Introduction

****This document is *subject to change*, likely minor changes, as we move through the next few weeks. I'm giving it to you earlier this year than I normally do because you'll need to do some more *advanced planning*.****

Throughout the rest of the term, and particularly during the last 2 weeks, you will work on a classical mechanics problem that can only be solved numerically. There are a number of specific goals for this project: exposure to some new physics, engaging in a physics research project, formulating research questions, and answering those questions, learning computational techniques, gaining experience working with a research group, writing a research report, and giving an oral presentation. More specifically:

1. **You'll struggle with a classical mechanics problem that is computationally intense and does not have an analytical solution. As a starting point, you will have to come up with good, appropriate, well-formulated questions to answer. This project will allow you to apply your knowledge of classical mechanics and will give you an opportunity to exploit some of your analytical and numerical tools from your physics toolbox.**
2. **You'll get practice using *Mathematica* (and/or other computational environments) as a computational, analytical, and graphical tools.**
3. **You'll read, critique, and understand an article from the *European Journal of Physics*, learn how to do a literature search, and hopefully locate and use some related research materials through the Carleton Library.**
4. **You'll gain experience working with colleagues on a research project. Within your research group, you'll need to divide up tasks, arrange meetings, assign responsibilities, and set deadlines. You'll obtain experience communicating with other research groups and individuals. Finally, your group will be responsible for producing a progress report, writing a short research paper, and giving a talk.**

The System

Your group will pick a physical systems to investigate in depth. Options include:

Fixed Counterweight, sling
Hinged Counterweight, no sling
Hinged Counterweight, sling
Floating Trebuchet Design
Vertical Drop Trebuchet Design
Some other Siege engine design that you clear with Jay

You will need to computationally model your system, and you'll need to compare at least some aspect of that model to a physical realization of your system. In the Before Covid (BC) days, each group built a model trebuchet out of k'nex. They then compared the data generated by the computational model with the physical one, and used the computational model to help guide them in optimizing the physical one. We will still build a computational model, and there will still be contact with a physical system, but due to covid, working together as a group of 4 to build and optimize a k'nex trebuchet will not work for most groups. Hence this year, your group will need to choose among 3 options:

1. If some subset of your group would like to volunteer to build a k'nex trebuchet for your group, you may do the project in the same way that the past 1.5 decades of Carleton students have.

2. If you'd like to expedite the building process a little, but you'd still like to build something, you're group may have a budget of $30 to buy a trebuchet kit. Depending on what you buy, this may still take several hours to put together. It will offer less design fexibility than building from scratch, but it will likely be faster. You'll want a model that still has some ability to vary a parameter (eg counterweight mass, arm length, etc) if possible. Jay experimented with the VEX trebuchet here: https://www.amazon.com/HEXBUG-VEX-Robotics-Trebuchet/dp/B07F3FQ5LF and thinks it could work well. If your group chooses this option, contact Jay to (a) verify that the kit you've picked is likely to work and (b) arrange purchasing.

3. If you'd like to avoid assmbing anything yourself, you may be able to make "experimental" comparisons with videos of Trebuchets found online or elsewhere. This probably should not be thought of as an easy way out. It will likely involve spending time searching for videos that will work well (are shot clearly, in slow motion, from a good angle...), some clever estimation of some parameters (they probably won't just tell you the height, etc), and higher skill with using the Tracker software (more later on how to use it) to extract data from the video. Jay played with this video and thinks it's likely to work: https://www.youtube.com/watch?v=WdKUH584mrY

The Project

You will come up with a research plan that includes the questions you would like to answer for your system. You must address at least 1 question per group member. All questions must have a computational component, and at least one question should involve some sort of match between theory and experiment. For the match, you can simply compare some quantity in the theory model and the physical model. Questions that can be addressed within the computational model are pretty easy to come by. When I change some parameter (arm length, counter-weight mass, ...), how does some other thing change (firing velocity, firing angle, max angular speed, ...)? Clearly you want to make certain that the questions you pick can be answered. You will explore your system numerically using parameters from your system. Denny's paper, which we'll read in a bit, is full of ideas for questions. As you explore your questions, keep the following points in mind. (1) Classical mechanics is well-tested in this regime. If there is a discrepancy between theory and experiment, it is probably due to errors in, or limitations of, your experiments and/or theoretical methods. A part of your job is to minimize or at least understand these issues. In other words, you can't blame Newton and Lagrange for imperfect results. (2) When writing up the results, it's best to focus on what you did and what you know, rather than apologize for what you can't do or don't know. For example, don't say, "we can't model this motion because we don't know how to account for friction." Instead one could say, "We modeled the motion without friction, and found a significant discrepancy with experiment. Thus we speculate that friction may play a significant role." Of course it would be better if one could show more clearly that friction is responsible, and better still if you could either model the friction in the theory or remove it from the experiment. While we're on the topic, beware of blaming friction. Sometimes teams blame friction for discrepancies when algebra or measurement errors are actually to blame. This behavior annoys the grader, something you don't want to do.

