Newton's Collision Balls (Newton's Cradle)

Description: This activity demonstrates conservation of energy and momentum. This version of Newton's Cradle uses six balls of equal mass rolling on a grooved track. If two balls are released from one end of the track, only two balls will move from the opposite end of the track.

Physics Principles:

- Conservation of Energy
- Conservation of Momentum
- Elastic Collisions

Conservation of Energy:

- If no energy is added to the system by external forces, then the total energy in the system should stay the same.
- We consider the frictional effects of the rolling surface and air resistance to be negligible.
- There is gravitational force of the ball with the earth, but it has no component in the direction of the motion. Similarly, there is the force of the track on the balls, but again, there is no component in the direction of motion. Thus neither of these forces affects the total kinetic energy in the system.

Conservation of Momentum: *p* = *mv*

- The total momentum of the group of balls remains the same in the absence of external forces.
- The ball initially in motion collides with the line of steel balls.
- Because the balls are of the same mass, the first ball will not recoil when it hits the line of balls, it will stop when it collides with the line of steel balls and the ball on the far end will move away at the same momentum due to conservation of momentum: .   Since all of the balls have the same mass, the velocity of the "ejected" ball is the same as that of the initially moving ball.
- The momentum from the first moving ball m transferred to the ball it strikes, which in turn transfers to the next ball and so on until the end ball moves out.
- Thus the change in momentum of the system is zero.

Elastic Collisions:

- Energy is conserved because total kinetic energy is the same before and after the collision.

$$\text{Momentum} = m_1 v_{1i} + m_2 v_{2i} = m_1 v_{1f} + m_2 v_{2f}$$

$$\text{Kinetic Energy} = \frac{1}{2} m_1 v_{1i}^2 + \frac{1}{2} m_2 v_{2i}^2 = \frac{1}{2} m_1 v_{1f}^2 + \frac{1}{2} m_2 v_{2f}^2$$

- Collision between the steel balls is approximately elastic, because there may be some (although negligible) deformation and a loss of kinetic energy.
- Truly elastic collisions do occur between atomic and subatomic particles.
- Momentum is conserved because external forces are negligible.
- Inelastic collisions, on the other hand, show a loss in kinetic energy, although momentum is still conserved. When colliding objects stick together, there is some energy conversion to internal energy, or elastic potential energy due to deformation of objects, and to rotational energy.

How it Applies to this Kit:

- The steel balls in this set up experience minimal deformation and are of the same mass, therefore the initial velocity at which the balls are released (v_i) will be the same as the final velocity (v_f). Therefore, the balls exchange velocities (note that they do have direction) because they have the same mass.

- When you push one ball into the line of several balls (make sure they are all touching), you will see that only one ball moves off of the end at the same velocity at which you sent the initial ball towards the line of balls. Similarly, you see that this will occur with 2, 3, etc balls.

Questions to Investigate:

- What if the masses of the balls were different? If the initially moving ball had a greater mass than what it hit? Or a lesser mass?
- Is momentum conserved if one ball moves toward the balls and two balls leave from the opposite end? What about energy?
- If you set two balls into motion toward the line of steel balls and there is a slight gap in between them, do you see that reflected in the balls that leave from the opposite end? Why?
- If the ball that was initially moved toward the line of balls did not come to a complete stop after striking the balls was momentum and energy completely conserved?
- What happens if one ball on each side is collided toward the line of steel balls at the same time? What about 2 balls on each side?

Online Resources:

- A conceptual analysis of Newton's Cradle: http://www.lhup.edu/~dsimanek/scenario/cradle.htm
- Newton's Laws: http://www.glenbrook.k12.il.us/gbssci/phys/Class/newtlaws/newtltoc.html
- Momentum Concepts: http://www.glenbrook.k12.il.us/gbssci/phys/Class/momentum/momtoc.html
- Visual Collisions: http://www.fearofphysics.com/Collide/collide.html
- Newton's Cradle Applet: http://www.walter-fendt.de/ph14e/ncradle.htm

References:

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