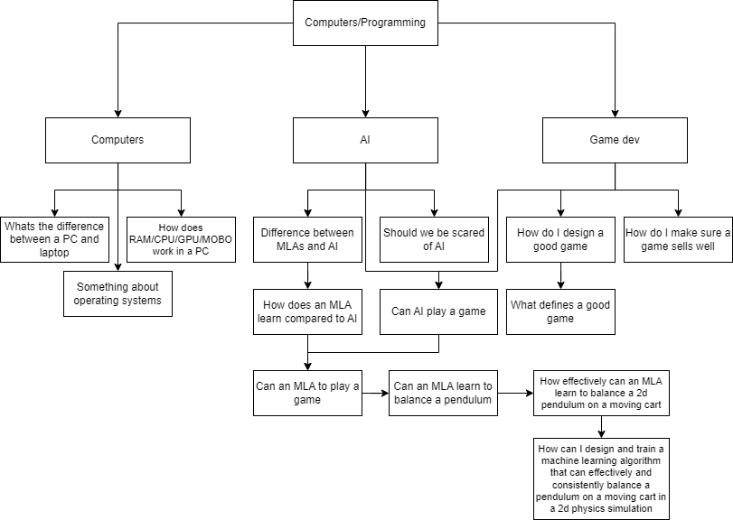
![A white background with black dots

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Description automatically generated](data:image/png;base64,iVBORw0KGgoAAAANSUhEUgAAAE0AAABOCAYAAABlnZseAAAAAXNSR0IArs4c6QAAAARnQU1BAACxjwv8YQUAAAAJcEhZcwAADsMAAA7DAcdvqGQAAAC7SURBVHhe7dCxAYAwDMCwlP9/hg48EM/S4t3nvYaV5y8LpgWmBaYFpgWmBaYFpgWmBaYFpgWmBaYFpgWmBaYFpgWmBaYFpgWmBaYFpgWmBaYFpgWmBaYFpgWmBaYFpgWmBaYFpgWmBaYFpgWmBaYFpgWmBaYFpgWmBaYFpgWmBaYFpgWmBaYFpgWmBaYFpgWmBaYFpgWmBaYFpgWmBaYFpgWmBaYFpgWmBaYFpgWmBaYFpgWmBaYFpq3NfDrYBJgn4mvoAAAAAElFTkSuQmCC)When deciding on a topic for my research project, I had 3 general topics that I wanted to investigate. These were computers, AI and game design. I had decided on these because I am very interested in all 3, and have been interested in most of them since a young age.

Recently with the AI boom, I was inspired to look deeper into AI and similar digital structures. I ended up developing more questions in the AI branch of my flowchart than any others (*figure 1*). However, I incorporated game development into some of my AI questions which helped guide me to my final question.

Ultimately, I believe it was a good idea to not follow into computers or game development as computers would be either very simple (Whats the difference between a PC and laptop) or very in depth and would take far longer to make (How does an OS work). It’s a similar story for game development, as designing a “good game” is not a simple answer, no matter how specific the question is. Making sure a game sells well is also something that cannot be completed in the given time frame for the research project, as it would likely take at least 12 months of analysis to be worthwhile. (*figure 2*).

***Figure 1*** *– Thinking process and question development mindmap.*

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| **General Topic** | **Strengths** | **Weaknesses** |
| Computers | * Wide range of topics * Career applicable knowledge | * Most options are either too easy or too hard to answer in a research project |
| AI | * Developing field of science * Applicable in other fields of knowledge | * Computer resource intensive * Technical knowledge barrier |
| Game development and design | * Largest interest of mine * Most creative options | * Timeframe is too large for RP * Games are difficult to develop |
| ***Figure 2*** *– Table consisting of strengths and weaknesses of general research topics* | | |

An interest in AI for me is the area of Machine Learning Algorithms (MLAs), which aren’t technically AI, but instead are closer to complex mathematical functions that turn some input values into output values.

