A Relay Race Explains Discrepant Observations of Simultaneity

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Abstract

This paper presents a story where two witnesses claim to see the same situation in apparently contradictory ways. Sometimes laboratories claim different results to the same experiment. Could both claims be correct? This paper shows a very simple situation (in essence, a hypothetical story in Ref [1]) in classical macrophysics, where this could easily happen. Expanding on that story lead to this article. The example discussed involves a sequence of events: Did they happen simultaneously, in forward order, or in reversed order? To answer the dilemma, a key SCHOLA LUDUS example for teaching models and modeling is developed, together with variation of parameters, as well as with identification and emphasis on the limiting case, Ref [2].

Introduction

In industrial and technological companies, a lot of modeling goes on. It is necessary to stay competitive. Most engineering design involves making models of systems and varying their parameters in order to obtain optimal system conditions according to some criteria or another.

Yet initially students have difficulty with the concepts of "system" and "model". They need key examples of a system, and of a model. Ideally what could be most useful is to present the students with a surprising or perplexing situation (system) that is clearly and satisfactorily solved by simple modeling. Once they see that this can happen, as in this example, they will hopefully be motivated to use modeling to solve other problems that they encounter.

Since the system modeled is a simple dynamic system involving constant velocities, the modeling is easy to perform even for ninth graders. Yet there is enough complexity in the number of parameters that students can learn a lot of modeling experience from the lesson activities performed. They can also appreciate the importance of modeling, and learn how to use modeling to make evaluations and decisions.

Additionally, the situation presented in this paper uses a surprising outcome that the students are asked to evaluate and judge as to whether it is (a) reasonably possible, (b) hardly possible, or (c) completely impossible. When initially asked, many students feel that it is impossible under all situations. They are then asked explain, or to defend their position.

When they are asked what would have to change in order for them to accept such a situation as actually being possible, many of them are stumped. This is then a good point to suggest modeling the situation and experimenting with the parameters of the model. They become aware of a critical shortcoming in their repertoire of tools to solve physics problems, especially when the physics is not explicitly stated in the description as it has been told to them. In such a case they have to "get the physics out of the situation and what physical parameters are relevant to the situation they are to model.

1 The Case Of Two Discrepant Witnesses

Do we perceive the world as it really is? Well here is a story, a dream maybe - or maybe not - that indicates how important is the vantage point from which we perceive the world, and how important is how we obtain the information for our perceptions:-

Two cows are standing along a straight edge of an electric fence. They are touching it with their noses because the electricity has been off for a while. Suddenly the farmer turns it back on. As the electric wave front travels along the electric fence it shocks each cow that it passes, and the cow jumps up with a "moo-ing" shriek. The farmer sees and hears the whole happening. Einstein, say, is walking far off on the far side. Assume that he is walking toward the fence, and that he is in line with it, the cows and the farmer, in that order. He also sees and hears the whole happening. From Einstein's perspective all the cows jump simultaneously, without any sound. Then, as the sound wave arrives he hears the second cow (the one closest to him) "moo" first. Finally, Einstein hears the "moo" of the cow that jumped first. This is the reverse order of what actually happened! How to explain this? Of course, light travels much faster than sound. But this is not completely satisfactory explanation because the information from the light wave indicates to Einstein that all of the cows jumped simultaneously, while the information from the sound wave indicates that they jumped at distinctly different times. Furthermore, the farmer who turned on the electricity gets completely different information from the very same sound waves!! True, he also visually perceives the cows to jump simultaneously, but he hears the cows "moo" in just the reverse order that Einstein heard them! If they ever meet and discuss their perceptions they will initially give discrepant accounts. Einstein will be excited and start modeling, while the farmer will probably just be confused

What is going on? Somehow we want to clear up such a potential paradox about our perceptions of sequences of events. Otherwise, how can we ever be confident that "something 'strange' like the above is happening again"? Besides, why should we take the information from the light wave as being somehow more reliable than the information from the sound wave (or vice versa)? Then who, or which of our senses can we believe? Clearly this is impossible state of affairs. So, we must model the above situation/happening and have it all become clear and understandable.

