# M. G. COLLEGE, IRITTY

PROJECT REPORT

# WAVE SIMULATION

SUBMITTED BY

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# CERTIFICATE

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This is to certify that this is the bonafide record of project work carried out by SHIVAPRASAD V of M. G. College, Iritty, for the academic year 2015-2018.

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Submitted for Kannur University B. Sc. Degree examination May 2018.

Examiners:

1.

2.

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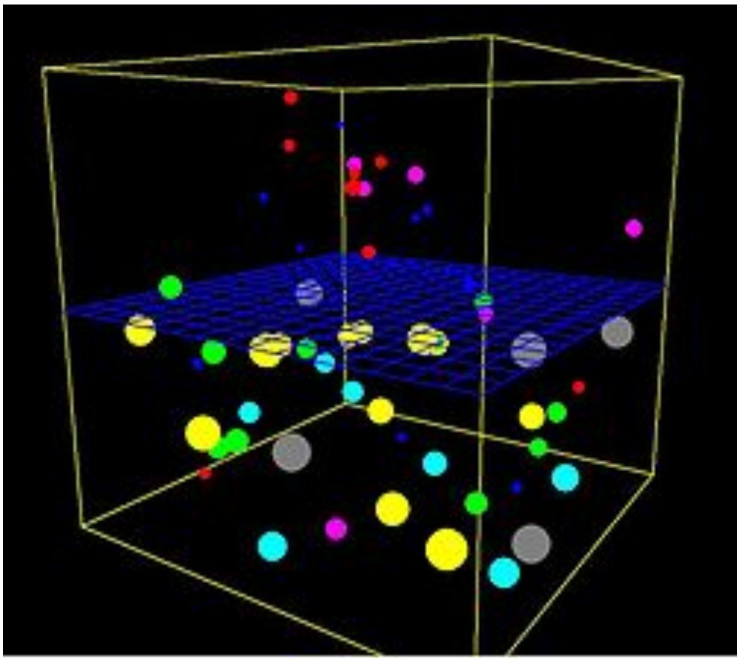
# INTRODUCTION

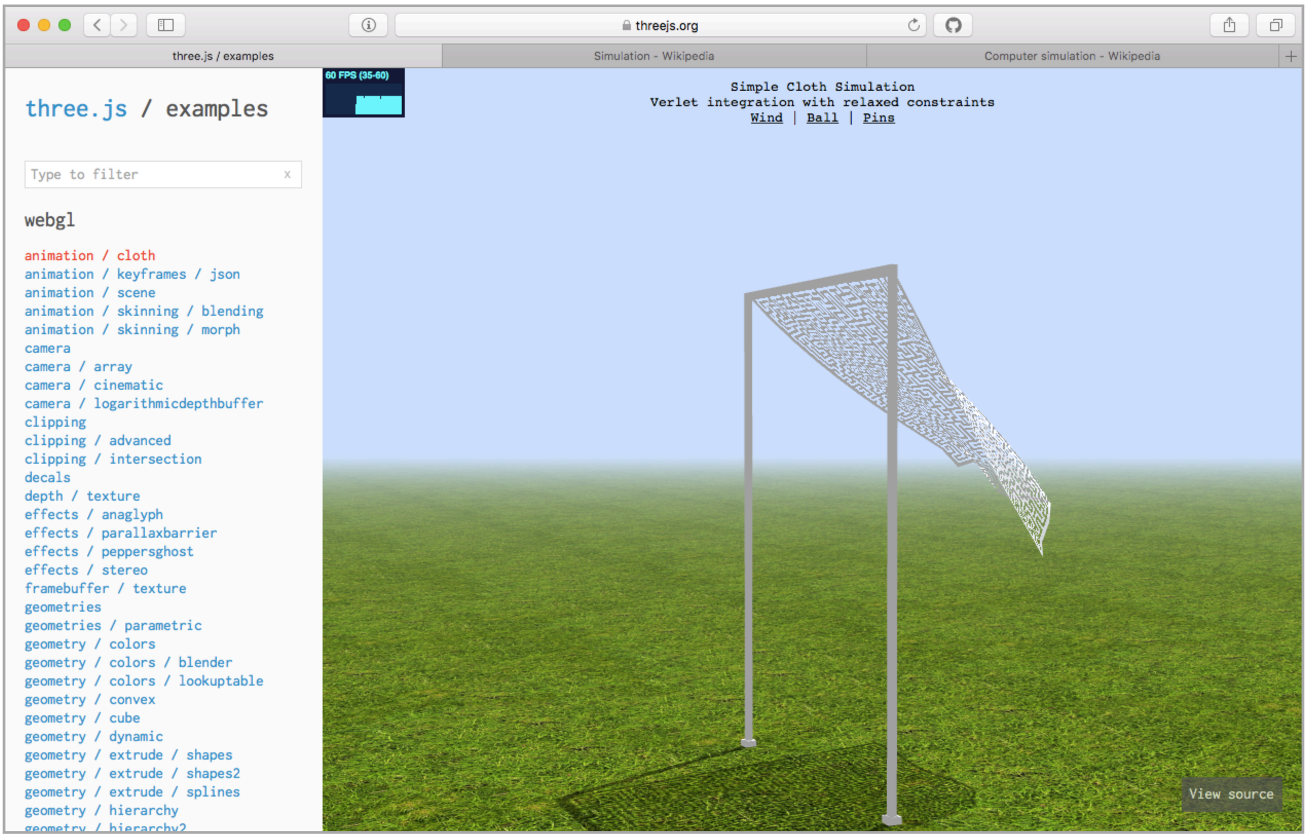
Simulation is the imitation of the operation of a real-world process or system. The act of simulating something first requires that a model be developed; this model represents the key characteristics, behaviours and functions of the selected physical or abstract system or process. The model represents the system itself, whereas the simulation represents the operation of the system over time.[1]

