

Pendulum Waves and Newton's Cradle

Simulation Report

Computer Modelling CA1

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Introduction

This report discusses the implementation of the simulation made with JavaScript and HTML5 canvas. This simulation was developed as a part of the Computer Modelling Module. These simplified simulations represent a pendulum wave machine and a Newton's cradle. These devices illustrate the nature of pendulum oscillations. I have chosen this subject because pendulums are hypnotizing, relaxing and interesting devices to look at.

Background information about pendulum

2.1 Simple gravity pendulum

The simple pendulum is a simplified version of the real pendulum. It aims to show how a pendulum works. The pendulum's mass is centred in the balls at the end of the strings and the mass of the string is negligible. The ball moves back and forth on a single plane. The friction and drag are inconsequential in this model. The only forces present are gravity and string tension and those are proportional to the mass of the ball. Thus, the period of the pendulum is independent. This means that the period will always be the same way no matter what object is hanging at the end of the string. Below is the formula to calculate the period.

T – period
L - length of the pendulum
g- gravity

$$T \approx 2\pi \sqrt{\frac{L}{g}}$$

Fig.1 Period formula

This formula shows that the period is independent on the weight that is hanging on the string. The main variable is the length of the string.

2.2 Pendulum Wave

Pendulum wave machines consist of simple pendulums hung next to each other. The length varies between them. In this model has the length of the longest pendulum been adjusted so it has 51 oscillations in a one minute period. The length of following pendulums is shorter so that each successive pendulum executes one additional oscillation per minute.

2.3 Newton's cradle

Newton's cradle is a device that shows the conservation of momentum and energy. It uses balls which are swinging. When one of the balls is moved, it falls and then transmits the energy through the balls in the middle and pushes the last ball up. The simplified solution depends on conservation of momentum and kinetic energy.

Description of the physics and mathematics components

3.1 Physics and Mathematics components

1. *Velocity* is a physical vector quantity. It is calculated with displacement divided by time. In my application, velocity is calculated for x-direction and y-direction per Newton's balls.

2. *Sine waves* are curves which represent repetitive oscillation. The amplitude of a sine wave is the maximum distance it reaches from zero. The period of the sine wave is the time it takes to complete one cycle. The frequency is the amount of cycles in one second. In the Pendulums Wave simulation, the frequency for each ball changes. All the pendulums start moving at the same time and immediately they fall out of sync. The phases change because of the different periods of oscillation and this change is applied to the x-position of balls.

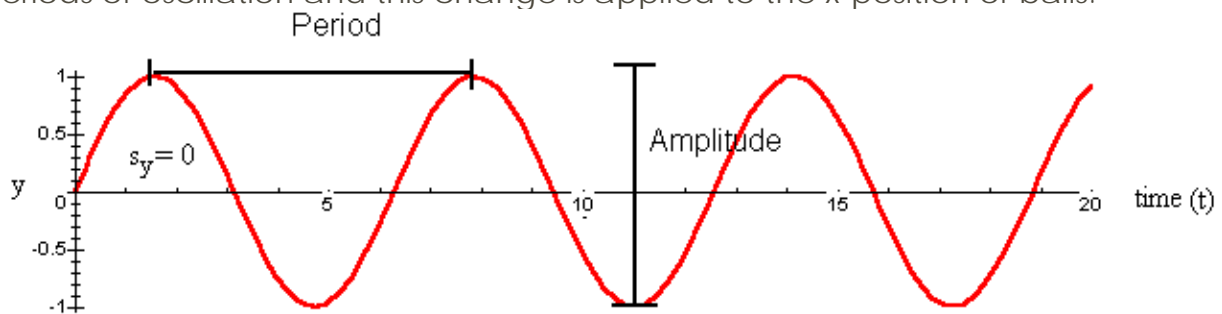


Fig.2 Sine wave image[2]

3. *Collision detection* was used to create the Newton's Cradle simulation. Each time when the ball touches the ball next to it, the kinetic energy is passed through the balls and the last ball is pushed up. In the application, collision is checked between balls in case they are touching the according amount of velocity is transferred to the other ball(s) on the other side.

4. Mathematical JavaScript components used

- Math.round – returns the value rounded to the nearest integer
- Math.PI – returns the ration of a circle's circumference to diameter

- `Math.cos` – returns the cosine of a number

3.2 Interactive elements

There are two buttons on the left-side panel. Those buttons allow the user to switch between two different canvases. In the first simulation, the user can change the number of balls and the colour of them. In the second animation, it is possible to switch between one ball and three balls swing.

Initial concept

In the initial concept for developing the Newton's Cradle the interaction was designed differently. It was planned to allow the user to drag the balls up and put them in motion when the user releases the ball. In the end, it is based on simple spring motion similar to one found in Lamberta Foundation HTML5 Animation with JavaScript book [3].

Overview of the implementation

Representation of physics is usually difficult without the usage of physics engines. In my simulations, the physics were simplified. In the case of the Pendulum Wave, the value for the first frequency was calculated [1] and already provided in the code. In the Newton's Cradle simulation, the user can see the cradle in motion. However, the conservation of momentum and energy is simulated.

Results and conclusions

In the end, the simulations are displaying the desired motion. There are no run-time errors in the application.

To sum up, this project let me learn about the pendulums physics. The idea for the project was developed just after the brief was given out. If I would be able to start again, I would start with a wider research of physics and after that start the implementation process. If I would have more time to complete the project I would implement drag functionality for the Newton's balls and improve the involved physics implementation.

References

- [1] "Pendulum Waves," Pendulum Waves. [Online]. Available: <http://sciencedemonstrations.fas.harvard.edu/presentations/pendulum-waves>.
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- [3] "Html5-animation," *GitHub*. [Online]. Available: <https://github.com/lamberta/html5-animation/blob/master/examples/ch08/05-spring-1.html>. [Accessed: 01-Mar-2017].