Science Toys Discovery Bundle

P8-9015

Contents

Drinking Bird

Single Cartesian Diver

Vortex Tube

Happy Unhappy Balls

Balancing Bird 6 inch

Celts

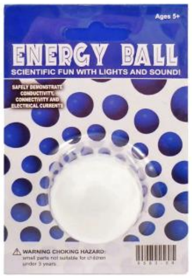
Super Springy

Radiometer

Dropper Popper

Mystery Stick

Balloon Helicopter Kit



Energy Ball

Hand Boiler

Revolution

SpillNot

Extreme Gyroscope

Item	Topic	Instructions
Drinking Bird (P3-5001)	Center of Gravity, heat transfer, thermodynamics	Instructional Guide Included
Single Cartesian Diver (P1-2000)	Pressure, buoyancy, density, Pascal's Law	Instructional Guide Included
Vortex Tube (P1-1120)	Pressure, fluid dynamics	Instructional Guide Included
Happy Unhappy Balls (P6-1000)	Energy conservation, potential / kinetic energy	Instructional Guide Included
Balancing Bird 6 inch (P3-5002)	Center of gravity, opposing forces, balance, equilibrium	Thanks to two well-placed weights at the end of the wings, the bird's center of mass is located below the tip of its beak, creating a stable equilibrium. Show students how deceiving an object's center of mass can be. Spin it on the end of your finger to demonstrate rotational motion, or discuss movement in two systems by moving your hand through the air to add translational motion.
Celts (P2-2120)	Oscillation, center of gravity	The physics of the Celt is very complex, but it still can be useful for teaching in introductory-level science classes. Place the Celt on its curved side and spin it counter-clockwise. Not very interesting? Try spinning it clockwise. The Celt reverses and goes back to spinning counter-clockwise! Ask students to observe the motion and make hypotheses.
Super Springy (33-0130)	Wave behavior, types of waves, harmonic motion	Demonstrate transverse waves by shaking the Super Springy from side to side. Show longitudinal waves by shaking it parallel to its length. Many other wave phenomena can be demonstrated, including reflection, interference, and the dependence of a wave's speed on its medium.
Radiometer (P3-8105)	Energy transfer, molecular energy	Instructional Guide Included
Dropper Popper (P6-6075)	Stored potential energy	Instructional Guide Included
Mystery Stick (P2-2200)	Harmonic motion	Instructions Included
Balloon Helicopter Kit (P4-2350)	Newton's Laws, applied physics	Instructional Guide Included
Energy Ball (P6-2300)	Circuits, electricity	Instructional Guide Included
Hand Boiler (P3-5005)	Thermodynamics, gas laws	Instructional Guide Included
Revolution (P3-6050)	Magnetic levitation, friction, magnetism	Your gravity-defying demonstration begins with a gentle spin from your fingers! Magnets take over, levitating the axle so it spins in near-perpetual motion.
SpillNot (P4-2500)	Center of gravity, acceleration	Instructional Guide Included
Extreme Gyroscope (P3-3500)	Angular momentum, gyroscopic precession	A classic educational toy, the gyroscope exhibits a mysterious force that seems to defy gravity. It is based on the principal of the conservation of angular momentum. Once spinning, it tends to resist change to its orientation. The Extreme Gyroscope is given its impulse by spinning it up with the non-twisting string or energizing it with the toothy T-handle.

Related Products

Horizon Energy Box (P8-3500) The Energy Box is full of topic-specific kits including the Wind Turbine Kit. More than 100 experiments, using 54 items, can be performed as described in the manual.

Conceptual Physics Alive: Introduction (99-0010) Master teacher Paul Hewitt teaches non-computational Conceptual Physics. Observe Hewitt teach in a classroom with real students, using engaging demonstrations and artwork.

Drinking Bird

P3-5001

INSTRUCTIONAL GUIDE

Background

The Drinking Bird uses evaporative cooling to move a fluid in its body. When the fluid moves, it changes the center of mass and makes the bird tip.

When the bird tips, the beak should touch water. The water sticks to this fuzzy head and starts to evaporate. This cools the gas inside, lowering its pressure. Some of this gas will also condense, lowering the pressure further. The pressure in the bottom is now higher than the pressure in the top, which pushes the fluid up the body. When enough fluid moves up, the center of mass (center of gravity) is moved above and forward of the pivot point. The bird tips, allowing the pressure to equalize and the fluid to flow back down into the bottom. The beak gets wet and the process repeats itself.