Computer simulations reproduce the behaviour of a system using a mathematical model. They have become a useful tool for the mathematical modelling of many natural systems in Physics. Computer simulations are computer programs that can be either small, running almost instantly on small devices, or large-scale programs that run for hours or days on network-based groups of computers.[2] Such large-scale programs are extensively used in almost all research labs all around the world.



Computer simulation of the process of Osmosis[2]

This project aims to develop a small-scale program that simulates transverse waves in one dimension. The aim is to develop a web application using web technologies viz. HTML, CSS, and JavaScript. The advantage of a web application is that it can be run on any platform with only a web browser. Even though JavaScript is not as fast as other languages like C or Python, the ubiquitous nature of the web platform has greatly increased the popularity of small-to-medium scaled, web-based simulations. Modern web browsers have also greatly improved the speeds of JavaScript execution.



Cloth simulation running in Safari web browser on a Mac computer[3]

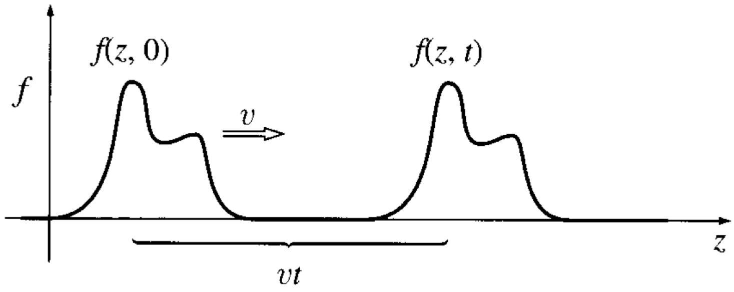
This project will also be able to use the in-house developed simulator to visualise the formation of Standing waves, Beats, etc. by the superposition of two waves travelling in opposite directions.

# AIM

To develop a one dimensional transverse wave simulation program using web technologies, and then use the simulator to visualise superposition of two transverse waves.

# THEORY

A wave is a disturbance of a continuous medium that propagates with a fixed shape at constant velocity. In time $t$, each point on the wave form simply shifts to the right by an amount $vt$, where $v$ is the velocity:[4]




The general differential equation of a one-dimensional wave that travels with a velocity $v$ in the $x$ direction is given by:

$$\frac{d^2y}{dx^2} = \frac{1}{v^2}\frac{d^2y}{dt^2} \qquad \ldots(1)$$

which admits a general solution of the form[5]:

$$y = f\left(t - \frac{x}{v}\right) + g\left(t + \frac{x}{v}\right). \qquad \ldots(2)$$

The waves travelling in the positive and negative $x$ directions are given by the first and second terms of equation (2), respectively.

