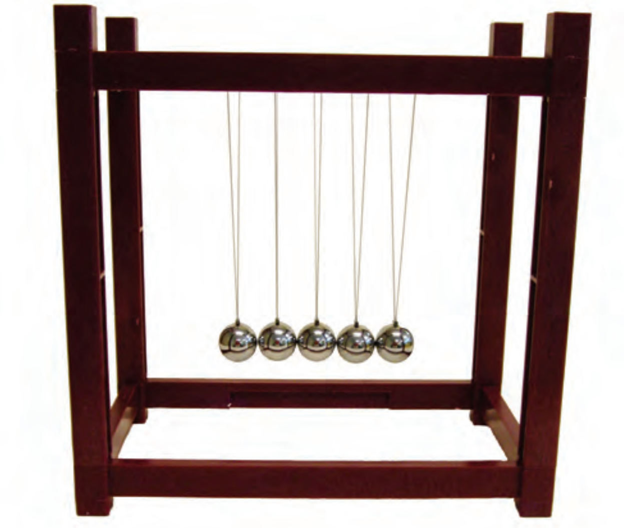
611-0065 (40-135) Newtonian Demonstrator

Warranty, and Parts:

We replace all defective or missing parts free of charge. Additional replacement parts may be ordered toll-free. We accept MasterCard, Visa, checks and School P.O.s. All products warranted to be free from defect for 90 days. Does not apply to accident, misuse or normal wear and tear. Intended for children 13 years of age and up. This item is not a toy. It may contain small parts that can be choking hazards. Adult supervision is required.



Introduction:

The 611-0065 Newtonian Demonstrator is a classic device that teaches both conservation of energy and conservation of momentum. The Demonstrator has been used for many years to teach Newton's Third Law, which states; "For every action, there is an equal and opposite reaction." As a ball is released from a given height and collides with the row of balls, a ball is sent outward from the other end to the same height as the first ball was dropped. The same happens for two balls, or three, or four. The design of the Demonstrator allows for minimal friction, but eventually, friction from the air, the string connections, and the interaction between the balls will slow the action to a stop.

Care and storage:

The 611-0065 Newtonian Demonstrator has a plastic frame that should be kept away from moisture and high humidity to prevent mildew. The steel balls should be occasionally cleaned and polished to prevent any foreign material from interfering with the interaction between balls.

How to use:

1. Carefully remove the Newtonian Demonstrator from its packaging. Make sure that you do not put a strain on any of the strings.
2. Place the unit on a smooth level surface away from any magnetic fields. Ideally, orient the row of balls and frame in the east-west plane.
3. Closely examine the row of balls from the side to make sure that they are all even. The strings may be very gently stretched in order to align all of the balls properly.

Releasing balls from one side: *See next page for starting positions*

1. Raise one ball from the row about 5 inches and release it as smoothly as possible. Observe the results.
2. Allow all of the balls to come to rest. Repeat the procedure using 2 balls, then 3 balls, and then 4 balls.

Releasing balls from two sides: *See next page for starting positions*

1. Raise one ball from each side of the row about 5 inches. Make sure that the two balls are an even distance from the remaining balls at rest.
2. Allow all of the balls to come to rest. Repeat the procedure using 2 balls on either side.

Discussion:

Conservation of momentum:

Momentum (P) is an object's

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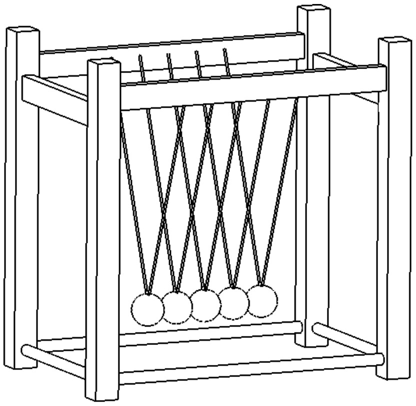


mass (m) times velocity (v).

