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UNIT I Mechanics

PX-0100

BACKGROUND:

Your Mechanics Unit contains a collection of Arbor Scientific's discovery-based teaching tools designed to supplement the concepts in Prentice Hall's *Conceptual Physics Textbook* and *Lab Manual*. The attached Teaching Guides were created specifically for use with many of your new tools and can be used along with the demonstration items to fuel your students' desire to explore.

Please visit us at www.arborsci.com for more tools and free resources for creating a hands-on learning environment in your science classroom, including videos of products in use, lesson plans, teaching strategies, and demo ideas. Sign up for our free e-newsletter **Coolstuff**, then check out the Archive for an online resource that's packed with lesson ideas, plans and tips!

A message from Paul Hewitt, author of Conceptual Physics:

Students learn in a variety of ways. They learn best when they DO, not just listen or read, in keeping with the adage, "I hear and I forget. I see and I remember. I do and I understand!" When we are physically active with physical equipment relevant to the concepts to be learned, we simply learn better—to nobody's surprise!

Good Energy with your activities!

Paul G. Hewitt

KIT CONTENTS:

Your Unit I Mechanics Kit includes one of each of the following items:

44-1090	Constant Velocity Car
P1-1080	New York Demo
P1-1120	Vortex Tube
P4-2140	Mini Air Puck (2)
P1-5200	Coin & Feather Demo
P1-5201	Hand-held Vacuum Pump
P1-6001	Newtonian Demonstrator
P3-3500	Extreme Gyroscope
P3-3520	Vertical Acceleration Demo
P3-3540	Ring & Disk Apparatus
P3-3617	Human Dynamics Cart
P3-5002	Balancing Bird, 6"
P4-1980	Pull Back Car
P4-2165	Flying Pig
P4-2200	Air-Powered Projectile
P4-2210	Rocket Launch Pad
P4-2215	Angle Wedges, Set of 6
P4-2223	Heavy Duty Air Pump
P4-2350	Balloon Helicopter Kit
P6-1000	Pair of Happy/Unhappy Balls
P6-2080	Alternative Energy Conversion Kit

P6-6075	Dropper Popper	PX-1204	Bouncing Dart
P8-3530	Fuel Cell Car Science Kit		

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Constant Velocity Car

44-1090

BACKGROUND:

The Constant Velocity Car can be used as an introduction to motion and speed. The battery-powered car can be used for a variety of activities.

Here is a sampling of relevant national and state science education standards:

- An object's motion can be described by tracing and measuring its position over time.
- The motion of an object can be described by its position, direction of motion, and speed. That motion can be represented on a graph.
- Analyze examples of uniform and accelerated motion including linear, projectile, and circular.

PRODUCT INFORMATION:

The Constant Velocity Car requires 2 C batteries (not included). For some experiments, you may wish to have two different speeds available. You may cut a dowel rod the length of one battery. Cover it with 2-3 layers of aluminum foil. Replace one of the batteries with the dowel rod. Make sure that the aluminum foil contacts the battery and the copper contact at the end of the battery compartment. (It does not matter in which end the dowel rod is placed.) The car will now operate at a slower speed.

ACTIVITIES

- Use a Fiber Glass Tape Measure and Digital Stopwatch to measure the motion of the car. Divide distance by time to get the speed of the car. Try it with both speeds. Use the measurements as examples for speed problems. Have the students calculate how far the car will travel in a given time based on its speed.

- Use the car with the Electronic Spark Timer to measure the speed of the car. Tape ½ to 1 meter of Spark Sensitive Tape to the back of the car and feed it through the timer so that the car will pull the tape through the timer. Choose the 10 Hz setting on the timer. Turn the timer on then turn the car on and let it go. Because the car was stationary at the beginning, the first dots may not be distinguishable. Mark the first clear dot (2 side by side dots) as the 0 point. Have the students measure the distance (x) from 0 to each dot. You may also have them measure the distance between each successive point (Δx, 0 to 1, 1 to 2, 2 to 3, etc.). Make a data table and graph. The graph should be a straight line (or very nearly). The speed can be found at any point by dividing the Δx by 1/10 sec.(the time between dots). (See below)

$$v = \frac{\Delta x}{\Delta t}$$

  The average speed can be found by dividing x by the total time traveled. (See below)

$$\bar{v} = \frac{x}{t}$$

  You may repeat the experiment at a slower speed (see Product Information).

- Use the car with the *EasySense Advanced* datalogger and *Motion Detector*. The included *Sensing Science Software* allows you to analyze and graph the motion of the car.

- Show independence of vectors. Put the car on a piece of poster board. Record the time that it takes to cross the board. Pull the board to the side at a constant speed. Record the time that it takes to cross. Show that the times are the same. You may also mark the starting and stopping points of each trial and show how the vectors for the board's velocity and car's velocity add to get the resultant velocity.

- Tie a string around the pole of a ring stand. Tie the other end of the string onto one side of the windshield of the car. The car will move in a circle around the ring stand. You now have a vehicle with constant speed and constantly changing direction. Therefore, it has a constantly changing velocity.

  Calculate the car's centripetal acceleration by using $a_c = \frac{v^2}{r}$ or $a_c = \frac{4\pi^2 r}{T^2}$

- Use the car to measure the coefficient of friction (μ). Put the car on a board. Turn the car on. Slowly raise the end of the ramp while the car goes up. You may have to pick up the car and return it to the bottom. Record the angle (θ) of the ramp when the wheels of the car start slipping. Use the angle to find the coefficient of static friction $\mu = \tan\theta$. To find the coefficient of sliding friction, start the ramp at a slightly higher angle than the one found for static friction. Start the car at the top of the ramp. The car should slide down the ramp. Lower the ramp slowly until the wheels are moving and slipping so that the car remains stationary on the ramp. Record the angle and use the same equation to find the coefficient of sliding friction. Alternatively, you may use a string to attach a *Spring Scale* to the headlights of the car. Turn the batteries around so that the car will run in reverse. Record the weight of the car (in Newton's) by hanging it from the scale. The normal force (F_N) is the same magnitude as the weight. Reset the zero on the scale and hold the end of the spring scale while the car pulls. With the wheels slipping and the car stationary, record the force on the spring scale (F_f). Use the equation $F_f = \mu F_N$ to find the coefficient of sliding friction. Try different surfaces.

- Remove the batteries. It does not matter how the switch is set. Push the car along a surface. The lights will still light up. The motor has become a generator. With the batteries still removed, use a wire to connect the battery terminals. Turn the switch to 'on' and push the car again. Now the lights do not light up. Why? The motor, lights, and battery terminals are wired parallel to each other. When a wire connects the battery terminals, there is much less resistance through the wire than through the lights. Not enough current flows through the lights to light them.