We have "intermediate"-speed video cameras which are good for most applications, though your cell phone is probably better than these now. We also have a high-speed camera if the "intermediate"-speed cameras prove insufficient. We have a program called "tracker" that will capture your siege engine in action and allow you to analyze the motion frame by frame. Jay will provide video instructions on how to use it later. Bruce Duffy, the 2nd Earl of Northfield, in Old Music 309, can provide more information on the software. He is also keeper of the cameras. Side by side comparisons of video and computational animations are also nice for talks.

If you choose to build a trebuchet, you may want to include some additional materials beyond the k'nex or beyond the parts that come in your kit. For example, you may want to using some additional counterweight mass, you may want to use some other materials to stiffen your throwing arm bit, you may want some cloth to make a sling, etc. If you'd like to design some non-k'nex components, ask Jay, he may have some, or, see Royal Blacksmith Aaron Heidgerken-Greene in the shop located near 036 in the Anderson basement.

You'll have both individual and group responsibilities as the project progresses. My goal is to generate individual responsibilities within a team effort, in a manner analogous to the role a center, a quarterback, and a receiver play on a football team. Individual responsibilities will help ensure that everyone plays an active role in the project, with no one taking over, and no one slacking. It will also help me as I write recommendations if I know who I should give credit for the cool trebuchet design, or the well organized introduction to the paper. This may also result in slightly different grades for different people on the project.

Individual Responsibilities:

1. **Each member of the group should take the lead on one question. Your final progress report should clarify who took the lead on which question. Though of course you should work as a team and help each other.**

2. **Each member of your group will assume one of the following roles: code keeper, paper editor, talk coordinator, "trebuchet master". If you have only 3 members, someone will have to take on 2 roles. I recommend combining talk coordinator and trebuchet master, since the main action on these tasks will occur at different times. You will indicate in your first progress report who is taking on which role. In each case, *everyone will contribute in the relevant area*, the coordinator is just in charge. Each member of the group should contribute to the code and manipulate it to answer their question, but the code keeper should be the one that maintains a master copy of the code, adds comments on how it works, etc. Everyone should contribute text to the paper, particularly about their question, and everyone should read and provide feedback on the final version, but the paper editor is responsible for putting all of the parts together and making it flow as one paper. The talk coordinator will play this role when it comes to planning and putting together slides for the talk. Similarly everyone should be involved in planning and attainning experimental data in the context of one of the above options, but the trebuchet master should coordinate this effort.**

3. **You must attend the final conference, speak for at least 20% of your group's time, be attentive and engaged during the other groups' talks, and ask at least one question of another group.**

4. You must submit an evaluation of your group members.

Full Group Responsibilities:

1. Your group will need to schedule meeting times, set deadlines, and divide up responsibilities. Sometimes groups have a difficult time with these tasks. Give yourselves lots of time for planning; in fact, start now. The planning process can take longer than you think. Just finding a mutual meeting time can be difficult, although all of you can certainly meet during 5A during the last 4 days of the course. If your research group has any difficulties functioning as a group, you should seek immediate help from *Medieval Group Facilitators of Northfield* (see bottom).

2. Your group will need to collectively conduct an exhaustive literature search on your topic and hand in to the Royal Project Coordinator (Royal PC) a summary of that search as a part of a future homework. Note that when I say "your topic", I mean something like, "technical aspects of a trebuchet with a hinged counter weight", and when I say "literature", I mean published stuff like *American Journal of Physics* articles, not Joe's Trebuchet Website. Your summary should consist of a list of the relevant references you found, and a brief (few sentences) statement of what the paper is about. There is surprisingly little out there on technical aspects of siege engines. I would say that if you find 3 or 4 really relevant sources and a few related but somewhat less relevant sources, you've done pretty well. Our science librarian can provide assistance if you need it and will likely visit class to discuss how to do this.