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| **Questions** | **Strengths** | **Weaknesses** |
| Can AI learn to play games | * Combines 2 interests for me | * Closed question * Too broad, not specific |
| Can an MLA learn to balance a pendulum | * Slightly more specific * Gives me knowledge in how to apply MLAs in other situations | * Closed question * Unclear whether real world or simultaed pendulum * Requires running an MLA and potentially a physics simulation (very time and computer resource intensive) |
| How effectively can an MLA learn to balance a 2D pendulum on a moving cart | * Very specific * Gives me knowledge in how to apply MLAs in other situations | * Requires running an MLA and potentially a physics simulation * Unclear whether simulated or real world pendulum |
| **How can I design and train a machine learning algorithm that can effectively and consistently balance a pendulum on a moving cart in a 2d physics simulation** | * Very Specific * Gives me knowledge to apply in other applications * Directly explains the context of the simulation * Explains it is simulated and not real world | * Needs a physics simulation * Requires running an MLA over some times |
| ***Figure 3*** *– Table consisting of strengths and weaknesses of research question options* | | |

Learning how to apply MLAs has become a recent specific interest of mine, but they can be very indepth, and it can be difficult to apply them succesfully to have the intended result. Because of this, I have decided to ~~to~~ learn how to apply an MLA to a simple physics simulation and analyse its “learning” to figure out the best way to train an MLA for a specific use case.

Over the course of the research project, I will be developing my *Information and Communication Technology* skills and my *Critical and Creative Thinking*. This is because a significant portion of my research will be running and potentially programming a physics simulation that an MLA can learn from. Whether I use a pre-built simulation or start one from scratch, I will need to understand how an MLA works so I can pass in certain parameters so it can learn effectively. Additionally, I will have to think critically about what paramaters to pass in. I will also not be copying any code from others, meaning that I will have to think creatively about how I am going to approach a problem in the code.

My audience should be interested in learning how machine learning algorithms actually work, similar to myself. They would be interested in how they can apply this knowledge within their own programs or applications. My findings will be analytical over several different training methods, showing how each one would function and which is best for my use case. What I find will be presented in a table or a similar comparison. This is because it can easily convey what data I want to help decide on the best algorithm for my use case. The presented data will include the name of each method to train the MLA, what each method is in basic terms, the pros, cons, time to train, and a standard effectiveness based on a consistent amount of training time.This can be helpful for my target audience analyse which method they should use for their own application.

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| **Research Question** | **Sub-questions** (colour matches relevent part of the research question) |
| **How can I design and train a machine learning algorithm that can effectively and consistently balance a pendulum on a moving cart in a 2d physics simulation**  ***Figure 4*** *– A table consisting of sub questions* | How can I use or build an accurate 2D simulation that models a cart pendulum system realistically |
| What are the fundamental concepts and ideas of MLAs, and how do they learn |
| How can I choose and design the various functions of, and apply an MLA into my chosen cart pendulum simulation |
| How can I train and test an applied MLA to my cart pendulum simulation, ensuring it effectively and consistently balances the pendulum |

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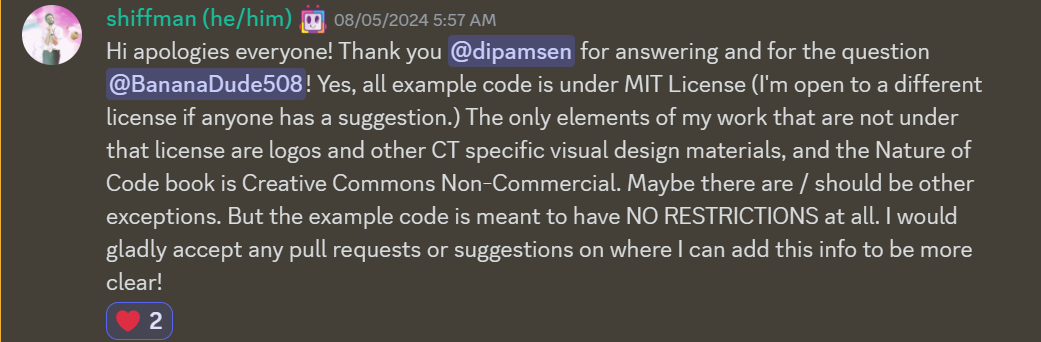
Description automatically generatedMy 4 subquestions are derived from the main question, including how to use or build a physics simulation that accurately simulates a cart and pendulum, what is an MLA and the fundamentals behind one, how do I choose and design an MLA and its training methods, and how can I apply, train and test one. I chose these sub-questions becaues it addresses all the necessary points of my question, to help better both my and the readers understanding of what are MLAs and how to use them. Deciding on a physics simulation method is very important, because not only does my whole project rely on having one, but having one that works accurately to the real world is ideal. Researching and explaining what a machine learning algorithm is and how they work is vital to understanding how I can build them effectively. Knowing how they learn and adapt to different cases is what allows me to pass in the required and correct values for it to solve an issue. Being able to actually apply and train an MLA is very different from simply theorising about how they work, as they could evolve and develop in unexpected ways. Because of this, running the same algorithm several times could be beneficial as it could get stuck in a local minimum without looking for a global minimum. (*Figure 5*, local/global minimums will be further discussed within sub-question 3 research)