Heat consists of random motion and the vibrations of atoms, molecules, and ions. The higher the temperature, the greater the atomic or molecular motion. Increased temperature means greater average energy of motion, so most substances expand when heated. Describe common physical changes in materials: evaporation, condensation, thermal expansion, and contraction.

Introduction

The Drinking Bird has a fuzzy head with a weighted beak. The body contains a fluid and can pivot forward on its legs. The drinking bird needs a glass or beaker of water positioned so that when he tips his beak will get wet.

The fuzzy head is important. It allows water be drawn up to the head. More water can stick to the fabric than to glass and it increases the surface area for the water to evaporate. The weighted beak makes it possible for the fluid to change the center of mass enough to make it tip.

The working fluid inside the traditional drinking bird is methylene chloride. It is a volatile (easily evaporated) fluid. The fluid will easily evaporate in the bottom and condense in the top, helping to create more of a pressure difference. Non-volatile fluids would work, but would not be as effective.

The key to making the fluid move is a pressure difference between the two sections of the bird. Since the body is sealed, a temperature difference is used to change the pressure. Instead of cooling the head by evaporation, it is possible to heat the bottom and make the bird tip. Anything that will cause the body to be at a higher temperature than the head will make the bird work.

Troubleshooting

- The pivot and legs are not adjusted properly – the bird cannot move freely.
- The head is dry – it is not reaching the water.
- The humidity is too high – the water will not evaporate quickly enough from the head.

SAFETY INFORMATION:

This product is not a toy and is not intended for use by children under age 8. Contains Phthalates. Keep away from heat and flame.

Activities

- Set up the Drinking Bird in front of a glass of water. Adjust the level of the bird and the glass so that the bird will dip his beak into the water when he tips. Hold the head in the water long enough so that it gets thoroughly wet. Let him go!
- Have the students give a complete explanation of why he tips – make sure to include the center of mass, evaporation, and the pressure difference.
- How long will the bird operate if the water is removed? It will still go for a while until most of the water on the head evaporates.
- Try other ways of making the bird operate. Some possibilities: cool the head with something else, such as ice, heat the body with your hand or some other warm object.
- Paint the bottom bulb of the bird black. Place him in sunlight or under a bright light. The body will absorb enough energy to make the bulb warm and the bird will operate without water.
- Have races between groups. Who can make their bird tip the most times in a minute (without touching it)? Try different temperatures of water, using a light, using a fan, and other methods.

Related Products

Hand Boiler (P3-5005) This energy transformation is sure to capture your students' attention! Hold the glass vessel in your hand, and your body heat causes the liquid inside to boil and shoot into the top bulb! Assorted colors and styles.

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

Radiation Cans (PX-2084) are perfect for experimenting 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.

Single Cartesian Diver

P1-2000

INSTRUCTIONAL GUIDE

Contents

- Cartesian Diver
- Instructional Guide

Required for activities:

- Empty 2-liter bottle

Background

We are so accustomed to the invisible air surrounding us that we sometimes forget that air has mass and weight, occupies space, and exerts pressure. Each of these properties are directly related to the concept of air *density*. A table with the densities of various gases is on the right. Let your students calculate the number of cubic meters in your classroom and multiply by 1.21 kg/m^3.

Gas		Density (kg/m^3)
Dry Air	0^oC	1.29
	10^oC	1.25
	20^oC	1.21
	30^oC	1.16
Helium		0.178
Hydrogen		0.090
Oxygen		1.43

* At sea-level atmospheric pressure and at 0^oC (unless otherwise specified)

Air density simply reflects the relation between its weight and the amount of space it occupies. Decrease the volume and the density goes up because the same amount of mass is being squeezed into a small area. Increase the volume and the density goes down as the mass is spread over a larger area. Air density is also related to air pressure. A scientist named Robert Boyle discovered this relationship. *Boyle's Law* simply states that if the density goes up or down, then the pressure goes up or down with it. Conversely, if you apply pressure to a gas by, say, pushing it into a smaller container, the density goes up. If you release pressure, the density goes down.

Air pressure and density can help explain the barometric property of air. When two air pressures meet, they push on each other (they are forces, after all). The two pressures will push on each other until they balance. For example, your windows don't break because the air pressure on one side is equal to the air pressure on the other.

