Abstract for Chaos Theory Explored Through Double Pendulums

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In my science fair project, investigated how big changes needed to be in order to affect double pendulums. I also researched how initial conditions affect the system. These parameters are angle, mass and length. In my research, I found that double pendulums are governed by chaos theory. Within chaos theory, there is something called the butterfly effect. The butterfly effect states that any change no matter how small will have lasting consequences. For example, a butterfly flapping its wings here can cause a hurricane across the ocean. I predicted that no matter how small the difference was, if there was a difference, there would be a split. I also predicted that small angles will not generate chaos. I expected mass and length to have no effect on the system. To perform this experiment, I used a computer with some code (found at <https://github.com/tharthar2/sci-fair-2020-final>) and an text editor. To perform it, all other values beside a variable on line 64 called sensitivity were fixed and sensitivity was modified by multiplying by 10 each time until the system no longer diverges in to multiple paths. For each modification, record how long it takes to split into different paths. Next, we fixed all parameters beside angle 1 and fixed everything else. For a given angle 2, I found a th1 that made it chaotic. I did this for about 10 angle 2 values. I then did the same changing the mass and length ratios. Before I discuss the results, I would like to acknowledge Dr. Han Htoon who helped me significantly with this project. When I changed the variation factor, the time it took to split went up. I also found that after 1e8, the time it took to split stabilized at 20 seconds. At 1e18, it was found that the system no longer split. I expect that this is not a real limit but, a computer limit. At that point, the computer found that the number was too small to compute[[1]](#footnote-1). When testing with angles, angles smaller than 20° were found to act like normal pendulums. It was found that most for a given angle 2, there was a minimum angle 1 needed to create chaos. This angle 1 generally decreased as the absolute value of angle 2 increases. When the critical angle of certain mass ratios was found, the mass ratio and critical angle had no correlation. However, when critical angle was plotted against mass difference, the data was symmetric when reflected across line *y = x + 79.15*. When the critical angle of length ratios was found and the critical angle was plotted against length ratios, a step function was found. The data was in groups of 3 points on the same y coordinate. When plotted against length difference, a similar pattern as mass emerges. In conclusion, I was partially correct. When it came to variation, I was incorrect in practice however, in theory, I should be correct. About angles, I was correct as demonstrated in the data. Finally, I was incorrect about mass and length. Both parameters showed interesting correlations.

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1. 1e18 is a big number however, the code divides 1 by this number to find the angle difference making the actual difference 1e-18. This was done to make it easier to plot in Excel. [↑](#footnote-ref-1)