- Connect the alligator clip leads of a *Genecon Hand Generator* to the battery terminals. (This is not always easy. You may have to wedge one "jaw" between the contact and the side.) The clips should be entirely inside the battery compartment so that they do not hinder the motion of the car. Turn the handle of the Genecon. The car will move and the lights will light up. Turn the handle the other direction and the car will move the other direction. Push the car. The lights will light up and the handle of the Genecon will turn (but not much.)

RELATED PRODUCTS:

- Use a durable **Stopwatch/Timer** (52-3200) to measure the time for experiments.
- Instead of meter sticks, use a 1.5 meter **Fiber Glass Tape Measure** (01-3985) or a 10 meter **Wind-Up Fiber Glass Tape Measure** (01-3900) to measure distance.
- The **Electronic Spark Timer** (P1-8000) can be used to make measurements in motion experiments. It runs on a standard outlet and has two timing rates.
- Use a **Genecon Hand Generator** (P6-2631) to power the car instead of batteries. The Genecon can be used alone or with many available accessories to study electricity and energy.
- Use one of our durable **Spring Scales** (01-6960 through 01-6965, depending on strength) to measure the force from a Constant Velocity Car or many other forces.

New York Demo Balance

P1-1080

BACKGROUND:

The New York Balance is a very simple instrument for demonstrating a basic principle of physics. Actually several principles can be studied such as torque, levers, center of gravity, and kinetic energy.

The unit consists of a center stand with a cast iron base, a 50 centimeter ruler, three knife edge clamps, a 50 gram weight and a 100 gram weight. Make sure to tighten the mounting screw securely for the stand and cast iron base. One of the knife edge clamps should have the hanger wire removed. This clamp will act as your fulcrum, or fixed point, from which the 50 centimeter ruler will pivot.

SETUP:

First, set up the balance with the fulcrum clamp set on the 25 cm mark. This is the center of the ruler. The clamp should be mounted with the screw on the bottom. This will place the balance arms above the horizontal center of the ruler. Next place the other clamps on each end of the ruler with the screw on top and the hanger wires hanging below the ruler. Line the balance arm of the left clamp with the 1 cm mark. Line the right clamp with the 49 cm mark. If the ruler does not balance, move the fulcrum (center) clamp towards the lower side slightly until the ruler does balance. Now add the 100 gram weight to the left hanger and the 50 gram weight to the right hanger. Of course the left side will go down until the weight touches the table. Move the left hanger with the 100 gram weight in towards the fulcrum until the ruler again balances. You should find the left clamp setting at about the 11 cm mark.

ANALYSIS:

So now let's analyze what has happened. We have a 50 gram weight that is balancing a 100 gram weight. But in order for the ruler to be balanced the forces must be equal on both sides. That means that there is another factor in this equation. This factor is the distance from the fulcrum that the forces are applied. The size of a turning force is called <u>moment of force or torque</u> and it is the distance from the fulcrum times the force applied.

In this case, the 100 gram weight is 14 cm away from the fulcrum. 14cm x 50 grams = 1200. Twelve hundred? Wait a minute, 1200 does not equal 1400. Then why is the ruler balanced? Take a good long look at the set up and try and figure out why. Take my word for it. The forces are equal or the ruler would not balance. OK give up? You may be forgetting about the weight of the clamps. When each was at the ends of the ruler then their weight was negligible because they balanced each other out. But now that they are set at different points from the fulcrum, each are applying a different amount of torque. The clamps with the weight hangers weigh approximately 19 grams on the right side 24 cm away from the fulcrum. Recalculating we now have 119 grams x 14cm = 1666 grams of torque on the left and 69 grams x 24cm = 1656 grams of torque on the right. This is much less than a 1% error, which is very good. Whenever you are making the transition from paper to the real world you can expect some error due to slight variation in material, human error or other outside forces that are not taken into consideration.

So for all practical purposes the ruler is now balanced. Whenever we have a smaller force (50 grams) that is moving a larger force (100 grams) we have a mechanical advantage. But in physics just as in life, you never get anything for free. In order to gain this mechanical advantage we have to give up something. In this case it is distance. If you will take another look at your set up and rock the arm up and down you will find that the clamp on the right side is moving about twice the distance as the clamp on the left side. When the left side goes down one inch the right side goes up two inches. This is the price that you pay. Actually this is just an approximation. In actuality, to figure the mechanical advantage you would take the smaller force (69 grams) and divide it by the larger force (119 grams) to give you a mechanical advantage of 1.72. This means that if the left side moves down one inch the right side will travel 1" x 1.72 or 1.72 inches. Not quite twice the distance. You see the distance traveled is directly related to mechanical advantage. This type of lever is known as a <u>first class lever</u>.

ALTERNATIVE SETUP:

Now for a different set up. Try putting the left clamp back on 1 cm and the right clamp back on 49 cm. Once again take the weights off and adjust the heavier side until the ruler balances, then replace the weights. Now what you are going to do is to move the fulcrum toward the left side. The screw will have to be loosened slightly so that the ruler can move through the clamp. But try to keep some tension on the screw so that the ruler will stay in place. When you have the ruler balanced you can tighten the screw. You should now have a weight on each end of the ruler but the fulcrum should be resting at about the 19.5 cm mark. This will place the 119 grams of weight on the left side 18.5 cm away from the fulcrum and the 69 grams of weight on the right side 29.5 cm away from the fulcrum. This gives us 119 grams x 18.5 cm = 2201 grams of torque on one side and 69 grams x29.5 cm = 2035 grams of torque on the other side. Yes, we still have an unbalanced formula but a balanced ruler. Welcome to the real world of physics. Quite often theoretical equations are hard to duplicate due to factors like friction, static, air currents etc. But you can be sure that the force on one side of the beam is equal to the other side. Can you guess where the problem lies this time? Do you notice that more ruler is sticking out on the right side than on the left? That's right; the extra length of the ruler is adding torque to the set up. You have 11 cm more ruler on the right side of the fulcrum. The weight of the ruler varies from stick to stick but you can figure for calculation purposes that each cm of ruler weighs approximately 0.6 grams. So you have 11 x 0.6 or 6.6 more grams of weight that needs to be figured into the calculations. This should be simple enough but things are not what they seem. You cannot just add 6.6 grams more of weight to the 69 grams already hanging on the end.

Why? Because all of the 6.6 grams of weight are not resting where the weight and clamp are. If we figure that we have 19.5 cm of ruler on the left, then 19.5 cm of ruler on the right will balance or cancel this out. Extending to the right of that we have 1 cm of ruler that is exerting a torque of 12.3 grams (0.6 x 20.5). Moving over another 1 cm, we have another piece of ruler that is exerting a torque of 12.9 (0.6 x 21.5). We can continue this all the way to the end of the ruler. A more simple way to do this is to take the equation 0.6 x (20.5cm + 21.5cm + 22.5cm+ 23.5cm+.....) all the way to the end of the ruler which would be 30.5 cm from the fulcrum. To make things easier for you this number is 168.3 grams (280.5 x 0.6) due to the extra length of ruler. Now, if we add this extra torque 168 to the torque already established of 2035 we get 2203 grams of torque on the right side and with 2201 already established on the left side. We are now extremely close. That is less than ½ of 1% error! You see that if you compensate for the variables, even a crude testing device can be very accurate. The lesson here is that the variables are not always noticeable.