***Figure 5*** *– simple graph showing local and global minimums and maximums*

*https://en.wikipedia.org/wiki/Maximum\_and\_minimum*

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| **What archival sources are appropriate** | **Name of specific resource** | **Ethical Considerations** | |
| Existing physics simulations | [myPhysicsLab: Moveable Pendulum](https://www.myphysicslab.com/pendulum/moveable-pendulum-en.html) | [Linked source code](https://github.com/myphysicslab/myphysicslab/blob/master/src/sims/pendulum/MoveablePendulumApp.ts) has the [Apache-2.0](https://github.com/myphysicslab/myphysicslab/blob/master/LICENSE) license, which allows full commercial, private or patent use without trademark, or any form of liability and warranty. | |
| Youtube videos | [The Coding Train: "Coding Challenge #159: Simple Pendulum Simulation"](https://www.youtube.com/watch?v=NBWMtlbbOag) | [Linked source code](https://editor.p5js.org/codingtrain/sketches/SN-39sHAC) has no immediately visible license attatched, which means it likely falls under standard copyright. However, after talking to Daniel Shiffman (author), he said the code is under the MIT license. (Figure 7) | |
| [Pezzza's Work: "How to train simple AIs"](https://www.youtube.com/watch?v=EvV5Qtp_fYg&t) | No code used from videos. As per copyright law, unpatented ideas that are not a direct copy of someone elses IPs are free-use. This means any ideas and understanding gained from these videos have on restriction on use in the research project. | |
| [Green Code: “I Built a Neural Network from Scratch”](https://www.youtube.com/watch?v=cAkMcPfY_Ns) |
| Weights & Biases: “Introduction to machine [learning](https://www.youtube.com/playlist?list=PLD80i8An1OEHSai9cf-Ip-QReOVW76PlB)” |
| [3Blue1Brown: “Neural networks”](https://www.youtube.com/playlist?list=PLZHQObOWTQDNU6R1_67000Dx_ZCJB-3pi) |
| [Tech With Tim: “Python Pong AI Tutorial – Using Neat”](https://www.youtube.com/watch?v=2f6TmKm7yx0) | [Linked source code](https://github.com/techwithtim/NEAT-Pong-Python) has no immediately visible license attatched, which means it likely falls under standard copyright laws. Since code from this video will be used to answer subquestions 3 and 4, I cannot use this as a source unless confirmation of legal use is confirmed. After talking to Tim Ruscica (author), I have full permissions to the code aslong as I do not profit from using it. | |
| ***Figure 6*** *– A table consisting of archival sources and ethical considerations* | | |

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| **What qualitative sources are appropriate** | **Name of specific resource** | **Credibility Considerations** | |
| Interviews | * Tim Ruscica (Tech With Tim on youtube) | Need to wait for a response from Ruscica before I know I can use him as a source. | |
| ***Figure 8*** *– A table consisting of qualitative sources and ethical considerations* | | |