Introduction

Buoyancy rules are also related to density. The buoyancy law states that an object surrounded by a fluid is buoyed up by a force equal to the weight of the fluid displaced by the object. In the case of a boat, as long as the boat weighs less than the total weight of the water that it displaces, it will float.

Buoyancy laws apply to the cartesian diver as well. As long as the combined density of the pipette, rubber cover, steel mass, and the air/water mixture inside are less than the density of the water it displaces, it will float. These cartesian divers were designed with just enough weight to bring it very close to the point of sinking, but not quite. But as soon as outside pressure is exerted, the air inside compresses, the volume of the air decreases, and more water is pushed into the pipette. The diver now is too dense to remain buoyant - hence, it sinks.

Activities

1. The diver usually requires a bit of water inside the pipette to float. To find out exactly how much is mostly a trial and error game. First, try this: Fill a clear glass with water. Get water inside the diver by squeezing the pipette and releasing so that it sucks up water. Then drop the diver in the glass. Does it float or sink? If it sinks to the bottom, the diver contains too much water. If it falls over and lays on top of the water, it needs more. The water level is just right when it stands upright but is mostly submerged. After a little experience, you will be able to suspend the diver at different depths in the glass by controlling the water level.
2. Fill a 2-liter bottle all the way to the top with water. Place the diver in the bottle with the correct amount of water contained inside of it (the steps in (1) can be done by trial and error now with the 2-liter by adjusting the water level until the diver behaves properly.) Put the cap on the bottle and squeeze the middle of the bottle. The diver should sink. When you release the pressure on the bottle, the diver should rise back up to the top.
3. Try demonstrating the above phenomenon without the squid rubber cover on the pipette (be careful not to tear the rubber when taking it off and putting it back on; see the last hint below.) This way, students can see the water level inside the pipette before, during, and after squeezing the bottle. To make it more visible, try using water with coloring in it. When the bottle is squeezed, the water level in the pipette goes up. Ask your students where all of the air goes? This demonstration requires students to understand the concept of air density.

Helpful Hints

- Make sure to fill the bottle to the very top with water.
- Use room temperature water when filling your bottle. Otherwise, as the water heats up or cools, it will affect the pressure in the bottle and the water level in the diver.
- The diver may sink on its own over time due to temperature and atmospheric pressure changes and gas coming out of solution in the water. To correct, first try opening the 2-liter bottle. If this doesn't work, remove the diver and readjust the water level as in step 1.
- Try not to leave the rubber squid in the water for a long period of time because it may start to deteriorate.
- If you decide to remove the rubber squid from the pipette, put a few drops of oil on the pipette before replacing. This will allow it to slide on easily and will help make a tight seal so that water doesn't get underneath.

Related Products

Super Diver Kit (P1-2000-01) The Cartesian Diver demonstrates all three properties using hands-on experiments. Make 30 plain divers with this kit.

Galileo's Thermometer Fahrenheit (P3-5006) Our Galileo's Thermometer is a great attention getter when discussing topics on pressure and fluids or the gas laws.

Hand Boiler (P3-5005) This energy transformation is sure to capture your students' attention! Hold the glass vessel in your hand, and your body heat causes the liquid inside to boil and shoot into the top bulb! Assorted colors and styles.

Vortex Tube

P1-1120

INSTRUCTIONAL GUIDE

Contents

- Vortex Tube
- Instructional Guide

Recommended for activities:

- Two 2-liter plastic soda bottles

Introduction

An initial small rotation causes the water to move in a circle near the tube opening. The water is forced downward and toward the lower bottle by gravity. As water approaches the small opening in the tube, they move in a gradually smaller circle. Each water molecule's angular momentum***** is conserved, so as its rotational radius decreases, its speed increases. (The same thing happens when a spinning ice skater pulls in her arms.)

The hole that develops in the center of the vortex allows air to move from the lower bottle to the upper one, making room for the water.

Directions

1. Remove the labels from two 2-liter soda bottles.
2. Fill one bottle 2/3 full with water and attach the Vortex Tube to the top.
3. Attach another (empty) bottle to the top of the Vortex Tube.
4. Quickly invert the assembly.
5. Rest the bottom bottle securely on a flat surface, and briefly rotate the top bottle in a circular motion.
6. Observe the vortex that forms as the water moves through the Vortex Tube!