Vortex Tube

P1-1120

DIRECTIONS:

1. Use two identical plastic soda bottles (most sizes will work). Do not use glass 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!

WHAT'S GOING ON?

An initial small rotation causes the water molecules to move in a circle near the tube opening. The molecules are forced downward and toward the lower bottle by gravity. As the molecules approach the small opening in the tube, they move in a smaller circle. Each 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.

* <u>Angular momentum:</u> A quantity that depends on a rotating objects speed and rotational radius. The quantity is conserved (does not change) in a closed system.

TEACHING IDEAS:

1. Add visual interest by putting food coloring or glitter in the water.
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 PRODUCT:

Air Cannon (P8-5700). Send fast, 6" diameter vortices across a room with this simple device.

Coin & Feather Demo

P1-5200

DEMONSTRATION:

Show students the coin and feather in the tube. Ask which will fall to the bottom of the tube first when you turn it on end. (Most will predict the coin.) Turn the tube quickly to vertical, and observe that the coin does indeed fall faster.

Any electric vacuum pump that reaches 24-27hg can be used. We recommend our Electric vacuum pump to work with the Coin & Feather demo. Reduce the pressure to 1.25 inHg (30mmHg) or less. If your pump gauge shows gauge pressure rather than absolute pressure, reduce it to -28 inHg (-700mmHg) or further.

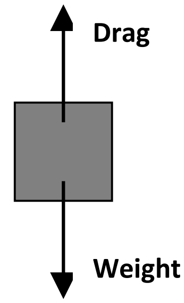
Repeat the demonstration, quickly turning the tube to vertical. Observe that now the coin and feather fall equally fast.

TIP:

If you notice that the feather is sticking to the inside of the tube, try rubbing the outside with a damp paper towel or cloth to discharge any static buildup.

EXPLANATION:

A falling object experiences two important forces: weight (down) and drag (up). Drag is a force that opposes motion, and depends on complex factors including the object's velocity, the reference area, and the density of air (or whatever fluid through which the object moves).The net force causes the object to accelerate. When weight equals drag, the object stops accelerating and reaches its terminal velocity.



acceleration = F_{net} / mass

F_{net} = Weight – Drag

When Weight = Drag, F_{net} is zero, and the object stops accelerating. For a light object with a large surface area, such as a feather, the two forces become equal very quickly, and the object has a slow terminal velocity. When you remove the air, the drag on both objects essentially becomes zero.

Then, **for both objects:**

F_{net} = Weight = mass * g

Acceleration = F_{net} / mass = mass * g / mass

Acceleration = g = 9.8 m/s^2

MORE INFORMATION:

This idea was first proposed by Galileo. His theory was finally tested in 1971. Watch Apollo 15 astronaut David Scott drop a hammer and a feather on the moon: http://youtu.be/5C5_dOEyAfk

More on drag and falling objects: http://www.grc.nasa.gov/WWW/K-12/airplane/falling.htm

RELATED PRODUCTS:

Electric Vacuum Pump (P7-6502)

Newtonian Demonstrator

P1-6001

BACKGROUND:

This apparatus, which provides a dramatic demonstration of several fundamental physical principles, is by no means a simple device. Indeed, 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. See the illustrations for suggested starting patterns.

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.

EXPLANATION:

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 head, 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.

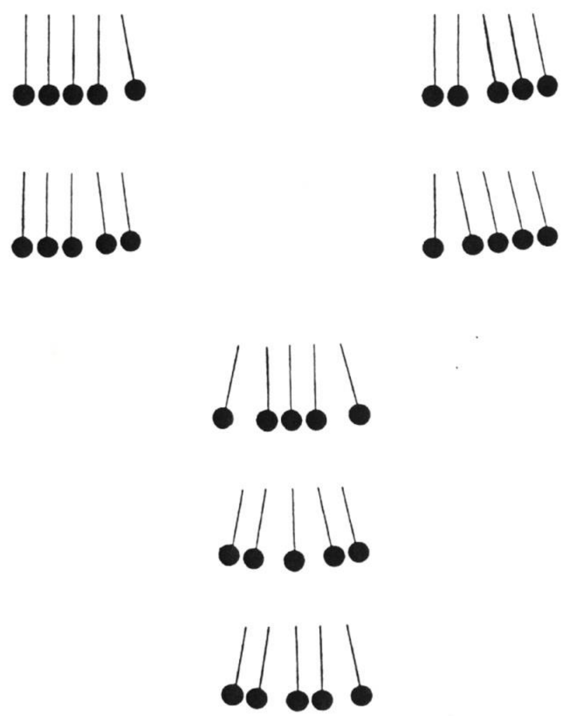
CARE:

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:



Vertical Acceleration Demonstrator

P3-3520

KIT CONTENTS:

Launcher apparatus
Two steel balls

ALSO REQUIRED:

Ring stand and right-angle clamp (or other support).

ACCESSORIES/REPLACEMENT PARTS:

Spare balls, pair (P3-3521).
Bullseye Level (P6-2604).
Right Angle Clamp (66-8290)
Ring Stand, 20" (66-4220).

INSTRUCTIONS:

1. Mount the apparatus at least 1.5m above the floor, so that both balls will land on the floor. Use a level to make sure the launched ball will be launched horizontally.
2. Pull the spring and latch the lever in one of the notches. The different spring settings will send the projected ball out at different speeds.
3. Place one ball on the platform, as close as possible to the spring plunger.
4. Place the other ball on the post. Rather than push it all the way in, let it balance near the end of the post.
5. Ask students to predict which ball will land first.

6. Release the spring as rapidly as possible and listen for the balls hitting the floor. Do you hear one simultaneous "click" or two distinct and separate "clicks"?

7. Repeat the demonstration, asking students to close their eyes and just listen.

WHAT'S GOING ON?

First, think about why objects fall. They fall because gravity forces them down. Gravity only acts straight down, and will only affect downward motion. Since the two balls are released from the same height and fall the same distance, the cover that distance in the same time. The fact that one of them is also moving horizontally makes no difference in its travel time.

RELATED PRODUCTS:

Air Powered Projectile (P4-2200). Use equations to accurately predict the motion of this "rocket." It can go up to 100 meters!

Marble Projectile Ramp (P2-8490). Designed to work with a photogate so students can measure the velocity of a horizontal projectile and predict its range.

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Ring and Disk

P3-3540

BACKGROUND:

In rotating systems, the rotational inertia is analogous to the mass in linear systems. Rotational inertia depends on the mass and how the mass is distributed around the point of rotation: the farther away, the higher the rotational inertia. Rotational inertia, like mass, resists acceleration. The higher the rotational inertia, the more torque it takes to cause rotational acceleration.

