absorbs certain wavelengths of visible light resulting in a color. The longer the conjugated chain, the longer the wavelength of light that is absorbed by the molecule. By changing the size of the two conjugated sections of the molecule, different dye colors can be produced. Heat from the surroundings provides the activation energy needed to return the planar form of the molecule back to its lower energy orthogonal colorless structure.

Although UV light is needed to excite the molecule to form the high-energy planar structure, heat from the surroundings provides the activation energy to change the molecule back to its colorless structure. If colored beads are placed in liquid nitrogen, they will not have enough activation energy to return to the colorless form.

## Experiments

1. What kinds of light contain UV? Expose the beads to light from different sources, including the sun, incandescent light bulbs, fluorescent light bulbs, colored lights, and a blacklight (P2-9035).
2. Can you get sunburned on a cloudy day? Can you get sunburned in the shade?
3. How effective are different sunscreens? Coat the beads with different brands and compare the rate of color change.
4. Can UV pass through window glass? Try different types of glass, including tinted glass and car windows.
5. How much UV protection do different types of sunglasses provide?
6. How does the amount of UV from the sun compare to the UV in tanning booths?

## Related Products

**Portable Blacklight (P2-9035)** Portable ultraviolet light source runs on 4 AA batteries.

**Willemite, Quartz Demo Kit (P3-6700)** A New Way to Explore Properties of Light Willemite is a fluorescent metamorphic rock with the unusual property of fluorescing only in the short wave UV.

**Demonstration Electroscope (P6-1170)** This electroscope's design makes it superior to traditional leaf-style electroscopes in part because the needle stays put as experiments are performed. Clearly demonstrate the photoelectric effect by shining UV light at the charged aluminum plate attachment.

ARBOR SCIENTIFIC

# Happy Unhappy Balls

P6-1000

INSTRUCTIONAL GUIDE

## Contents

- Happy ball
- Sad ball
- Instructional Guide


Recommended for activities:

- [Inclined Plane (P3-3541)]

## Background

Happy and Unhappy Balls sometimes known as Happy Sad Balls, are a pair of black spheres which appear to be almost identical. The “unhappy” ball is formed from a proprietary rubber compound developed and manufactured under the trade name “Norsorex,” while the “happy” ball is made of conventional neoprene rubber. Although the two balls appear to be quite similar, their physical properties are markedly different.

**Low v. High Hysteresis**: Hysteresis is a measure of the rate of restitution of the natural tendency of rubber to return to its original shape after deformation. This rate of restitution is caused by internal frictional forces resulting from the molecular structure of the rubber. The dead or “unhappy” ball exhibits the greatest hysteresis.

**Rate of Restitution**: The ball with low hysteresis (the “happy” ball) exhibits a more rapid return to its original shape, resulting in its greater bounce (it has a high coefficient of restitution).

Paradoxically, as the balls are cooled below room temperature, the bounce of the “happy” ball is diminished somewhat while that of the dead ball increases. **Figure 1** shows the changes in the energy absorption rate of Norsorex with changes in temperature.

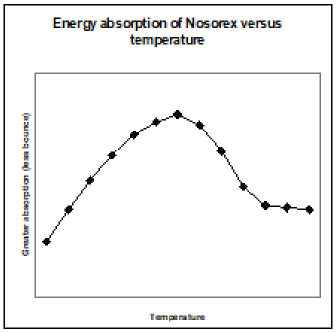
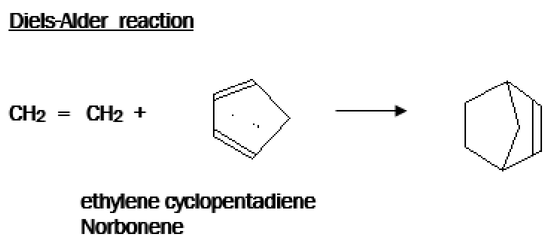



Figure 1




**Coefficient of Friction**: The molecular structure of the two types of rubber is also responsible for discrepant qualities in the surface friction of the balls. The “happy” ball exhibits lower surface friction and rolls more rapidly than the dead ball.