***Figure 7*** *– An image confirming Shiffman’s claim of code being under the MIT license on discord.*

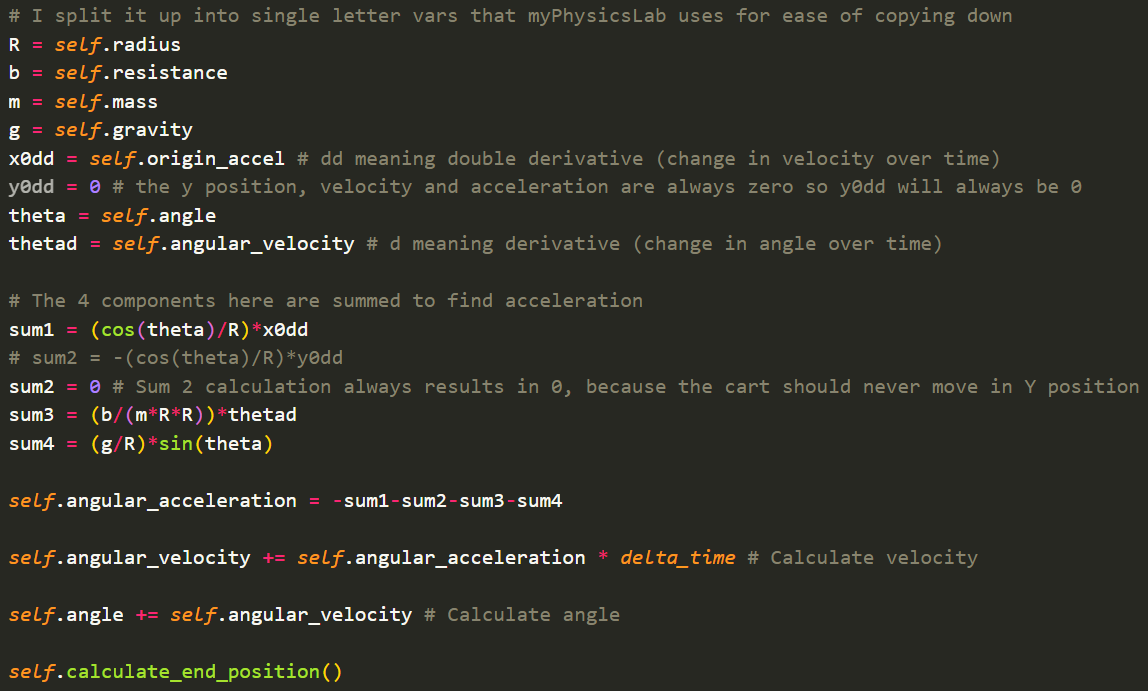
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| **What action research processes are appropriate** | **What subquestion does this help answer** | **Ethical/Compatibility Considerations** |
| Build or find a physics simulation | How can I use or build an accurate 2D simulation that models a cart pendulum system realistically | Throughout researching and developing my chosen method of simulating a 2D cart and pendulum system, I need to understand its realism to ensure its simulates accurately, and I also need to ensure that it is compatible with my chosen method of building a machine learning algorithm. |
| Design, build and train an MLA | How can I design the various function of, and apply an MLA into my chosen cart pendulum simulation  How can I train and test an applied MLA to my cart pendulum simulation, ensuring it effectively and consistently balances the pendulum | As I design my MLA, I need to keep in mind what values from the physics simulation I have available to use. Depending on my simulation method, I may not have the available variables to pass in, and I may only be able to access them through modifying the source code or physics engine. This could be illegal or otherwise un-doable ethically because my simulation could be calculated in a closed source engine. |
| ***Figure 9*** *– A table consisting of research processes and ethical considerations* | |

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| **REFERENCE DETAILS** | myPhysicsLab Moveable Pendulum 2021, Myphysicslab.com, viewed 20 July 2024, <https://www.myphysicslab.com/pendulum/moveable-pendulum-en.html>. | |
| **Reliability** | This source is very reliable, as the simulation provided at the top of the page seems very accurate and provides the physics formulas they used, and the derivations to show they are accurate. | |
| **Authority/CREDIBILITY** | Author has 2 degrees, one in mathematics and has been developing physics simulations for over 20 years | |
| **Purpose** | The author developed this website as both an online science museum and as a personal project. | |
| **Key Information:**   * Formula for angular acceleration of a pendulum on a moving pivot () * Example simulation to double check against | | |
| **USEFULNESS** | | **LIMITATIONS** |
| I can apply the acceleration formula gained from this source in a physics simulation if I decide to build it myself with no libraries or sources. This source helps answer sub-question 1 (How can I use or build an accurate 2D simulation that models a cart pendulum system realistically), which is all about finding or building a physics simulation. The source was very easy to understand, as it has an intuative simulation at the top of the page and a step by step derivation with variable definitions of the final formula. The source should be very accurate, as if there were any inconsistencies within the final formula, I could notice it within my simulation or the example simulation. | | The source does not have a coded implementation of the formula and it is left to me to implement it. The source does contribute to my first subquestion, but may not be applicable if I decide to use a premade physics engine or library. Without testing the formula, there is no way to know if it the right one for my simulation, and it may not function correctly for my simulation. The source also does not have any further useful information beyond the formula. |
| **CAPABILITY** | | |
| This source will help me develop my skills in *Information and Communication Technologies* and my *Critical and Creative Thinking*. This is because I will need to convert the mathematical formula into code that a computer can understand, and then debug and adjust it if it doesn’t work properly. | | |