Activities

1. Add visual interest by putting food coloring or glitter in the water. The glitter works particularly well because each particle can represent a "unit" of water whose angular momentum is conserved.
2. Relate the bottle vortex to vortices in nature, such as tornadoes, hurricanes and smoke rings.
3. Notice that the vortex can easily rotate either way, and does not start without an initial rotation. The vortex is not influenced by the Coriolis Effect, and neither is the vortex that forms when you empty a sink. These systems are far too small to be affected by the earth's rotation.

4. Introduce the topic by challenging a student to a race. Fill two bottles 2/3 with water and cap each with a Vortex Tube. Ask the student to empty the bottle as fast as possible (without removing the Vortex Tube). Surface tension at the hole will make it quite difficult to do quickly. Students may have to shake or squeeze the bottle to get the water out. Record the student's time. To empty your bottle, invert it, hold the Vortex Tube steady in one hand, and rotate the top of the bottle in the other hand. This will create a vortex at the tube opening, allowing the water to quickly escape. This "trick" has been used to quickly empty large glass bottles that would "glug" and release water slowly. Note: This works best with smaller or more rigid bottles, whose sides are not likely to collapse when a partial vacuum forms in the bottle.

Related Products

Airzooka Air Cannon (P8-5700) A takeoff from the old Trashcan Air Cannon; this amazing new vortex launcher sends a strong blast of air all the way across the room! No batteries or fuel needed. Just point and shoot! Powerful and accurate!

Bernoulli Bag 4 pack (P6-7350) How many breathes would it take to inflate an 8-foot long, 10-inch diameter bag? Just ONE using Bernoulli's principle! Commonly called the Wind Tube or Wind Bag.

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.

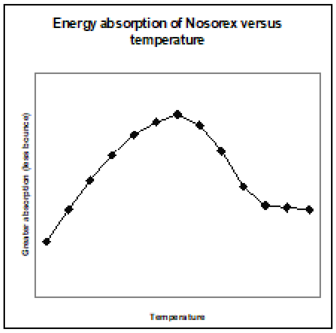
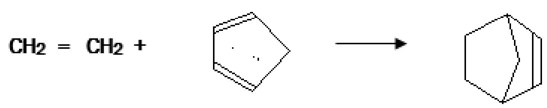


Figure 1

Diels-Alder reaction



ethylene cyclopentadiene
Norbonene

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?

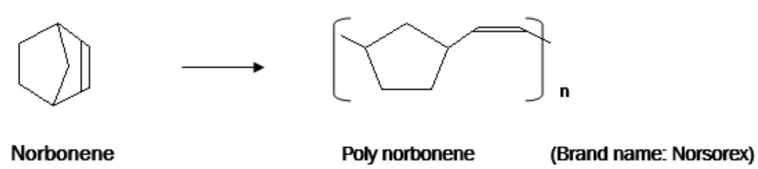
3. **The Chiller Instinct:** Determine the rate at which each ball returns to shape after being compressed by a vise or heavy tongs. Chill the balls first as before, then repeat. Are there differences in the rate at which the balls return to shape?

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!

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.

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.

This page intentionally left blank.

Balloon Helicopter Kit

P4-2350

INSTRUCTIONAL GUIDE

Contents

- 2 Balloons
- 1 Helicopter Attachment
- Instructional Guide

Background

The balloon helicopter is a classic toy with a simple design. The physics that explains its motion, though, can be difficult to explain. Students will observe the motion of the helicopter and study its construction before applying Newton's 3rd Law twice to explain how it moves.

Newton's 3rd Law says that every force is opposed by an equal and opposite force. This lab will reinforce the idea that the two forces involved in this law are applied to different objects.

Set-Up

When an ordinary balloon is inflated and let go, the balloon exerts a force on the air in it, forcing it to move out the stem of the balloon. The air, in turn, exerts a force on the balloon, forcing it to move in the opposite direction.

The helicopter kit diverts the air sideways, through the helicopter blades. The blade forces the air sideways, and the air forces the blade back the other way. This force causes the blades to spin.

The spinning blades push downward on the air around them as they move. The air around them exerts a corresponding upward force on the blades. This upward force from the air in the room is what causes the helicopter to fly.

Lab Activity

Educational Objective
Use Newton's 3rd Law to explain the motion of a balloon helicopter.
Lab Tip
Students should have experience drawing force diagrams before doing this lab.