A *plane progressive simple harmonic wave* is the simplest and most important type of wave in which the displacement of a particle is a simple harmonic or sinusoidal function of time and distance:[5]

$$y = a \sin\left[\frac{2\pi}{T}\left(t - \frac{x}{v}\right)\right] \qquad \ldots(3)$$

where $a$ is the amplitude and $T$ is the time period of the wave.

Some other common wave functions are also demonstrated by the simulator, viz.:

- Square wave:[6]

$$y(t) = a \cdot (-1)^{\left\lfloor \left(t - \frac{x}{v}\right)/T \right\rfloor} \qquad \ldots(4)$$

where ⌊ ⌋ denotes the *floor function.*

- Sawtooth wave[7]:

$$y(t) = 2a\left(\frac{t - x/v}{T} - \left\lfloor \frac{1}{2} + \frac{t - x/v}{T} \right\rfloor\right) \qquad \ldots(5)$$

- Triangle wave:[8]

Can be modelled as the absolute value of the sawtooth wave, i.e., equation (5).

## STANDING WAVES

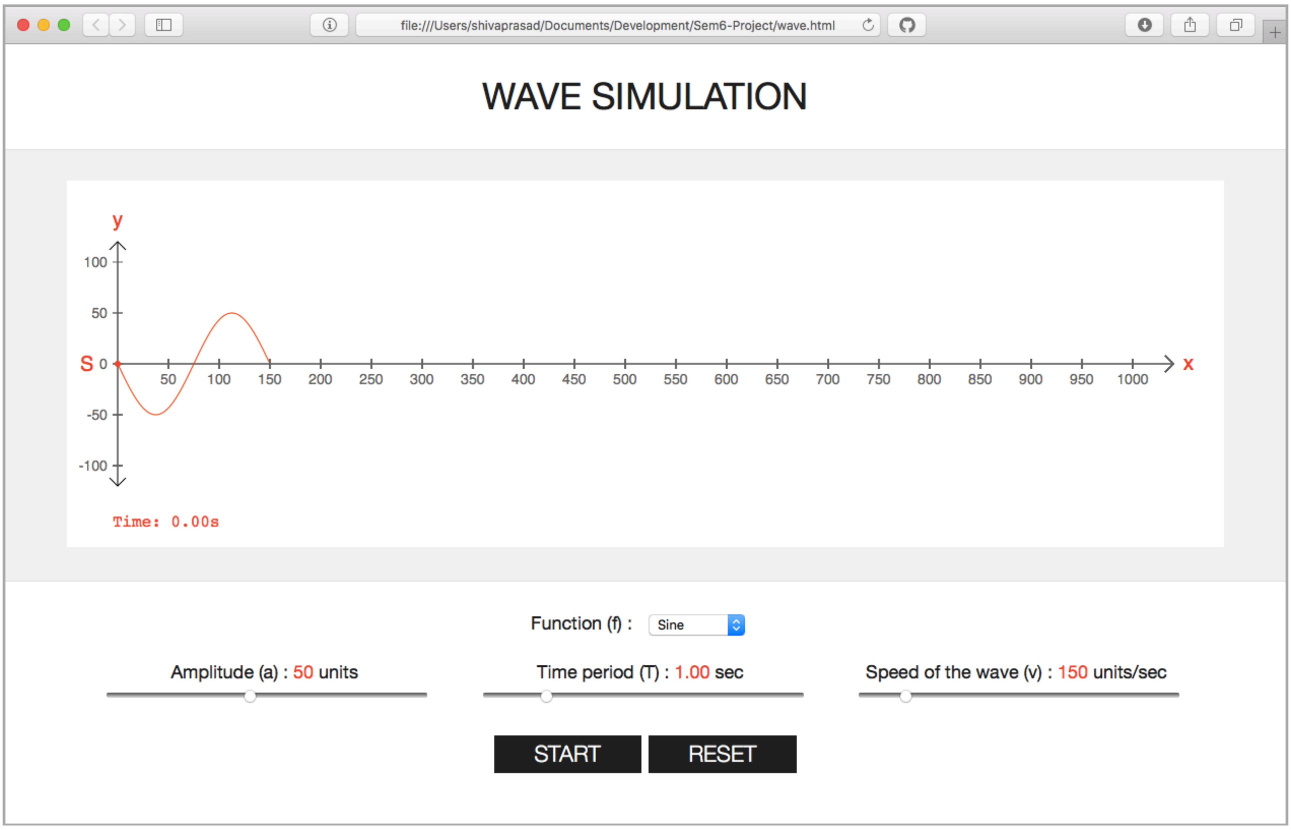
When two identical waves travelling in opposite directions superpose, the wave formed do not propagate in space, but oscillate in time. Such waves are called Standing waves or Stationary waves.