When a body rolls down, it has linear acceleration in downward direction. The friction, therefore, acts upward to counter sliding tendency as shown in the figure. This friction constitutes an anticlockwise torque providing the corresponding angular acceleration as required for maintaining the condition of rolling (if linear velocity is increasing, then angular velocity should also increase according to equation of accelerated rolling). *

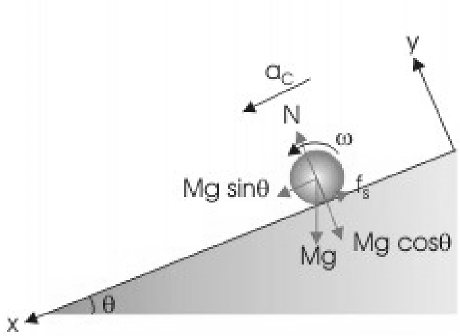


Figure 1*

Note that it is static friction that applies the torque to the rolling object. Static friction in this example is a self-adjusting force that depends on the weight and motion of the object. Its exact analysis is complex and can be found in detail at the source cited below. A simple approach approximates that the torque on both objects is essentially equal.

The disk has its mass evenly distributed from the center to the edge. The ring has its mass concentrated at the edge, and thus has greater rotational inertia. The following equation, analogous to Newton's Second Law (F=ma) relates torque, rotational inertia, and angular acceleration.

$$\tau = I\alpha$$

$$\alpha = \frac{\tau}{I}$$

The ring's larger rotational inertia causes its angular acceleration to be lower. Therefore, when accelerated by the same torque as the solid disc, it loses the race.

INSTRUCTIONS:

1. Construct a simple inclined plane.
2. Hold the two wheels at the top and ask students to predict which will reach the bottom first. Note that the wheels are the same mass and the same radius.
3. Release the wheels from the same point and observe that the solid disk reaches the bottom first.

BIBLIOGRAPHY:

* Singh, S. Rolling along an incline, Connexions Web site. http://cnx.org/content/m14312/1.9/, Apr 17, 2007.

RELATED PRODUCTS:

Rotating Platform (P3-3510). 40cm diameter platform for use with hand weights or our bicycle wheel for rotational studies.

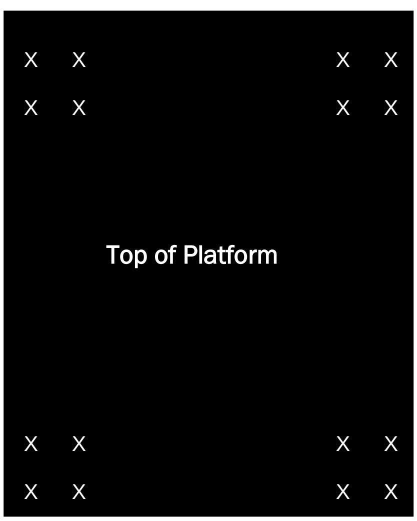
Human Dynamics Cart

P3-3617

BACKGROUND:

The Human Dynamics Cart is a platform mounted on four low-friction wheels, the Human Dynamics Cart allows students to become part of the experiment or demonstration.

WHEEL INSTALLATION:



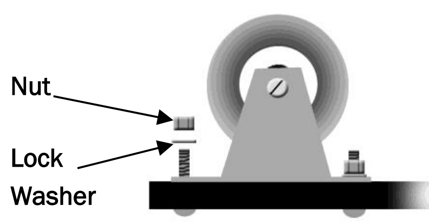
Locate the four groups of pre-drilled holes in each of the corners of the cart platform.

From the top of the platform (Black side) insert the attachment bolts supplied with your Dynamics Cart. The holes have a tight tolerance so do not force the bolts if they are too tight to go through. Do not use a hammer to drive them through. This can damage the laminate surfaces. Simply use a screw driver the screw the bolts down into place.

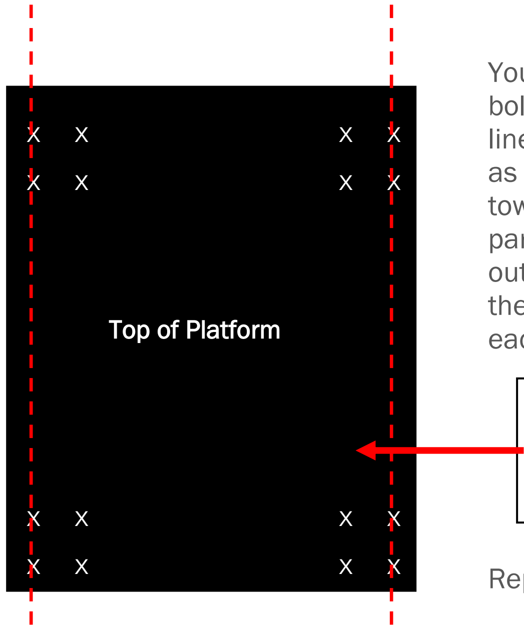
After the bolts are inserted into the platform, turn the platform over to the bottom side (Brown side). Place the four wheel assemblies into position over the protruding bolts. <u>Axel nuts should be facing toward the inside of the cart.</u>

On each of the protruding bolts attach a lock washer and then the nut. <u>Do not tighten yet.</u>

After the wheel assembly bolts have been installed, each wheel must be secured for alignment.



Wheels must be properly aligned for maximum performance.



Your cart platform has been pre-drilled with the outside bolts placed in parallel lines, as illustrated by the dotted lines in the figure to the left. Using the outside bolt holes as a reference for being straight, push the wheel assembly towards the inside of the platform to align the wheels to be parallel. It is helpful to place a straight edge along the outside edge of the wheel assembly frames on each side of the cart, similar to the dotted lines in the figure. Tighten each of the four bolts until snug.

Push wheel assembly in, against the outside bolts as you tighten the bolt nuts.

Repeat this process at it wheel assembly location.

ACTIVITIES:

Newton's Second Law

Newton's Second Law, F=ma. If an equal force is applied to objects of different mass, the smaller object will undergo greater acceleration.

1. On one cart, seat a large student. On a second cart, seat a small student. Separate the carts by a distance, at least 10 feet.
2. Give each student one end of a non-stretch rope.
3. Ask the students to pull gently on the rope, causing their carts to move. Who moves farther?

Newton's Third Law

Newton's Third Law, "Equal and Opposite." When an object exerts a force on another object, the second object exerts an equal an opposite force on the first object.

1. Repeat the setup in the last experiment, with one student on each cart.
2. Connect a spring scale or force sensor to each end of the rope.
3. Ask students to report the force they see measured on their scales while they pull. The forces should be approximately equal, regardless of the mass on the cart.
4. Single-cart variation: Connect the second scale to an immovable object. When the student pulls himself toward the object, both scales will still be approximately equal.

