Lab 3B:
A Video Creation for the Wave Equation

-- Analysis

PHYSICS 204
DANIEL A. MARTENS YAVERBAUM
JOHN JAY COLLEGE OF CRIMINAL JUSTICE, THE CUNY

A. **Specific Goals**:

To connect the mathematical implications of two independent graphs to the physical properties of wave motion.

B. **The Two Functions Under Discussion**:

1. *** $y = A_1 \cos(kx + \varphi_1)$.
2. *** $y = A_2 \cos(\omega t + \varphi_2)$.

(Note: The Sine Function and the Cosine Function can be regarded as interchangeable as long as the "phase constant" [second term in parentheses] is adjusted accordingly.)

1) *** Every term that appears in both functions has a subscript to distinguish its value in one function from its value in the other—EXCEPT ***y***. This is not an accident. In at least two complete sentences of English, why does the same y appear in both functions? (Consider what it physically means for a particle to be involved in some wave motion.)

C. **Determining Constants**.

Use the graphs you generated in the lab to answer the following questions. Show all work and clearly identify your final answers.

1) *** In radians per second, what is the ***angular frequency*** of your wave?
2) *** In Hertz, what is the standard ***frequency*** of your wave?
3) *** In seconds, what is the ***period*** for your wave?
4) *** In radians per meter, what is the ***angular wave number*** for your wave?
5) *** In meters, what is the ***wavelength*** of your wave?
6) *** A pulse passes your eye. You specifically notice a point at the ***crest*** – that is, peak – of the wave. How many seconds will you have to wait for precisely 5 more crests to pass?
7) *** How many troughs should pass your eye every second?
8) *** In meters, how far is it from a crest to the very next ***trough*** – that is, valley – on your wave?
9) *** In meters per second, at what ***speed*** does a pulse of your wave propagate from one end of the string to the other? (Strictly speaking, this is called the ***phase velocity***.)

10) *** Scrutinizing the speed.
    a. On what physical properties of your spring does the ***wave speed*** (***phase velocity***) depend?
    b. Should these physical properties change significantly while a pulse is traveling? Why or why not?
    c. Imagine that a member of your lab group begins shaking the string harder so that the standard ***frequency*** doubles.
        i. What should happen to the ***wave speed*** (or phase velocity)? Should it change? If so, should it increase or decrease? By precisely how much?
        ii. What should happen to the ***wavelength***? Should it change? If so, should it increase or decrease? By precisely how much?

11) If the two functions both apply independently but simultaneously to a particle (or to a particular y position), we can determine a function that is the ***superposition*** (sum!) of both. Assume that $A_3 \equiv A_1 + A_2$ and, just to make things simpler for right now, assume that $\varphi_1 + \varphi_2 = 0$.

$$y = A_3 \cos(\omega t + kx).$$

    a. *** Assume for the moment that time, ***t***, is CONSTANT. That is, imagine that you are focusing your attention on one frame or snapshot of the wave motion. Given this temporary assumption, differentiate your function twice—in order to get the second ***partial derivative*** of ***y*** as a function of ***x*** (where ***t***, as stated above, is treated as a constant).

b. *** Now do the reverse: Assume for the moment that time, ***x***, is CONSTANT. That is, imagine that you are focusing your attention on horizontal coordinate of the wave motion. Given this temporary assumption, differentiate your function twice—in order to get the second ***partial derivative*** of ***y*** as a function of ***t*** (where ***x***, as stated above, is treated as a constant).

c. *** Now find a relation between the two derivatives you computed above. This relation will be a second order differential equation. The relation should look extremely familiar! Hint: It will be an ***equation*** that applies to ***waves***.

d. *** Given the equation you derived in (c), above, determine the relationship (equation) between ***wave speed***, ***angular frequency*** and ***angular wavenumber***.

e. *** Gven the relation (equation), you derived in (d), above, determine a relationship between ***wave speed***, ***standard frequency*** and ***wavelength.***
The three relations you found above, in parts (c), (d) and (e), are true for all time—in life and in this class.

12) In this lab, we will have to be a bit thoughtful about obtaining and combining our uncertainties. Before diving into the customary methods, carefully consider the subtle way in which we took measurements – in order to have computer software analyze the data. In at least three complete sentences of English, describe where the most prominent source of measurement uncertainty in this lab probably occurred. Explain any confusions or difficulties that you might have encountered in applying our uncertainty method to this particular method of measurement.

D. NOTES/REMINDERS REGARDING METHODS & FINDINGS SECTION.

13) As always: Begin with a fully labeled diagram of your set-up. Provide a thorough, clear and complete description of your findings. As always, this description should serve as a narrative form of what is really a derivation or proof (or argument). It will walk the reader step-by-step from the given – the method of set-up – all the way to the final found relationship (function) among constants and variables. This findings section should flow continuously and include along the way whatever mathematics, diagram references and words are necessary to make the case. The ultimate goal of a findings section is to put the reader in a situation where s/he not only understands what the experiment found, but could then reproduce both the experimental and thought process without you.

14) The thought process embodied in the above steps -- particularly (10), (11) and (12) – *must* be incorporated and discussed in the ***Analysis*** sub-section of your formal lab report. That is why you have been asked to think about them.