## Brief: “Interacting Waves” Educational App

### Motivation:

Understanding wave interference, superposition, and wave propagation is foundational in physics, oceanography, acoustics, and many other fields. However, these are inherently dynamic and spatial-temporal phenomena that are difficult to fully grasp through static images or equations alone. The “Interacting Waves” app is designed as an interactive educational tool that allows students or educators to visualize how multiple sine waves combine over time. It can be used to illustrate constructive and destructive interference, wave sets, phase relationships, and more, in an intuitive and engaging way.

### Target Users:

Undergraduate students in physics, earth sciences, or engineering; high school physics teachers; science communicators.

### UI & Features:

The app provides a clean, responsive interface with the following elements (fig 1):

1. **Wave Selection:**
    - A dropdown to select the number of sine waves (1–5).
2. **Individual Wave Controls (for each selected wave):**
    - Sliders for **Amplitude**, **Wavelength**, and **Speed** (phase velocity).
    - All controls are arranged in a compact, grid-like layout for side-by-side comparison.
3. **Main Plot Area:**
    - An animated plot showing all individual waves plus their **real-time sum**.
    - The sum is shown in a bold red dashed line to highlight the interference effects.
4. **Global Controls (below the figure):**
    - Slider for **maximum x-domain** (zoom in/out).
    - Slider for **animation speed** (controls how quickly phase propagates over time).
5. **Visual Design:**
    - Uses **pastel background** blocks and rounded containers for a soft, educational aesthetic.
    - Designed for use in classroom environments, presentations, or self-paced learning.

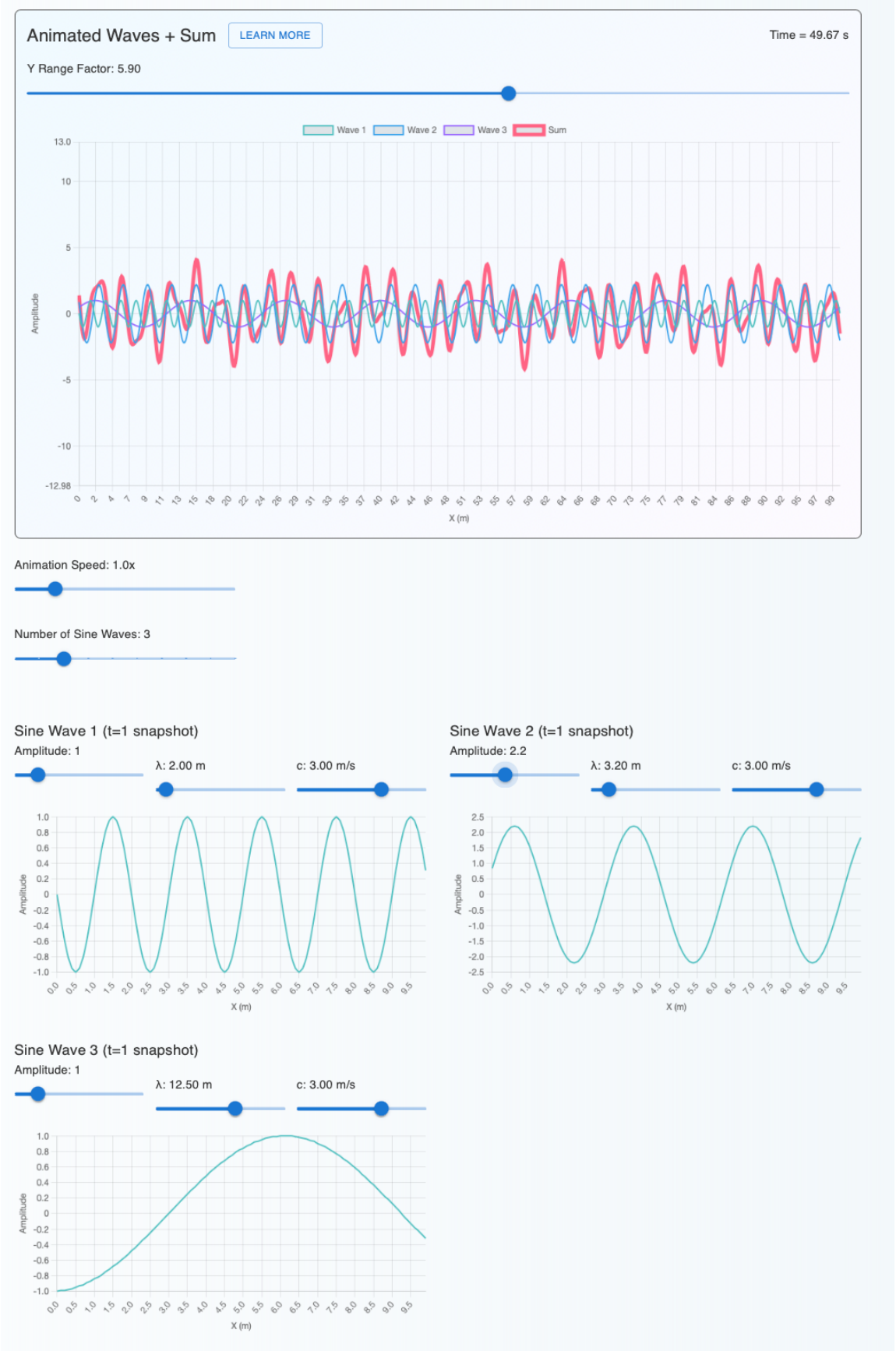


*Figure 1. Snapshot of output from the wave app showing the interaction of 3 sinusoidal waves with different wavelengths. The thick red line shows the combined wave.*

**Technical Frameworks:**

- **Frontend & Backend:**

  Built using **Dash** (Python) — a lightweight framework for building interactive web apps using Plotly for visualizations. Dash enables fast prototyping and is ideal for scientists and educators with Python experience.

- **Core Libraries:**
  - dash, dash_core_components, dash_html_components
  - plotly.graph_objs for custom charting
  - numpy for waveform calculations
- **Optional Alternatives:**
  - ReactJS + Chart.js for a JavaScript implementation
  - Streamlit or Panel for Python-based alternatives with less custom control

**Use Cases:**

- **Wave Interference Demonstrations:**

  Show how varying phase speeds, amplitudes, or wavelengths leads to constructive or destructive interference.

- **Wave Sets in the Ocean:**

  Demonstrate how multiple wave trains can interfere to form wave groups or modulated wave envelopes.

- **Fourier Synthesis:**

  Introduce students to the concept of decomposing complex signals into simpler sinusoidal components.

- **Acoustics or Optics:**

  Explore how sound or light waves combine in phase or out of phase — ideal for lab preparation or flipped classrooms.

- **Homework or Interactive Lectures:**

  Embed the app in a teaching website or use it live during class to adjust parameters in real time.