Momentum and Collisions

1. Seat one student on a single cart.

2. Toss a heavy object, such as a sandbag or medicine ball, to the student.

3. When the student catches the object, the cart will continue to move in the original direction of the throw.

Momentum and Explosions

1. Seat one student on a single cart, with a heavy object such as a sandbag or medicine ball.

2. Ask the student to throw the object away, and observe the recoil of the cart. Experiment with the effect of different weights and throwing speeds.

Momentum and Rocket Engines

Many students believe that rockets "push off of the ground" on launch. Correct the misconception with this advanced demonstration that uses a fire extinguisher.

Important: This demo should only be done by an adult wearing a safety helmet and eye protection. Use only a CO2 fire extinguisher in a ventilated area. Contact a professional to help you remove the nozzle from the extinguisher and use it safely in this context.

1. Arrange your demo area to prevent crashes. Use a cushioned landing area or an assistant.

2. Put on safety gear. Sit on the cart. Hold the extinguisher firmly.

3. Release gas from the fire extinguisher, and observe the cart's acceleration in the opposite direction.

Balancing Bird

P3-5002

BACKGROUND:

The Balancing Bird uses two well-placed weights at the end of its wings so that its center of mass is located below the tip of its beak, creating a stable equilibrium.

PRECAUTIONS:

- In the unlikely event that the wings of the bird become loose, please discard the bird immediately. The weights at the tips of the wings may become dislodged, and could pose a choking hazard.

Pull Back Car

P4-1980

BACKGROUND:

An object experiences an acceleration when its velocity changes. Since velocity entails both speed and direction, an acceleration occurs when an object's speed, direction of motion, or both change. This means that an object moving in a straight line with increasing or decreasing speed or moving in a circle with constant or variable speed is accelerating.

You would never pay good money to visit an amusement park that only offers rides that move with constant velocity. If you have your eyes closed while moving at a constant velocity, you can't even tell that you're moving. Unlike constant velocity, acceleration is something you can feel. That's why people love roller coasters, swings, and rotors. They provide a change in speed, direction, or both. For many of us, the more abrupt these changes are the better!

Acceleration results when an unbalanced force acts on an object. According to Newton's 2nd Law, the acceleration is directly proportional to the unbalanced (or net) force and inversely proportional to the mass. This is consistent with everyday experience. Two cars with the same mass will have different accelerations if one car has a more powerful engine. Likewise, a massive semi will take much longer to get up to the speed limit than a sports car, even though they both have big engines.

ACTIVITIES:

The Pull Back Car lends itself to a number of experiments in mechanics. The net force is supplied by a spring. The spring is wound by dragging the car backward across a floor or other surface.

The inertia of the car may be increased by placing small masses in the car's roomy front seat, thus enabling students to see how acceleration and mass are related. The car accelerates predictably during the first 1.5 meters of its motion. After that, the acceleration decreases (and becomes negative) and the car may veer to the side.

The following suggestions for activities have been tested in the classroom. But be assured, you and your students will think of many more ways the Pull Back Car can be used in the study of physics.

1. You may wish to have your students explore with the cars prior to formal laboratory work. This can best be accomplished by simply placing a few cars on your desk prior to class. Upon entering the room, students will instinctively pick them up and start racing them. Student observations can later be used as a basis for a discussion of uniform and accelerated motion.

2. Have students devise an experiment to determine their car's top speed. Students may be asked whether the speed they measured represents an average or instantaneous speed. This usually prompts a lively discussion regarding the determination of the speed of an object

at a given instant. You may wish to use this opportunity to introduce the concepts of limits and the derivative.

3. The Pull Back Car is a wonderful device for introducing acceleration. After discussing the definition of acceleration, students may be work in groups to devise a procedure for measuring the acceleration of their Pull Back Car. Once they have determined the acceleration of their car, they should be asked to compare it with the acceleration of other group's cars.

4. If available, a ticker tape timer may be used to study the details of the car's acceleration. Students can use the tapes to determine if the car's acceleration is constant throughout the motion or just during a portion of it.

5. As a library or Internet assignment, students may be asked to see how their car's acceleration stacks up against the acceleration of real cars. Automobile magazines generally provide amazingly detailed data on the cars they review.

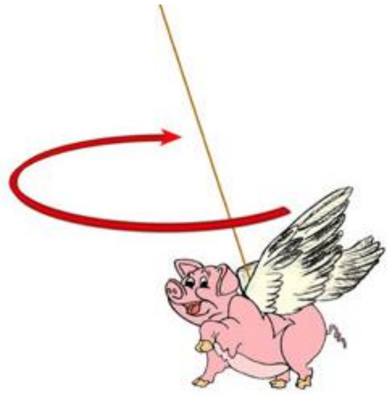
6. Have students gradually add mass to their car. They will observe that the car will accelerate, regardless of its mass, but that the acceleration decreases with increased mass. You may wish to have students do a quantitative investigation by measuring the acceleration of their car as a function of mass. This may be done using ticker tape timers or photogates.

BIBLIOGRAPHY:

Conceptual Physics: The High School Physics Program. Paul G. Hewitt. Pearson Education, Inc.

Flying Pig

P4-2165



BACKGROUND:

The Flying Pig provides students with a fun way to study circular motion. The pig and its string trace a conical pendulum and allow a perfect opportunity for calculations and measurements of circular motion.

The instructions included below can be altered to suit your students' abilities and skills. You might consider doing the pre-lab activity together, especially for students with less algebra and trigonometry experience.

Students should be familiar with forces, specifically centripetal force, and how it is calculated. Students should also know the definitions of the fundamental trigonometric functions and how they can be used to find the sizes of parts of a right triangle.

$$F_c = \frac{mv^2}{r}$$

SETUP INSTRUCTIONS:

1. Unscrew the battery cover and insert two AA batteries. (Do not use rechargeable batteries.) Replace the cover.
2. Gently pull the wings outward until they lock.
3. To activate the wings, use the on-off switch located on the pig's side.
4. The hanger may be permanently screwed to the ceiling, as shown on the box, or you may hang the pig from a Magnetic Ceiling Hook (P4-2166). In either case, it is best to have a rotating pivot, such as a fishing swivel, to avoid twisting the string.
5. Attach the string to the hook on the pig, just behind the wing mechanism.

LAUNCH INSTRUCTIONS:

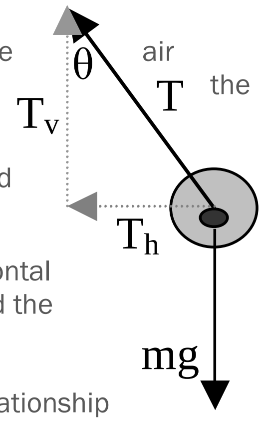
1. Hold the pig by its body, so that the string is about 30° from vertical.
2. Turn on the motor.
3. Give the pig a slight shove in a direction that is tangent to the circle where it will fly.