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| **REFERENCE DETAILS** | Pezza’s Work 2024, *How to train simple AIs*, *YouTube*, viewed 13 August 2024, <https://www.youtube.com/watch?v=EvV5Qtp\_fYg>. | |
| **Reliability** | This source is reliable, as the process of developing the final MLA is shown throughout the whole video and each change is explained, and the results of the final machine learning model is shown in action balancing a pendulum. It does not reference any other sou | |
| **Authority/CREDIBILITY** | The author Pezzza may not be as credible as someone like Grant Sanderson (3blue1brown on youtube), but has almost 150 thousand subscribers by working on primarily AI and ML content on their channel. | |
| **Purpose** | The video aims to explain how machine learning works to an audience that likely doesn’t know much about it as to not overwhelm them while giving them an introduction. It aims to show how you can apply an MLA and design one. | |
| **Relevance** | This source is very relevant to my research, as it is a similar application to mine and explains several of the processes used applied within development of the MLA, and how adding the different variables can affect the outcome. | |
| **Key Information:**   * Covers basic concepts in training machine learning algorithms, using reinforcement learning in a cart-pendulum simulation as an example. * Covers basic MLA concepts and training methods * Uses reinforcement learning in a 2d cart pendulum simulation, similar to my application. | | |
| **USEFULNESS** | | **LIMITATIONS** |
| This source gives an example of a reinforcement learning MLA which is directly relevant to my research. It visually and easily explains how an MLA can learn to stabilize a pendulum through several generations and iterations with feedback, which is very similar to how most of my training methods will occur. The approach taken in the video helps bridge theory to application and makes it easier to grasp the basic aspects for my research. | | While very relevant to my research, this source has limited application. It focuses on using a basic implementation without diving into more advanced topics such as complex algorithm design or potential challenges in real world scenarios. Additionally, it doesn’t provide any in-depth mathematical explanations or alternative methods of learning, instead just following down the same road for the whole video. Investigating several methods may help develop a more effective MLA and is directly relevant to my research. |
| **CAPABILITY** | | |
| This source helps me develop my *Critical and Creative Thinking* as it explains thinking processes and subtly hints towards how to think by yourself and develop the MLA independendtly. This source will help me to develop the ability to think critically and logically as it requires me to break down exactly how he applied the method he used to teach the MLA. I need to properly analyze the techniques shown in the video as they don’t have any code or applications directly shown so it is up to me to think about how. | | |