## Experiments

Challenge your students to perform the following experiments and come up with logical explanations for the observed events.

1. **A Rolling Ball Gathers Momentum:** Set up an inclined plane at least one meter in length and roll both balls simultaneously from the same starting point. Note which ball reaches the end of the incline first. Does it do so consistently? What clues does this provide about the friction of the balls relative to the surface and in comparison, with each other? The "unhappy" ball, of course, because of its higher coefficient of friction, rolls more slowly. It is this friction which makes rubber of this type very desirable for racing tires where road adhesion is required at high speed. Too much friction, however, will cause heat buildup and excessive tire wear, so this property must be balanced by blending high-friction rubber with a more firmly vulcanized rubber.

2. **Sphere of Flying:** Drop both balls onto a hard surface from a fixed height and determine the height of the first bounce (if any). Place both balls in a container of ice or a freezer for about twenty minutes and repeat your measurements. What differences are observed? Why does the dead ball bounce? Would you think that the dead property of the rubber is temperature dependent? Why?

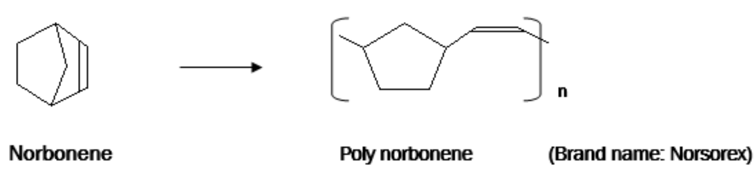
3. **The Chiller Instinct:** Determine the rate at which each ball returns to shape after being compressed by a vise or heavy tongs. Chill the balls first as before, then repeat. Are there differences in the rate at which the balls return to shape?

**Restitution** is the "desire" of a substance to return to its original shape, almost a molecular memory of its original form. The dead ball has a very low coefficient of restitution, the other ball a high coefficient; each property can have practical benefits. In running shoes, for example, the superior ability of a "dead" rubber to absorb shocks helps to alleviate the tremendous pounding to the foot, leg, and ankle. A rubber with a high coefficient of restitution – that is, one with a lot of bounce – would be ideal for handballs or other applications. Ask your students to think for practical uses for both types of rubber.

**Chemical Formulation: Figure 2** outlines the primary steps in the formation of Norsorex. First, ethylene cyclopentadiene is converted to the monomer norbornene via a Diels-Alder reaction, then the monomer is converted polymerized by a process which opens the norbornene ring, creating alternating bonds between the five-member ring and the newly-exposed double bonds. This polymerization process means that vulcanization can be done utilizing the double bond.

Figure 2

Ring-opening polymerization




## Related Products

**Astro Blaster (P1-5000)** The Astro Blaster lets you dramatically demonstrate the Law of Conservation of Momentum to almost any age level. Drop it on a hard surface, then stand back as the top ball bounces to heights up to 5 times the original drop!

**Dropper Popper (P6-6075)** The ultimate "Super Ball" is really only half a ball! Turn this popper inside out and drop it.

**Discrepant Events Kit (P6-6025)** 12 Demonstrations that Reveal the Magic of Science! Award-winning physics teacher Buzz Putnam shares his secrets to grabbing students' attention and making them think!

# Dropper Popper

P6-6075

INSTRUCTIONAL GUIDE

## Instructions

Flip the Dropper Popper inside out and drop from shoulder height, flat side down. On impact, the popper returns to its original shape and bounces higher than your head!

**Lesson Ideas:**

**Conservation of Energy:** A perfectly elastic ball would bounce back to its original height. How does this popper bounce higher? You stored extra energy in it when you pushed it with your fingers.

**Activation Energy:** Energy is stored in the popper as in a molecule. With a little bit of "activation energy" (dropping from a height), the stored energy can be released.

## Troubleshooting

- Knead the rubber so the popper will stay inside out until it lands. Flip inside out and Pop in your hands multiple times to break it in. You can flip and pinch backwards to encourage it to stay open longer.
- Dropper Poppers perform differently depending on temperature, humidity, and surface texture. Works best when used on carpet. When used on a hard surface a greater force is needed therefore it must be released from a greater height.