4. If the pig does not fly in a circle for 10 seconds, carefully catch it and try the launch again.

$\sin(\theta)=\frac{r}{L}$ $\theta=\sin^{-1}(\frac{r}{L})$

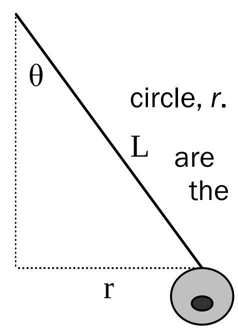
PRE-LAB INSTRUCTIONS:

Students will calculate the theoretical speed of the pig, to be compared to the pig's actual speed, measured in the activity. (Solutions are in parentheses.)



1. Draw a diagram of the flying pig, showing the forces that act on it. Ignore air resistance. (Forces will include the pig's weight, mg, and the tension in the string, T, as shown.)
2. With dashed lines, draw the vertical and horizontal components of T, and label the angle θ between T and the vertical.
3. In what direction, horizontal or vertical, does the pig accelerate? (Horizontal only.) What does this tell you about the net vertical force on the pig, and the relationship between mg and T_v? (T_v=mg.)
4. Which force in the diagram is the centripetal force? (T_h) What is the relationship between T_h , T_v and θ? ($T_h=T_v \tan \theta$.)
5. Write an equation that shows the relationship between mv²/r to T and θ. ($\frac{mv^2}{r}=T_v \tan\theta$)
6. Refer to your answer in step 3 and make a substitution in the equation to eliminate T_v. ($\frac{mv^2}{r}=mg\tan\theta$)
7. Solve the equation for v. ($v=\sqrt{rg\tan\theta}$) Notice that the mass term cancels.

ACTIVITY INSTRUCTIONS:



1. When the pig is flying in a consistent circle, measure the radius of the circle, *r*.
2. Determine the angle that the string makes from vertical, θ. If students are familiar with basic trigonometric functions, this can be determined using the sine function. Students may also attempt to measure the angle directly with a protractor.

   where L is the length of the string.
3. Calculate the theoretical velocity, using the equation you developed in step 7 of the pre-lab with the measured values for r and θ.
4. Measure the speed of the pig. To do this, measure the time it takes to complete 10 revolutions, and divide by 10 to find the time for a single revolution, t. The linear distance covered in that time is the circumference of the circle, 2πr. Velocity is found by dividing the distance by the time to cover that distance.

$$v=\frac{2\pi r}{t}$$

5. Compare the two velocity values. Suggest sources of error.

ACKNOWLEDGEMENTS:

Thank you to Paul Robinson and Paul Hewitt for their assistance in the development of this product and its accompanying instructions. The lab is currently in development for inclusion in the *Conceptual Physics Lab Manual*.

RELATED PRODUCTS:

Rotating Stool (P3-3610). A sturdy lab stool with a rotating seat, useful for a wide range of rotational demonstrations.

Rotational Accelerometer Accessory (P3-3612). Attach two liquid accelerometers to the top of the Rotating Stool to show the centripetal acceleration in two different locations.

Digital Stopwatch/Timer (52-3200).

Wood Meter Stick (P1-1070)

Air-Powered Projectile

P4-2200

BACKGROUND:

From its beginnings in experiments on the football field of Glenbard South High School in Glen Ellyn, Illinois, the Air-Powered Projectile has become a standard device for projectile motion experiments. Field data will conform to a high degree of accuracy with theoretical data of physics formulas. Your students will be amazed when they see proof that these formulas really work.

SEND IMAGINATIONS SOARING:

The Air-Powered Projectile is a safe, chemical-free tool for exploring projectile motion. It is free of the numerous variables that plague solid-fuel and water rockets, and it flies straight and true with minimum wind effect, so your experiments have precise, consistent results.

PRODUCT INFORMATION:

The Air-Powered Projectile uses compressed air as fuel to power its launch. One of four thrust washers (sizes Low, Medium, High, and Super) is pressed onto the top of the launcher, **the projectile slides down and then is pressed onto the launching tube.** Air is pumped into the launcher with the air pump. When it reaches the pressure needed to launch the projectile, the thrust washer is forced off the launching tube, sending the projectile into the air.

WARNING:

Goggles should be worn and care taken in the launching of the Air-Powered Projectile as it launches at a high velocity! Do not lean over the launch pad when pumping the air pump.

For those who will be launching the Air-Powered Projectile in a cold climate, limit your outside launches to days above 50° F to reduce the possibility of the projectile body cracking. Please launch projectiles to land in large grassy areas, such as a football field. Repeated landings on hard surfaces such as concrete or asphalt may damage the red projectile body.

ACTIVITIES:

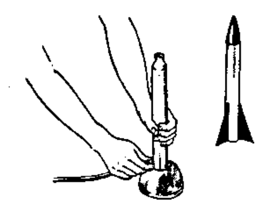
An example used in many classrooms is to have students launch the projectile vertically and time how long it takes for the projectile to complete the trip up and down. This time is then divided in half to get a pretty good approximation for the time of the upward portion of the trip. Your students, knowing that the Air-Powered Projectile slows at the rate of 10 m/s^2, can now calculate the initial speed. (We have found using 10 m/s^2 instead of 9.8 m/s^2 allows the students to do the calculations in their heads.) Let's say it took the projectile 6 seconds total time in the air when launched vertically. Then the time spent on its upward trip would be 3 seconds, multiplied by the acceleration due to gravity-- the projectile's initial speed would be 30 m/s. Air resistance is not formally calculated but taken into consideration when calculating the initial velocity.

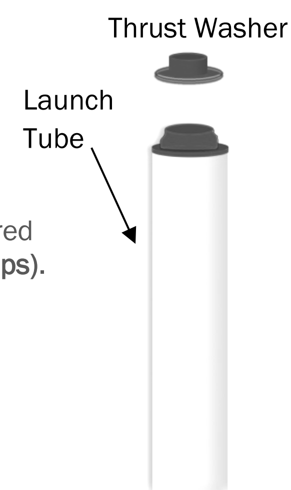
With this bit of information, your students can calculate the distance the projectile will travel at any angle the launch pad is placed! For example, if an angle of 60 degrees was assigned, a little trigonometry would yield both the vertical (y) and horizontal (x) components of velocity. Since all the energy of the launch is not going into upward thrust, your students should expect a lower velocity for the y direction.

The initial velocity stays the same at 30 m/s. The equations would be vy = 30 m/s (sin 60o) = 26 m/s and the v_x = 30 m/s (cos 60^o) = 15 m/s. If the projectile starts out at 26 m/s in the y direction and gravity slows velocity by 10 m/s each second, it will take 2.6 seconds to reach the top and 2.6 seconds to fall to the ground, totaling 5.2 seconds in the air. Since the projectile travels in the air for 5.2 seconds at 15 m/s in the horizontal direction, it will go 78 meters before hitting the ground (5.2 seconds x 15 m/s = 78 m). Your students will be stunned by how accurate their calculations will be.