$P = mv$

In an elastic collision, the total momentum of two colliding bodies must be equal before and after they impact each other.

$P_{initial} = P_{final}$

Thus:

$m_1v_1 + m_2v_2 = m_1v_1 + m_2v_2$

initial final

Where: m_1v_1 is the mass of the colliding object (released ball) times its velocity.

m_2v_2 is the mass of the impacted object (stationary ball) times its velocity.

In the first procedure with our Newtonian Demonstrator, the mass of the lifted ball is accelerated by gravity and strikes the row of balls with a momentum of m_1v_1. There is a temptation to treat the four balls at rest as a single mass. However the interaction of each ball must be calculated with each ball in succession with their individual initial and final velocities. If we treat the entire row of balls as a mass of 4m, the result would be for all four balls to swing out upon impact. This is of course not what happens. Instead, each ball transfers its momentum independently to each successive ball, until the end ball. The end ball has no further place to transfer the momentum, and thus is propelled into the air to the height that the original ball was dropped from. Thus maintaining the conservation of momentum.

Conservation of energy:

Energy is also equal throughout the system. The closed mechanical system maintains that no energy is gained or lost, and that the Potential Energy (PE) is equal to the Kinetic Energy (KE).

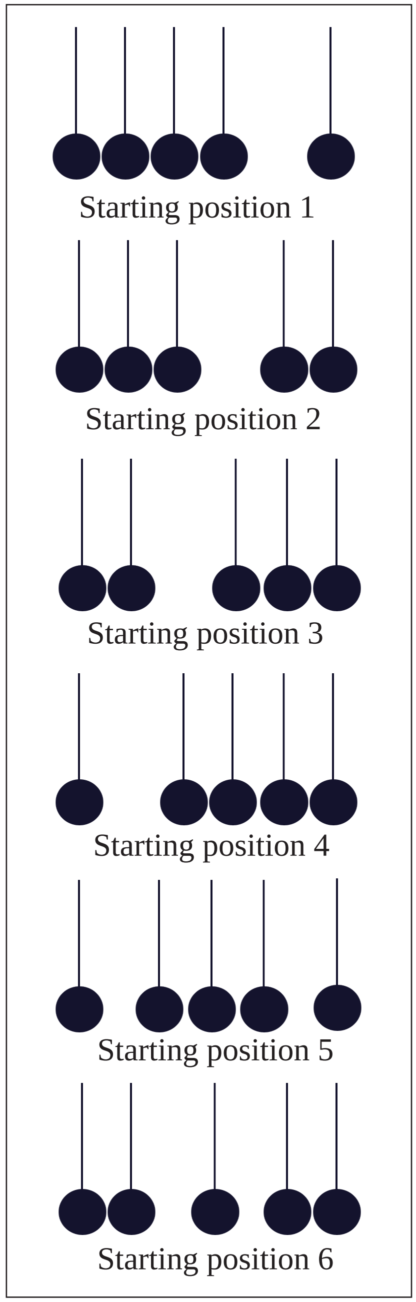
$PE = KE$, or $PE - KE = 0$

The ball is lifted to a height (h) above its resting point, and is given Potential Energy. When the ball is released, the force of gravity (g) accelerates the ball of mass (m). The Potential energy is converted into Kinetic Energy.

$PE = KE = mgh$

The energy is transferred through each individual ball as they collide, and the final ball is released upwards to the original height (h). At this point, all of the Kinetic energy has been converted to potential energy, and the cycle repeats itself in the opposite direction.

The system is not perfect, and there is energy transferred away from the demonstration in the form of friction. Air friction, friction from the string joint, and imperfections in the alignment of the balls all contribute to the system eventually coming to a rest.



Science Standards
40-135 Newtonian Demonstrator
Content: Physical Science
Grades 5-8:
Motions and forces.
Transfer of energy.
Grades 9-12:
Motions and forces.
Conservation of energy.

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