Module 3 – Conservation Laws

NEWTON'S CRADLE

INTRODUCTION

Most people have seen the toy known as Newton's Cradle. What you do is lift a ball or two and release them. The balls collide with those not lifted and the same number of balls rise. The system oscillates back and forth.

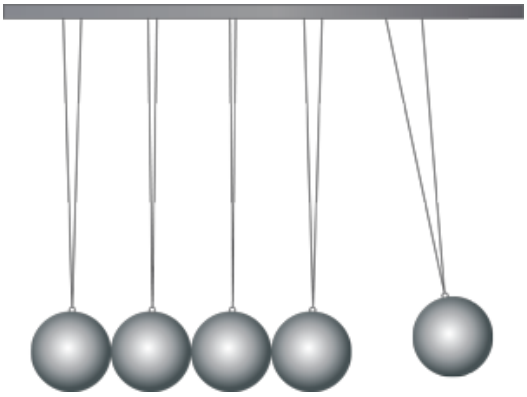

Figure 3

Newton's Cradle displays four intimately related physical concepts: Newton's Second Law, Newton's Third Law, Conservation of Energy, and Conservation of Momentum.

To set the toy in motion, we raise one of the outside balls to a height before releasing it and initiating the toy's telltale clacking of balls striking each other. By lifting the ball, we have done work on the system, and thus, giving the ball potential energy. When the ball is released, it accelerates downward, but along a curved path due to the tension in the string or wire holding the ball to the cradle. The ball reaches its maximum velocity at the bottom of the swing, where it impacts the next ball in line. At this point, a number of things are happening.

NEWTON'S LAWS

The swinging ball's mass has been accelerated in the gravitational field of the earth, thus, it has force (mg, Newton's Second Law). When it strikes the next ball, it does so with this force, creating an action-reaction pair (Newton's Third Law) where the force from the swinging ball is transferred to the next ball, and ultimately through the rest of the balls, until the last one. Each of the intervening balls experiences an action-reaction pair as the force is transmitted to the last ball.

CONSERVATION OF MOMENTUM

When the first ball strikes the next one in linethe mass of the ball has velocity, thus kinetic energy and momentum (mv)it conveys its momentum to the second ball. The first ball has lost its momentum to the second ball, and it stops. The momentum is transmitted through the rest of the balls to the last one. Both properties are conserved: the momentum at the beginning of the collisions equals the momentum at the end (when the last ball begins its swing up and away) and, more broadly, energy is conserved.

CONSERVATION OF ENERGY

The potential energy of the first ball—equal to the work put into the system by raising it to the initial release point—converts to completely kinetic energy at bottom of the swing. The Conservation of Energy states that energy cannot be lost or destroyed, only converted (or exchanged). When the first and second balls collide, the first transfers its kinetic energy to the second. The second ball immediately transmits the kinetic energy to the third. This continues down the line. Then, the last ball swings out and up, as if continuing the arc that the first ball began. This ball's energy, solely kinetic initially, begins transitioning to potential energy until, at the very top of the arc where it stops for the briefest of moments, the ball possesses only potential energy, as the first ball did. Conservation of energy, conservation of momentum, and two of Newton's Laws all wrapped up and demonstrated in a simple toy.

Although you'll notice that after a while the balls eventually come to a stop, this does not mean the conservation laws are not in effect. The energy is accounted for in a variety of ways, each one "taking" a little energy from the system. The balls lose energy to the air as they move through it (air friction), they make sound when they collide and they heat up a small amount upon collision (both are energy conversions). The wires or strings connecting the balls to the cradle frame have friction at their attachment points as they move. Each of these factors "steals" energy from the system and the balls slow down and eventually stop.

What happens if we release two balls? Three balls? Conservation of momentum dictates the result.

The toy shows that the total momentum of the system remains unchanged since the number of balls and their velocity is the same before and after each collision.

PROCEDURE

This experiment consists of three parts.

1 Open the experiment instructions and worksheet.

- Conservation Laws Experiment Instructions (PDF[1])
- Conservation Laws Experiment Worksheet[2]

[1] http://www.webassign.net/ebooks/eraucolphysmechl1/lab_3_2_procedure/manual.pdf
[2] http://www.webassign.net/ebooks/eraucolphysmechl1/lab_3_2_procedure/worksheet.pdf

2 After you have thoroughly read the instructions and worksheet, open the experiment simulation[3] in which you will conduct the experiment and collect your data.

3 Record your data in the worksheet. (You will need it for the experiment report assignment in WebAssign.)

[3] http://www.walter-fendt.de/html5/phen/newtoncradle_en.htm