IT'S SIMPLE AND SAFE:

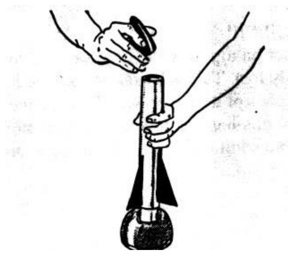
1. Select a launching site clear of obstructions and preferably about 50 meters in diameter. Attach the Arbor Scientific air pump to the rocket launcher and adjust the launching pad to the desired angle. Set the rocket launcher in its launching position.



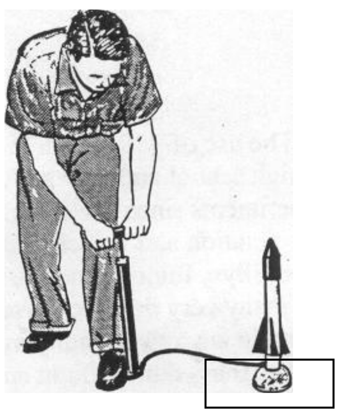


2. Select the super, high, medium or low thrust washer according to desired altitudes. Snap the thrust washer onto the launcher top **(be sure it snaps)**.

3. PUSH THE ROCKET COMPLETELY ONTO THE LAUNCHER. MAKE SURE THAT THE TOP OF THE WASHER SEATS INTO THE HOLE AT THE TOP OF THE ROCKET. FAILURE TO DO THIS WILL CAUSE REDUCED PERFORMANCE AND INCONSISTENT RESULTS.



4. Attach the nose cone onto the rocket. Push the cone on all the way it will only slide approximately ½" onto the rocket body.
5. Stand sideways to pump and pump until the rocket launches automatically.



6. Have a student retrieve the rocket and nose cone.
7. Push the thrust washer out of the end of the rocket with your thumb or finger and repeat the above steps for the next launch. The thrust washers fit tightly when new and are easier to push out if a small amount of lubricant is applied to the tapered plug on top of the thrust washer.

TEACHERS' NOTES:

A number of things can happen to generate error in the calculations of your students. The largest of these is in their ability to pace off the distance when estimating the expected range of the Air-Powered Projectile. To avoid this, have the experiment take place on the football field or prior to the experiment have distances measured with a meter tape.

Additionally, when doing the calculations the majority of your students will actually use the wrong angle of launch. For example, if the angled wedge used in the launch pad was the 55 degree wedge, the actual launch angle was its complementary angle or 35 degrees. A way to show why the correct range was calculated in spite of the error would be to introduce them to the projectile range equation, $R = (v_o^2/g) \sin 2\theta$. The fact that the sine of twice an angle and twice the complement of an angle yield the same result demonstrates the mathematical reason why your students still got the right answer. Be sure to measure the angle of the launch pad and not the wedge, because the wedge can move.

RELATED PRODUCTS:

- Our exclusively designed **Launch Pad** (P4-2210) is stable and durable.
- The set of six **Angled Wooden Wedges** (P4-2215) allows you to vary the angle of your launches from 30 to 55 degrees.
- The **Heavy Duty Air Pump** (P4-2222) is a necessity for any successful launch.
- **Replacement Washers** (P4-2225) and the **Spare Projectile Body** (P4-2205) allow your experiments to continue even if you lose your original components.
- The **Classroom Set** (P4-2230) gets everyone involved. Includes 6 projectiles, 6 launch pads, 6 air pumps, one set of wedges, one deluxe trundle wheel and one set of replacement washers.
- Use the **Altitude Finder** (P4-2250) with the Air-Powered Projectile or with the **Bottle Rocket Launcher** (P4-2000) to find the altitude that the projectile went.

ACKNOWLEDGEMENTS:

Our thanks to Stephen Rea, physics teacher, Plymouth-Canton High School, and Mark Davids, physics teacher, at Grosse Pointe South High School, for help in preparing this Data Sheet and for sharing this lab.

Rocket Launch Pad

P4-2210

BACKGROUND:

The Launch Pad is a hinged platform designed to be used with an Air-Powered Projectile (P4-2200). The Launch Pad makes it easy to launch the Projectile consistently at various angles. The base for the Projectile can be attached to the Launch Pad with the supplied bolts and wing nuts. Six Angled **Wooden Wedges** (P4-2215) are available that allow you to vary the launch angle from 30º to 55º.

HOW IT WORKS:

Put the base of the Air-Powered projectile on the side of the Launch Pad with the Arbor Scientific logo. Put the bolts through opposite corners of the base and through the holes on that piece of the Launch Pad. Tighten the wing nuts on the bolts by hand. You may push the nails through the holes on the bottom piece of the Launch Pad to hold it securely on the ground.

If you have the Angled Wooden Wedges, you may use them to vary the launch angle. Open the two halves of the Launch Pad so that they are at a right angle. Put the long side of the wedge into the groove on the bottom of the Launch Pad. The point of the wedge should stick out between the two pieces of the Launch Pad. The wedge should be firmly in the groove. Lower the top half of the Launch Pad onto the wedge.

RELATED PRODUCTS:

The set of six **Angled Wooden Wedges** (P4-2215) allows you to vary the angle of your launches from 30 to 55 degrees in steps of 5 degrees.

The **Air-Powered Projectile** (P4-2200) is a safe, easy-to-repeat projectile.

The **Heavy Duty Air Pump** (P4-2222) is a necessity for any successful launch.

Replacement Washers (P4-2225) and the **Spare Projectile Body** (P4-2205) allow your experiments to continue even if you lose your original components.

The **Classroom Set** (P4-2230) gets everyone involved. Includes 6 projectiles, 6 launch pads, 6 air pumps, one set of wedges, one deluxe trundle wheel and one set of replacement washers

Balloon Helicopter

P4-2350

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.

USING THE BALLOON HELICOPTER:

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.

Goal:

Use Newton's 3rd Law to explain the motion of a balloon helicopter.

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.

Happy and Unhappy Balls

P6-1000

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, they exhibit marked difference in their physical properties:

PHYSICAL PROPERTIES:

<u>Low v. High Hysteresis:</u> Hysteresis is a measure of the retardation of the natural tendency of rubber to return to its original shape after deformation. This retardation is caused by internal frictional forces resulting from the molecular structure of the rubber. The dead or "unhappy" ball exhibits the greatest hysteresis.

<u>Rate of Restitution:</u> The ball with low hystersis (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.

<u>Coefficient of Friction:</u> 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.

SUGGESTED EXPERIMENTS:

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

1. <u>A Rolling Ball Gathers Momentum:</u> Set up an inclined plane at least one meter in length (a table tilted 15-20 degrees by books propped under the legs will suffice) 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 build up and excessive tire wear, so this property must be balanced by blending high-friction rubber with a more firmly vulcanized rubber.

2. <u>Sphere of Flying:</u> 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? Explain any observed differences in the behavior of the "happy" ball.

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

EXPLANATION:

<u>Restitution</u> 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 which the foot, leg, and ankle are subjected. 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. They might surprise you with their creative answers.