Pre-Lab Question:

1. State and briefly explain Newton's Third Law.

Materials:
Balloon Helicopter Kit, Balloon

Procedure:

1. Fill the balloon with air. (Do not attach the helicopter kit yet.) Hold the balloon with the stem pointing up and let it go. Describe what happens.

2. Draw a diagram of the balloon and the air in the balloon during the motion. Show the forces on the air and on the balloon. Describe the effect of these forces on the air and on the balloon.

3. Attach the helicopter kit to the balloon and inflate it. Hold the balloon with the stem (and helicopter kit) pointing up, and let it go. Describe what happens.

4. Examine the helicopter kit. Draw a diagram of the helicopter blades and the air from the balloon during the motion. Show the forces on the air and on the balloon. Describe the effect of these forces on the air and on the blades. (You can ignore the part of the air that goes through the center whistle.) Hint: to explain the balloon's motion, you must show 2 forces on the helicopter blades. Don't forget about the air in the room.

Optional Extension

5. A Harrier Jump Jet can use its jet engines to force air backward (like a normal jet) or down. Draw diagrams of the forces on a Jump Jet hovering over the ground and a Jump Jet accelerating forward. Be sure to describe what is exerting each force on the jet.

Related Products

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!

SpillNot (P4-2500) Solve the Problem of Spilled Drinks with Physics! The SpillNot is a genius gadget that will let you carry an open beverage without spilling it. With a little bit of practice, spin a cup of liquid around in a circle without even losing a drop.

Energy Ball

P6-2300

INSTRUCTIONAL GUIDE

Contents

- Energy Ball
- Instructional Guide

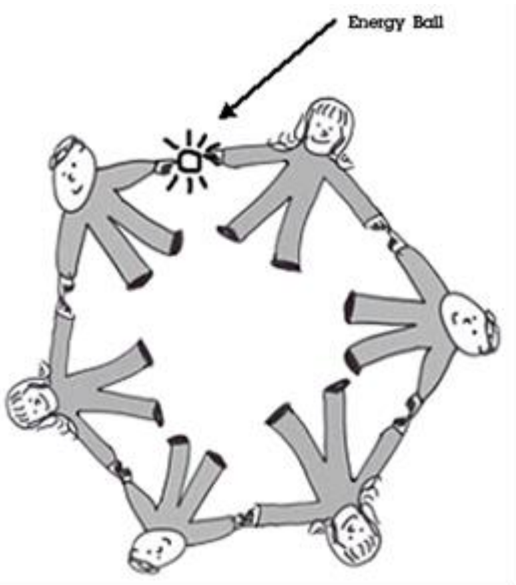
Background

This very cool device consists of a 1.5-inch ball with two small metal electrodes. When the two electrodes are touched simultaneously, the ball flashes and makes a strange noise. The Energy Ball is completely self-contained and requires no additional batteries or energy source. It is often used to demonstrate the fundamentals of circuitry

Activities

Conducting Electricity with your Body

1. Touch both of the electrodes at once to activate the ball.
2. Then, hold hands with another person and have each person touch one of the electrodes.
3. Explain why their bodies can conduct electricity.



Conducting Electricity with Materials

1. Lay out a several-foot length of aluminum foil on a table.
2. In one hand, hold the Energy Ball with the thumb touching ONE electrode. Hold the other electrode against the aluminum foil.
3. Place the other hand on the aluminum foil. The Energy ball will activate instantly!
4. Repeat this experiment with several materials such as a hand rail, pencil, cloth, etc.
5. Ask students to explain what makes a material a good conductor or insulator

Explanation

The Energy Ball utilizes a field effect transistor (FET), so even the slightest conduction between the two electrodes activates the light and noise. The FET acts as an electronic switch. When it senses a decrease in resistance between the ball's outer terminals, it switches to the ON state. Current then can flow from the battery through the switch and to the light and noisemaker. When in its OFF state, the FET is very close to its instability point, so it is able to switch ON even when the resistance between the terminals is still very high – even through a long line of people.

Students may ask if the current that activates the light and noise is traveling through their hands. It is not. The part of the circuit that contains the battery, bulb, and noisemaker is parallel to the circuit that the students are making with their hands.