## BEATS

When two waves of nearly the same frequencies, but otherwise identical, are superimposed, a wavering wave pattern is obtained, called Beats. This phenomenon occurs commonly in sound waves.[9]

# DESIGN

The HTML page has a straightforward layout. The wave is drawn on a `<canvas>` HTML element, which is updated continuously, at a rate of 50 times per second (every 20ms). The input parameters can be controlled via the HTML `<input>` element sliders. The updates are applied realtime, i.e. even while the simulator is running.




The whole simulator is split over 6 files:

1. `intro.html` : The front page of the application.
2. `wave.html`, `sup_waves.html` : The webpage markups.
3. `style.css` : The stylesheet describing the layout.
4. `wave.js, sup_waves.js` : The actual simulator code in JavaScript programming language.

# PROCEDURE

The simulation starts at time $t = 0$. Each and every point on the wave is calculated every 20 milliseconds, and the calculated wave is drawn. Thus the output is updated 50 times in a second, giving smooth continuous animation. The parameters are updated each time before drawing the waves to get the latest values.

A regular `for loop` is used to draw all the points, using the method called `lineTo()` of the `canvas` element (variable `scr` below):

```
for(x=0; x < maxx-100 && x < d; x++) {
    y = fun(x, time);
    scr.lineTo(50+x,maxy/2-y);
}
scr.stroke();
```

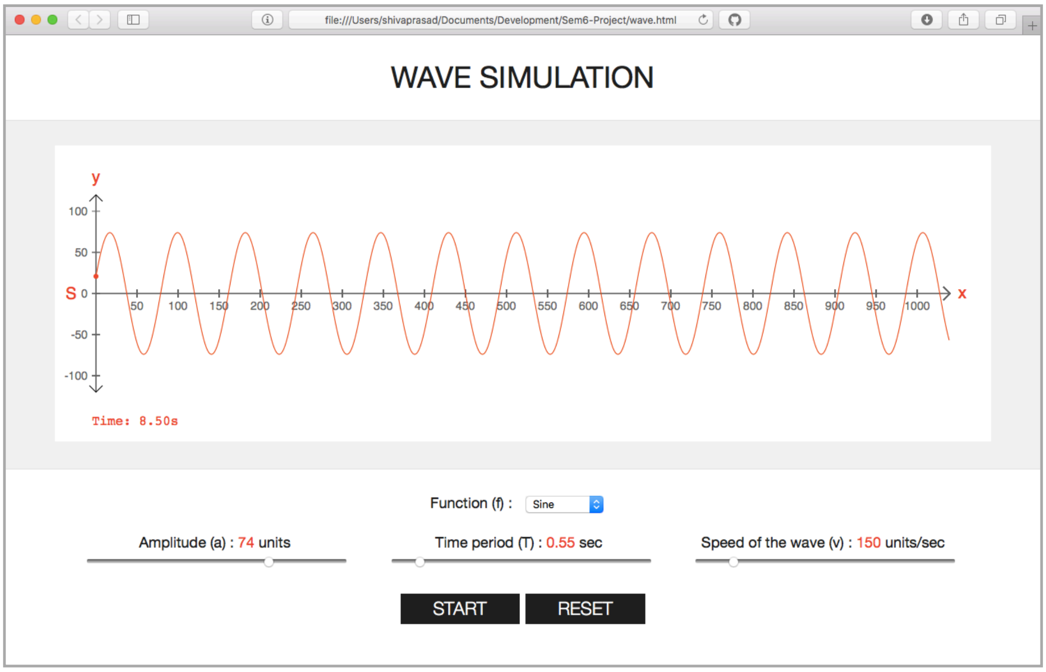
The following Javascript functions model the wave functions (equations (3), (4), and (5)) used to calculate the wave points:

```
function sin(x, t) {
    return a * Math.sin(2*Math.PI * (t-x/v)/T);
}
function saw(x, t) {
     return 2*a * ((t-x/v)/T - Math.floor((t-x/v)/T) -
1/2);
}
function sqr(x, t) {
    return a * Math.pow(-1, Math.floor((t-x/v) / T));
}
function tri(x, t) {
    return -2 * (Math.abs(saw(x,t)) - a/2);
}
```