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| **REFERENCE DETAILS** | Action Research (*Figure 10*) | | |
| **Purpose** | I coded a physics simulation as part of my research for my first subquestion (How can I use or build an accurate 2D simulation that models a cart pendulum system realistically) in order to allow me to answer my third (How can I choose and design the various functions of, and apply an MLA into my chosen cart pendulum simulation) and fourth (How can I train and test an applied MLA to my cart pendulum simulation, ensuring it effectively and consistently balances the pendulum) subquestions. | | |
| **Key Information:**   * Functioning physics simulation designed to allow movement injection via an MLA. * Custom made instead of pre-built engine such as unity to allow easier MLA use at the cost of realism. | | | |
| **USEFULNESS** | | **LIMITATIONS** | |
| This research directly helps answer my first subquestion as I have created a testable environment which I can tweak any values I like, as opposed to an engine such as unity which has set values and is much harder to modify gravity, mass, or pivotal values to be realistic. By building a simulation in python, it allows me to use a library like ‘[neat-python](https://github.com/CodeReclaimers/neat-python)’ (neuro-evolution of augmented topologies) much easier to build, integrate and train the MLA later on within research. This research process was very effective to help answer my first subquestion, as building a basic simulation which I can improve ([*github*](https://github.com/BananaDude508/Research-Project/tree/main/Code), *pendulum.py lines 36-48*), which helped me decide that building the simulation myself would be more effective than using a system such as the unity physics engine. | | | Python is not a high performance programming language, meaning that compared to others such as c++, it performs significantly slower. This can hinder my research by limiting the amount of iterations and learning the MLA can do within a given time frame, potentially limiting its usefulness and adding errors within my analysis. These performance issues may also carry over to the MLA performing slower as time continues, as the size and complexity of it grows. While the program is easier to make and implement an MLA within, the real time precision of the script may be innacurate, as after some minor testing there are bugs with this formula. |
| **CAPABILITY** | | | |
| This research directly helped me develop my *Information and Communication Technologies* capabilities, as it required being able to implement not just the formula, but also a basic rendering engine ([*github*](https://github.com/BananaDude508/Research-Project/tree/main/Code)*, pendulum.py lines 27-29, pendulum.py lines* | | | |

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| *83-88, cart.py lines 23-44, game.py lines 29-*32) using the ‘pygame’ library so I can see and use the simulation effectively. In order to efficiently apply the physics simulation for a real-time solution, I also need to understand values like ‘delta\_time’, which is the time of each frame (usually 1/60th of a second in this application, [*github*](https://github.com/BananaDude508/Research-Project/tree/main/Code)*, main.py lines 55,56,60*) which I use to make the simulation consistent with the framerate. Using delta time means that if the simulation runs at half the normal frame rate, it should stil act the same visually. |
| **Next Steps** |
| After researching the best method of building a physics simulation and deciding on building one from scratch because it allows for using an MLA easier and helps develop my skills in programing, the next step is to research how an MLA learns so I can understand how to effectively design and apply one. |



***Figure 10*** *– Python implementation of the formula found from myPhysicsLab.*

*(*[*github*](https://github.com/BananaDude508/Research-Project/tree/main/Code)*, pendulum.py lines 57-80)*

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| **REFERENCE DETAILS** | Green Code 2024, *I Built a Neural Network from Scratch*, *YouTube*, viewed 27 August 2024, <https://www.youtube.com/watch?v=cAkMcPfY\_Ns>. | |
| **Reliability** |  | |
| **Authority/CREDIBILITY** |  | |
| **Purpose** |  | |
| **Relevance** |  | |
| **Key Information:** | | |
| **USEFULNESS** | | **LIMITATIONS** |
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| **REFERENCE DETAILS** | Tech With Tim 2022, *Python Pong AI Tutorial - Using NEAT*, *YouTube*, viewed 29 August 2024, <https://www.youtube.com/watch?v=2f6TmKm7yx0>. | |
| **Reliability** |  | |
| **Authority/CREDIBILITY** |  | |
| **Purpose** |  | |
| **Relevance** |  | |
| **Key Information:** | | |
| **USEFULNESS** | | **LIMITATIONS** |
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| **REFERENCE DETAILS** | Action Research (*Figure 11*) | |
| **Purpose** |  | |
| **Key Information:** | | |
| **USEFULNESS** | | **LIMITATIONS** |
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| **CAPABILITY** | | |
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A screen shot of a computer program

Description automatically generated

***Figure 11*** *– Python implementation of running the MLA  
(*[*github*](https://github.com/BananaDude508/Research-Project/tree/main/Code)*, main.py lines 82-102)*

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| **Key Findings** | **Sources that support this idea**  **Primary/Secondary** | **How reliable is this key finding?** | **Summary of how this answers your RP question.** |
| The formula for a 2-way driven cart-pendulum simulation | * <https://www.myphysicslab.com/pendulum/moveable-pendulum-en.htm> (primary) | Very reliable. Despite only having one source, there is a visual simulation that backs it up and it contains a full derivation of how the formula can be found. | Subquestion 1: This source directly answers my subquestion by giving me an answer to a physics simulation solution |
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