Related Products

Energy Stick (P6-2400) Turn your body into a conductor of electricity! Make a giant human chain of electricity! This safe, easy-to-use toy is perfect for teaching students about the science of electricity, opened and closed circuits, and much more. And it's really simple!

Plasma Globe (P2-7110) Safely create and explore lightning right in your classroom. The Plasma Globe offers you a safe, fascinating way to demonstrate how lightning works as well as explain the concepts of potential differences and electron orbital jumping.

Hand Boiler

P3-5005

INSTRUCTIONAL GUIDE

Contents

- Hand Boiler
- Instructional Guide

Background

The liquid inside the Hand Boiler does not actually boil. The “boiling” is caused by the relationship between the temperature and pressure of a gas. The thermal energy given off as body heat raises the temperature of the gas in the chamber. The increased temperature causes gas molecules to move faster, thereby increasing the pressure in the closed system. There must be a temperature (and pressure) difference between the two large chambers for the liquid to move. When held upright (with the smaller bulb on top), the liquid will move from the bulb with the higher pressure to the bulb with lower pressure. As the gas continues to expand, the gas will then bubble through the liquid, making it appear to boil. The fact that the liquid is volatile (easily vaporized) makes the hand boiler more effective. Adding heat to the liquid produces more gas, also increasing pressure in the closed container.

Caution! Contains flammable liquid! The hand boilers contain ethyl alcohol. Keep away from heat or flame. Flush with water if contact with eyes. Do not drink.

Activities

Have the students hold the boiler upright by the larger bulb. How long does it take for the liquid to “boil”? Is there a student in class whose hand does not make it “boil”? Take the temperature of the students’ hands. Notice the difference. How do you make the liquid go down again? Hold onto the top bulb only. What happens if you hold both bulbs? Why? Can you make the liquid move by using cooling instead of heating? Try putting ice on the bulbs and see what happens. After several uses, the boiler won’t work for a while. Why not? Will the boiler work if upside down? Why not?

Related Products

Advanced Gas Laws Demo (P1-2065) Quantitatively confirm the Combined Gas Law with one complete apparatus! Students can verify this relationship using air and this unique apparatus.

Fire Syringe (P1-2020) A Smokin' example of Charles's Law. 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.

This page intentionally left blank.

ARBOR SCIENTIFIC

SpillNot

P4-2500

INSTRUCTIONAL GUIDE

Contents

- SpillNot
- Instructional Guide

Recommended for activities:

- Beaker

Background

Newton's Laws are essential in explaining how the SpillNot prevents liquids spilling while walking or running. Walking with a cup held firmly in your hand subjects the cup and its liquid to constant lateral accelerations with each step. The resulting starting and stopping motion causes the liquid in the cup to slosh back and forth. The behavior of the liquid in the cup is simply obeying Newton's law of Inertia: objects at rest try to stay at rest and objects in motion try to stay in motion. In the case of the liquid in the cup, the fluid's surface goes from being horizontal and parallel with the rim of the cup to rising up the walls of the cup at an angle. The angle increases with acceleration until it reaches the rim of the cup and spills over. In the mathematical language of physics, the angle θ between the surface of the liquid and the horizontal plane is represented as:

$$\theta = \tan^{-1} {}^{a}\!/_{g}$$

where 'a' is the acceleration of the cup and 'g' is the acceleration due to gravity. This rise and fall of the liquid in the cup is further amplified when the frequency of steps, while walking, resonates with the natural frequency of the back and forth sloshing of the liquid in the cup. So how does the SpillNot prevent spilling?

Suppose a cup with its liquid contents is to be carried on the SpillNot rather than directly by the cup's handle. The SpillNot's handle is a flexible strap, which is above and directly in line with the cup's center of mass. When holding the cup on the SpillNot at rest, the upward force applied to the handle is equal to the weight of the cup and the SpillNot. If a person abruptly applies an additional horizontal force to the top part of the SpillNot handle, the cup and SpillNot will lag behind the handle due to its greater inertial mass and will appear to swing back at an angle. As the hand holding the handle of the SpillNot continues to accelerate forward, the tension in the flexible handle of the SpillNot is now applying a force angled upward and horizontal. Now both the cup and its liquid content are tilted at the same angle preventing the liquid from spilling.