<u>Chemical Formulation:</u> Figure 2 outlines the primary steps in the formation of Norsorex. First, ethylene cyclopentadiene is converted to the monomer norbornene via the 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.converted into electromagnetic radiation.

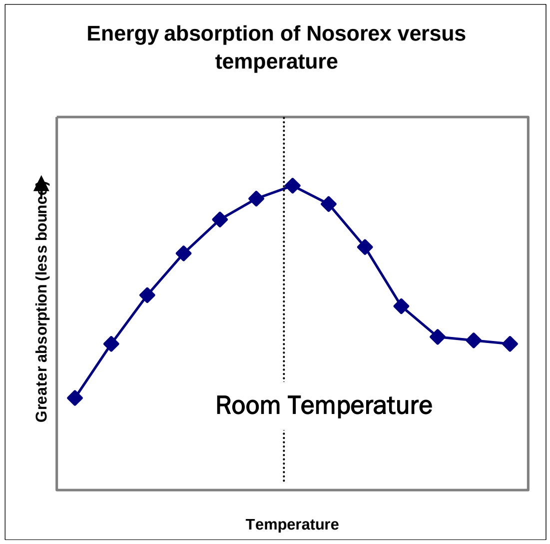
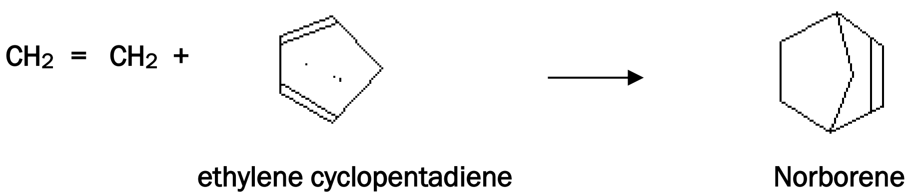


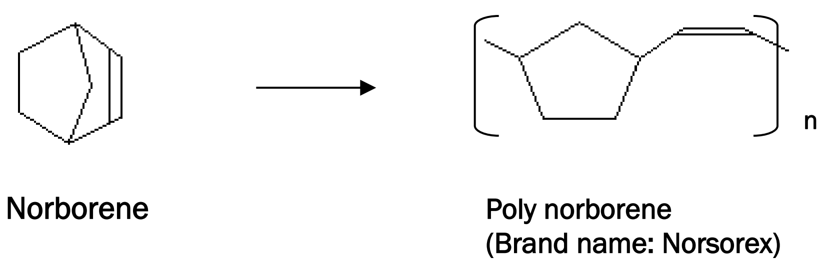
Figure 1

Diels-Alder reaction



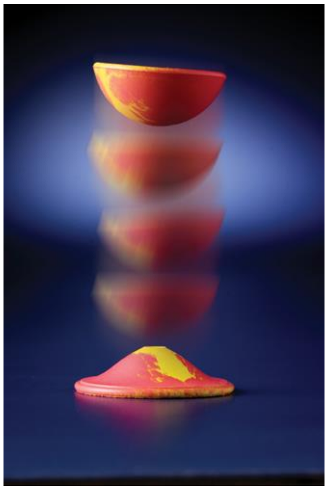
Ring-opening polymerization

Figure 2



Dropper Popper

P6-6075



INSTRUCTIONS:

Push inward on the Dropper Popper 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:

- Make sure the small center hole is open.
- Knead the rubber so the popper will stay inside-out until it lands.
- Be patient. It's not easy to align it right every time.

RELATED PRODUCTS:

Happy/Unhappy Balls (P6-1000). One ball bounces, the other does not!

Astro Blaster (P1-5000). Drop the stack of balls, and the top ball bounces to 5 times its original height!

Bouncing Dart

PX-1204

BACKGROUND:

If you fell from a tree limb onto a trampoline, you'd bounce. If you fell into a large pile of leaves, you'd come to rest without bouncing. In which case, if either, is the change in your momentum greater? This activity will help you answer that question. You will compare the changes in momentum in the collision of a "bouncing dart" where bouncing does take place and where it doesn't.

Originally developed for Paul Hewitt's Conceptual Physics, the Bouncing Dart demonstrates the energy transfer that occurs in elastic and inelastic collisions. The dart has an elastic end and an inelastic end. Swing the dart so that it collides with a massive (1kg or more) dynamics cart, and compare the distances the cart moves when hit by the different ends.

PRODUCT INFORMATION:

The dart consists of a thick wooden dowel with a rubber tip on each end. Although the tips look and feel the same, the tips are made of different kinds of rubber. One end acts somewhat like a very bouncy ball. The other end acts somewhat like a lump of clay. They have different elasticities. Bounce each end of the dart on the table and you'll easily see which end is more elastic. In the activity, you'll do the same against the dynamics cart as a pendulum.

RELATED PRODUCTS:

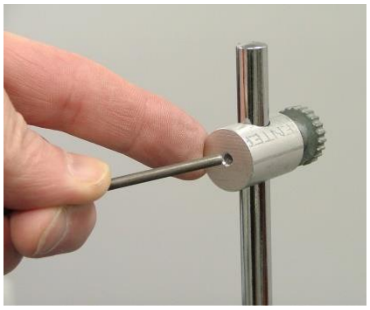
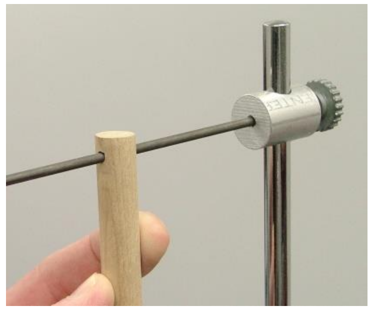
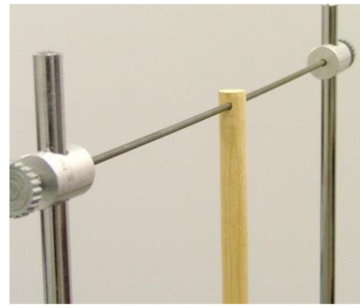
Pair of Dynamic Carts (P3-3530). High-impact plastic cars for any mechanics experiment involving linear motion.

Liquid Accelerometer (P3-3525). Illustrate accelerations in various dynamic situations.

Ring Stand Base with Rod (66-4220). Mount your support rings to this ring stand with base.

SETUP INSTRUCTIONS:

1. Using two ring stands, slide the two ring stand clamps on to the vertical ring stand rod to approximately the same height. Then insert the thin metal rod into the small hole in one of the clamps. Slide the Bouncing Dart's long vertical dowel onto the rod at the small hole provided, so that it would swing freely at a pendulum.

Then slide the other end of the thin rod into its matching hole on the other ring stand clamp. Adjust the clamp positions so that the rod is level, allows the bouncing dart to swing freely as a pendulum and that it is at the right height to strike the middle rear of the dynamics cart at the cart's lowest point.

BIBLIOGRAPHY:

Conceptual Physics Lab Manual by Paul G. Hewitt. Pearson Education, Inc. pp.65.