LAB 4B:
The Superposition of Solutions

PHYSICS 204

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The Research Question:

1) Assuming that it is possible to infer, derive or construct mathematical functions – such as differential equations – using a sufficient amount of data gathered from some physical phenomenon studied in a physics laboratory, is it possible to build a simulation or model of a physical phenomenon from the solutions to a differential equation?

2) Specifically, can we fashion a meaningfully precise visual simulation of ***wave motion*** – using the knowledge we have of the differential equation for ***Simple Harmonic Oscillation***?

3) Given the attempt to construct some kind of visual simulation for wave motion (whether successful or unsuccessful), how precisely can we identify the following relationships:

a. Wave motion and simple harmonic oscillation?

b. The propagation speed of a wave and the angular frequency of an oscillator?

c. Oscillators, superposition and wave motion?

d. The energy in one wave pulse, superposition and the energy in another wave pulse?

4) If the answer to (3), above, is NO, then why not? If yes, then WHAT IS THE PROPAGATION SPEED FOR SUCH A SIMULATED WAVE?

The Data Collection:

1) Choose your medium of comfort: a desktop application, a mobile app, a small paper flipbook.

As accurately as possible, create an animation for One SIMPLE HARMONIC OSCILLATOR: $y = Acos(\omega t)$.

$\boldsymbol{A}$ and $\boldsymbol{\omega}$ can be anything you want, but you want to be able to identify/measure/control them as PRECISELY as possible.

2) Now do precisely the same – on same scale but in a separate 'coordinate system' (or separate pad of paper or separate screen, etc.) for another SIMPLE HARMONIC OSCILLATOR, but this time: $y = Acos(\omega t + \pi)$.

$\boldsymbol{A}$ and $\boldsymbol{\omega}$ must be as close to possible as what they were before. Remember: You want to be able to identify/measure/control them as PRECISELY as possible. Everything should be as similar as possible to before, except the value of what we will now call '$\boldsymbol{\phi}'$. (For (1), $\boldsymbol{\phi}$ = 0, for (2), $\boldsymbol{\phi}$ = π, etc.)

3) Now do precisely the same – on same scale but in a separate 'coordinate system' (or separate pad of paper or separate screen, etc.) for another SIMPLE HARMONIC OSCILLATOR, but this time: $y = Acos(\omega t + \pi/2)$.

4) Now repeat this above process as many times as you can – halving the '$\boldsymbol{\phi}'$ as many times as you meaningfully, reliably and precisely can – in your physical simulation. It might be just one more time. Fine. Be honest and precise; don't be crazy and wrong. (The great is the enemy of the good.)

5) NOW, 'fill in': If, for example, you have a simulation for $0, 1/2$ and $1/4$ and 1, then make a simulation for any ϕ necessary such that you have a complete set of SHO's for $\phi's$ that increase by ONE CONSTANT VALUE within a given range.

6) Now set up all your SHO's so that they are superposed on one common axis of space – but NOT the axis along which each oscillates. Set them up so that they are separated by ONE CONSTANT interval as measured along this new space axis. In other words, set them up so that the constant interval by which each ϕ differs is some constant multiplied or divided by the constant interval by which the location (along a NON-oscillation axis) of each SHO differs. The 'angular delay' (or 'angular headstart') of any given oscillator, therefore, should be a linear function of its position on the NON-oscillation axis.

The '*FUN*' (and/or RESULT):

1) Given all the instructions described above, set all your superposed oscillators in simultaneous motion.

2) Given the linear function described in (6), find the slope. (You will need this for the below. Be careful about units).

a) Describe what you observe.

b) Now describe it mathematically. No, really. As a second – order differential equation.

c) HINT: First write down the solution to this Dif. Eq. Now dif. Twice. Now write down the Eq.

d) At what SPEED – in meters/sec – does your wave propagate?