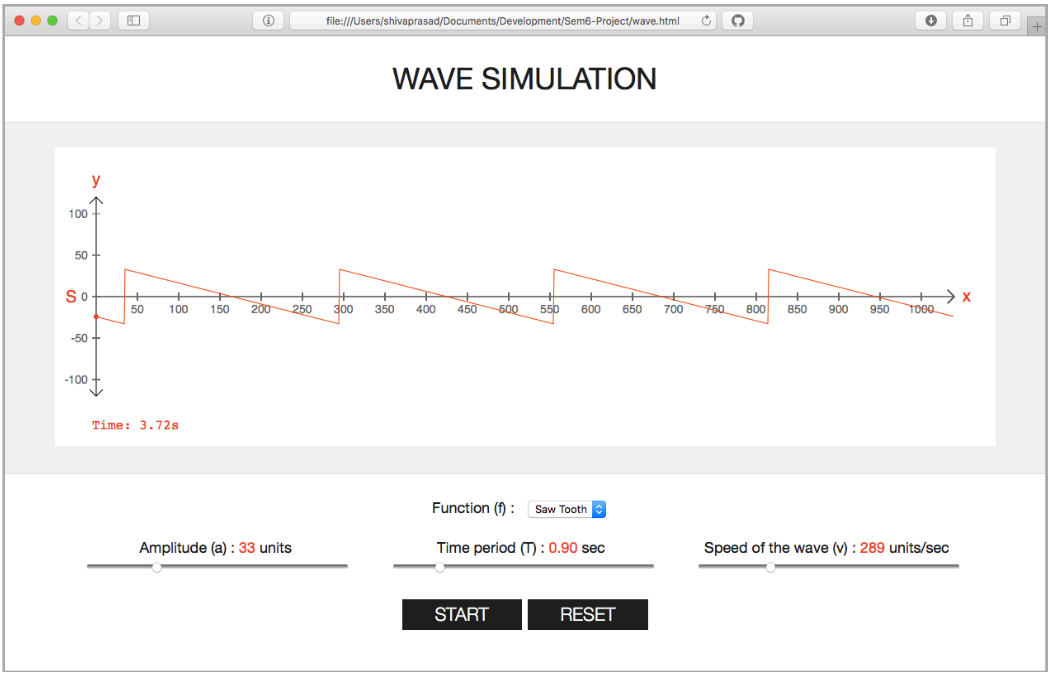
# OBSERVATION

The outputs observed on running both the single-wave and two-wave simulators with various input parameters are shown below:

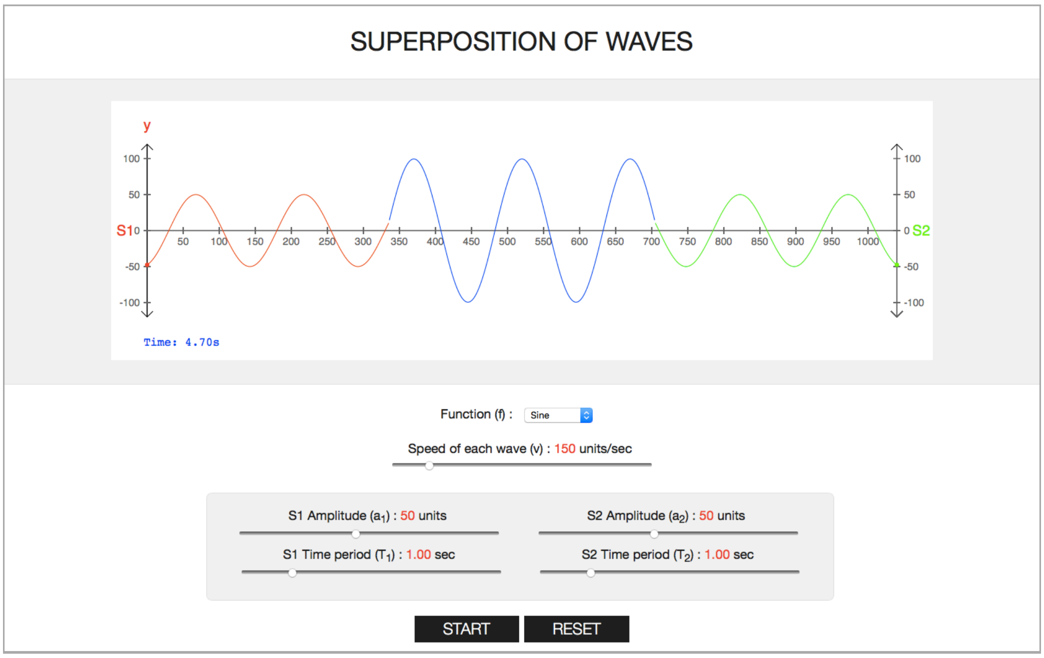
Sine wave:



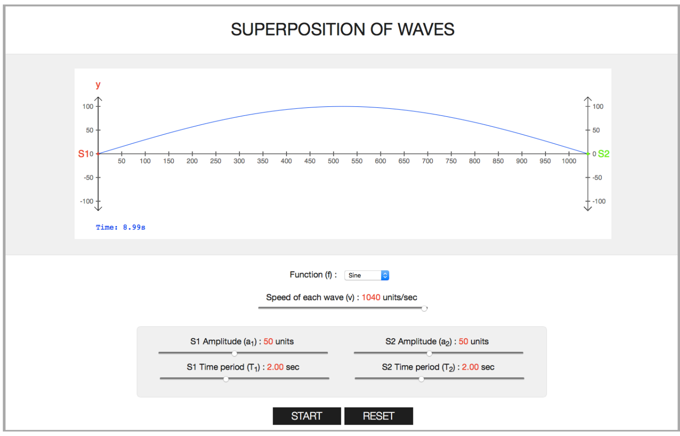

Sawtooth wave:

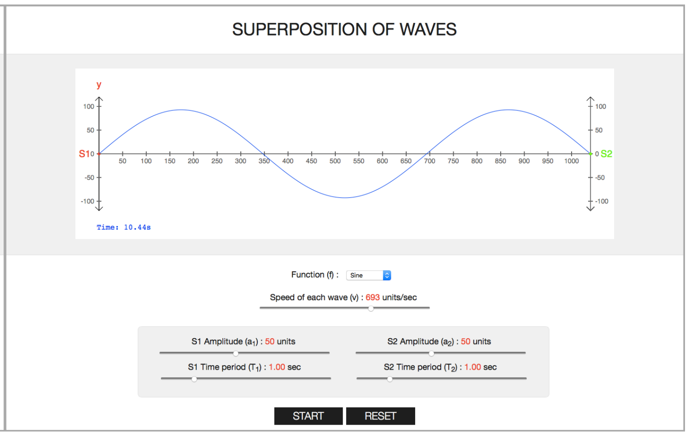


## Formation of standing sine waves:




## First and Third harmonics in the standing sine waves:




## Beats:

# CONCLUSION

The purpose of this project was to develop a computer simulator that models transverse waves in one dimension using web technologies, and then to study the behaviour of both single waves and superimposition of multiple waves. The intended software has been successfully developed, and the behaviour of the output analysed.

The simulator thus developed can be easily extended by adding new wave functions as JavaScript code. The base code can be improved to handle more complex simulations also.

Currently it runs in many modern web browsers with little or no modification. Thus it is available on all platforms, computer as well as mobile. This can pave the way for the project to become a valuable teaching aid to Physics teachers and students alike. I have decided to make the source code open-source, in hope it will spark interest in Physics students with a flair in computer programming.

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