Activities

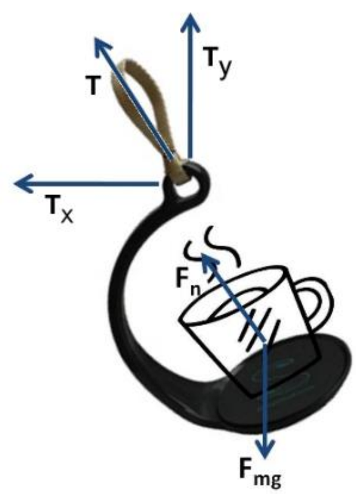
Two Examples of Centripetal Forces Using the SpillNot

In the first example, the SpillNot is held over the head and swung in a horizontal circle. In the second, the SpillNot is held in front and made to swing in a vertical circle. You might want to use a plastic cup with colored water on the SpillNot for these demonstrations. Even without the calculations, the different role that tension plays in contributing to the central force is an important distinction to make.

Horizontal Swing

When held over the person's head while swinging the SpillNot and its cup, the flexible handle will cause both to swing out at an angle depending on the speed the swing. At the point where the flexible handle attaches, there are two forces acting on the SpillNot. The first is the force of gravity (mg) pulling down on the SpillNot and the cup and the second is the tension (T) in the flexible handle, which is pulling up at an angle. Keeping the speed constant in a circle requires an inward or centripetal force. In this case, the centripetal force is not a specific force like gravity or friction but another name for the net force causing centripetal acceleration. The cause of the net force in this case is the horizontal component of the tension in the SpillNot handle.

As the diagram shows, the tension component in the horizontal direction (T_x) is directed toward the center of the circular path of the SpillNot. The upward, vertical component of the tension (T_y) balances the gravitational pull (mg). Also shown in the diagram, are the individual forces on the cup, where the force normal (F_n) replaces the tension for the whole apparatus.



The centripetal acceleration (a_c) can be represented by Newton's second law as:

$$a_c = T_x/m \quad \text{or} \quad a_c = T \cdot \cos\theta\,/m$$

Here, 'T' is the force of tension exerted by the handle on the SpillNot, 'm' is the mass of the SpillNot and cup, and "θ" is the angle of swing from the horizontal.

Further analysis of the motion can be made to calculate the angle (θ). Measuring the radius of the circle for the SpillNot and timing one revolution, one can calculate the centripetal acceleration (a_c). With this value we can calculate the angle (θ) using the horizontal component of the tension (T_x) and vertical component (T_y), where (T_y) is equal to the weight of the SpillNot and cup (mg). This agrees with the formula given earlier: $\theta = \tan^{-1} ma_c/mg$ or $\theta = \tan^{-1} a_c/g$.

Vertical Swing

In the second demonstration of centripetal forces, the SpillNot is swung in a vertical circle. In this case, the centripetal force keeping the SpillNot moving in a circle is the result of the vector addition of the tension (T) in the handle and the gravitational force (mg). However, unlike the horizontal swing, the speed of the swing must be fast enough to produce a centripetal acceleration equal to or greater than gravity (g) or approximately $10 m/s^2$. Since the force of tension is constantly changing during the swing, we will consider the points at the top and bottom of the swing where tension is at its minimum and maximum. At the top of the swing, both the tension in the SpillNot handle and the force of gravity (mg) are directed downward and combine together to produce the centripetal force. At the minimum speed to make it completely around the top, the tension approaches zero with gravity providing all the centripetal force at the very top.

At the bottom of the swing, however, tension in the handle is at its maximum. Here the centripetal force is equal to the force of tension minus the force of gravity (mg).
The minimum speed needed to complete the vertical circle can be calculated using the acceleration of gravity (g) for the centripetal acceleration at the top of the circle, where gravity alone provides the force towards the center of the circle. Using the equation for centripetal acceleration ($a_c = v^2/r$) and substituting the value 'g' for 'ac', we get the equation

$$v = \sqrt{g \cdot r}$$

In this case, 'g' is approximately $10 m/s^2$ and 'r' is the radius of the circle.

Related Products

Flying Pig (P4-2165) Add some excitement to your lessons on circular motion with the Flying Pig. Suspended from the ceiling, his wings flap and carry him in a regular circle.

Exploring Newton's First Law: Inertia Kit (P6-7900) Students investigate inertia by observing a marble's motion around a specially designed circular track.

Inertia Apparatus (P3-3524) Do you know what will happen when the spring is released? Test students' understanding of inertia and Newton's First Law in a memorable way!