2 Live modeling of the main story

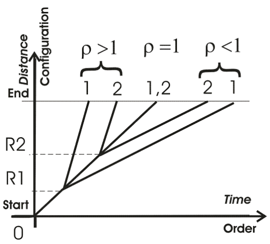
Setting up the model: A live modeling is a good start for secondary school students because it requires going back to first principles in order to answer such questions as, (a) How shall we model the perception of the jumping cows as experienced first by Einstein and secondly by the farmer? (light waves). (b) How shall we model the light waves? (with photons). (c) How do we model the millions of photons traveling in all directions? (By using a representative photon - a volunteer - for each of the two directions that are of interest, the first from the cow to Einstein, and the second, from the cow to the farmer). (d) How do we model the transmission of the sound information to the two witnesses? (analogously to the way we model the photons). (e) How do we model the transmission of electric current? (One student can represent the wave front of the current traveling along the wire from the just-closed switch towards the cows).(f) How do we model, Einstein, the farmer and the cows? (student volunteers are placed along the configuration of the story

NOTE: It is important for each "cow" to have a number, and for the "photons" and "sound waves" by each cow to carry the same number. As they reach Einstein (resp. the farmer) they hand-over their numbers so that the order of arrival can be recorded by the two witnesses.

Of course, we model the velocities very much slower than is actually the case for light (300,000 Km/s), and even for sound. This reduction in velocity has a special effect on the modeling results and makes them different than actually observed. I.e., in actual situation, the information arriving to the farmer through the light wave has a very minor, difference because of the delays of travel time, and hence the light from each jumping cow starts traveling at slightly different times. Theoretically, if the farmer could distinguish infinitely fine resolutions, he would never see the cows jump simultaneously. Since the model does not include this limiting aspect of our visual perception mechanism, according to the model developed below, the farmer can never see them jump simultaneously. However, Einstein, can (according to the model) see the cows jump simultaneously if the velocities of electricity along the wire and of light in air are equal, and if his perception mechanism has enough resolution.

3 Modeling of a robotic relay race

After the students have live-modeled the situation involving Einstein's and the farmers' discrepant perceptions, they can be asked to model an analogous situation which is abstractly the same, and initially easier to model:- Assume that two robotic carts, R1, R2, have been purchased by an industrial research company, RCO Assume further that RCO makes its own robotic cart, C1, to another design. RCO is planning to make a comparative test of the carts with a robotic relay race that is described next. Cart C1 starts the race (analogous to the electric current that starts flowing along the fence when the switch is closed). R1 and R2 have been placed on the race track in a configuration that is analogous to the cow positions along the fence. As C1 reaches R1(resp. R2), R1 (resp. R2) starts moving. The speed of C1 is v. R1 and R2 always move at the same speed, V. Let $\rho = V/v$. For a fixed ratio of ρ in what order will the carts arrive at the finish line? It is seen that the answer depends on the value of ρ To model the situation we use a linear graph to represent the constant velocities of the carts, as shown in the first graph in figure 1, which shows the start and ending distances of the race, the starting configurations of the carts, and the end results for each of the three cases:



$\rho > 1$, the finishing sequence is (R1,R2, C1)
$\rho = 1$, the result is a tie
$\rho < 1$, the finishing sequence (C1, R2, R1).

Figure 1: Graph models of both situations

Note: This is analogous to Einstein standing at the end of the race (see fig 1), seeing the cows jump either in "correct order ($\rho > 1$), or simultaneously ($\rho = 1$), and hearing them moo in reverse order ($\rho < 1$).

References

[1] MAGUEIJO, J. Faster *Than the Speed of Light: The Story of a Scientific Speculation.* Published by William Heinemann , January 2003, ISBN 0434009482.
[2] TEPLANOVA, K *Computers and modelling at SCHOLA LUDUS teaching of physics*. GIREP Conference 2004. Ostrava. pp.