## Related Products

**Happy/Unhappy Balls (P6-1000)** One of our all-time favorites! Side by side, these two black rubber spheres look identical. But, when you throw them to the ground, one bounces wildly about the room, while the other just lies there no matter how hard you throw it.

**Astro Blaster (P1-5000)** The Astro Blaster lets you dramatically demonstrate the Law of Conservation of Momentum to almost any age level. Drop it on a hard surface, then stand back as the top ball bounces to heights up to 5 times the original drop!

**Magnetic Accelerator (P4-1365)** Is energy conserved in a magnetic field? Watch as students try to figure out this amazing demo.

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# Ice Melting Blocks

P6-7060

INSTRUCTIONAL GUIDE

## Contents

**Ice Melting Blocks:**

- One black aluminum block
- One black high-density foam block
- Two rubber O-rings

**Recommended for Activities:**

- **Infrared Laser Thermometer (68-6510)**

## Background

Heat can be transferred by conduction, convection, or radiation. In this experiment, students will discover the different rates at which materials can conduct heat. Aluminum is a better conductor of heat than high-density foam.

## Investigation

1. Touch both blocks. Which feels warmer? (The foam block will feel warmer.) Predict which block will cause ice to melt faster.
2. Place the O-rings on the blocks to prevent water from flowing off. Place an ice cube on each block.
3. Observe the rates at which the ice cubes melt. Which material is conducting heat into the ice faster? (The aluminum block will melt ice much faster than the foam block.)
4. After a few minutes, remove the ice and water, and touch the blocks again. Explain what you observe. (The aluminum block feels even cooler now, and it is cooler. Energy stored as heat inside the block was transferred to the ice when it melted. Now the block has less thermal energy than before.)
5. The aluminum block felt cool at the beginning for the same reason that it melted the ice faster. It is better at conducting heat away from your hand, and makes your skin feel cool.

## Related Products

**Thermal Conductivity Bars (P6-7090)** Study heat conductivity in different metals. Observe the temperature gradients along the metal bars, and watch them evolve.

**Ball and Ring Apparatus (33-0630)** This brass ball fits easily through the matching ring when they are both at room temperature. Heat the ball in a flame, and experience the results of thermal expansion.

**Compound Bar (P6-7070)** Thin strips of two different metals are laminated together in this simple demonstration, also known as a Bimetallic Strip. Demonstrate thermal expansion.

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# Colliding Steel Spheres

P6-6070

INSTRUCTIONAL GUIDE

## Contents

- Two 1-pound, 2-inch diameter steel spheres
- Instructional Guide

**Recommended for activities:**

- Paper
- Aluminum foil

## Background

Most students can tell you that mechanical systems convert some energy to heat. When objects collide, the kinetic energy transforms into sound, heat, and kinetic energy in the opposite direction. But it can be difficult to observe the heat produced.

## Activities

**Caution: Do not place fingers or important documents between the spheres!**

1. Hold the spheres on either side of a sheet of plain paper. Carefully (but firmly) crash the spheres together, with the paper in between. Look at the paper. There should be a hole. To confirm that the hole was actually burned in the paper, sniff the paper and smell the smoke.
2. Try thicker papers, or multiple layers. Avoid paper with wax coatings (such as manila folders), as the wax will prevent a hole from forming.
3. Use a sheet of aluminum foil. The force of the colliding spheres creates a permanent concentric ripple in the foil, showing how energy is dispersed through solid matter.

## Related Products

**Fire Syringe (P1-2020)** A smokin' example of adiabatic heating. Using the Fire Syringe to compress air into a smaller volume is a classic example of how rapidly doing work on a gas results in an increase in temperature.

**Dropper Popper (P6-6075)** The ultimate "Super Ball" is really only half a ball! Turn this popper inside out and drop it. The stored energy is released upon impact, and the popper bounces higher than your head!

**Newton's Cradle (P1-6001)** Newton's Cradle dramatizes Newton's Third Law, which states that for every action, there is an equal and opposite reaction. Use to illustrate that momentum and kinetic energy are conserved.