3. Your group must submit progress reports to the Royal PC. They will be a part of the last few homework assignments. They should include

Project Goals
Anticipated Group Meeting Times
Upcoming Group Responsibilities (include time estimates for individuals involved)
Things you're stuck on
How You're Working as a Group (bad, ok, good, great)

4. As a part of HW8, you'll need to submit to *Technical Tasson & Associates* the Lagrangian or Hamiltonian for your system along with any technical questions you'll want to discuss. You'll then arrange for at least one technical consulting sessions with *Technical Tasson & Associates* (TTA), at which your questions can be discussed. However, you can consult with TTA at other times as well.

5. Your group needs to submit a completed research paper based on your work by the end of finals week. Your paper should be about 4-6 pages long (excluding appendices) in the Latex template provided in the homework. This length may include appropriate use of figures. This length is only a guide. I won't freak if you deviate slightly from this as long as you've done a complete and appropriate job. You should follow the format of articles in the *American Journal of Physics*. There are copies of the journal on our reserve shelf and online. You should use the AJP Latex template that you used earlier in the course for the body of the paper. A draft of the body of your paper is due as noted in the "treb dates" document. You need not have all of the data and computer code ready yet, but I'd like to use this opportunity to give you some feedback on the structure of your paper. You should strive to make your equations digestible. Look at how Denny does this. The more complete your draft is, the better feedback the Royal PC will give you, and the higher your grade is likely to be on the project. Please also read the complete list of "paper writing does and don'ts" before and after you write your paper!

Your paper should have 2 appendices. The first should detail what each person did on the project. There should be a paragraph for each person. Such a paragraph might look like the following for a hypothetical group member named I. Thoreau-Stone. "I. Thoreau-Stone served as trebuchet master for our group. After a group discussion, during which many designs were tossed out, I worked out most of the practical details on what k'nex would be used to make it a reality, though everyone helped snap things together and make adjustments to the plan during construction. I then organized a sign-out procedure for the machine as others sought to make small changes and take data to address their questions. I wrote section 4 of the paper about how counterweight mass affected range, which was her question. I addressed the question using the master code that we developed as a group, but I adjusted it to vary the mass. I had some technical help from Cal Kulate who provided the idea for the loop. I also contributed some edits to the introduction of the paper and produced 4 slides for the talk."

Your second appendix should consist of the mathematica (or other) code, which can be just stapled to the back of your paper.

7. Your group should communicate with other research groups. You're not in competition. Communication and cooperation with other research groups is definitely encouraged.

8. Your group is responsible for a ~12-minute presentation (plus 2 minutes for questions) summarizing your group's findings at the final siege engine conference during the exam period. Everyone in your group must participate in this presentation. All group members are expected to attend the conference and to participate in the talks and discussions. You will also need to practice a version of your talk with Jay before the real talk. Like the paper draft, it need not be complete, but I want to give you some feedback about how you present things.

9. You must submit your evaluation of your group members by the end of finals week. See group member evaluation form attached.

Support Organizations and Services

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Official Sponsor
Department of Physics and Astronomy Research Department
Ye Olde Castle Anderson

Our research department is responsible for financing the "The Siege Engine Project". Your obligation in accepting our financial support is to submit to our Royal Project Coordinator (Royal PC), Jay Tasson, a group member evaluation, a research paper, and a conference talk. The Royal PC will assess your project a grade based on the attached rubric, which will be combined with the rest of your grades in the course for inclusion in your official castle record (transcript).

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The National Organization
of Numerical and Symbolic Computationalists and Visual Presenters
Headquarters: Northfield, MN
Contact Person: Sir Jay
phone: 507-222-5251 (office)
email:jtasson@carleton.edu

Our organization provides one-to-one tutoring services for our clients. In addition to Sir Jay, we also have available the royal PSFs. Help will be available during the usual time commitments by Sir Jay and the loyal and faithful band of problem solving facilitators.

Bruce Duffy, the 2nd Earl of Northfield, is very familiar with the computers and software in the department and can help you with any computer problems that you experience (or at least give you some sympathy).

Finally Sir Jay is available on an emergency basis. If you need to contact him, try his Olin quarters, his virtual gather quarters, or use phone or email; messages by carrier pigeons or flaming arrows are also accepted.

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Technical Tasson & Associates
Contact Person: Prince Jay, Scientific Consultant
email:jtasson@carleton.edu

Our technical consulting group, which specializes in physics and mathematics, provides technical consulting and advice. Contact Prince Jay, one of our Scientific Consultants, by phone or email to make arrangements for an on-site visit.

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Medieval Group Facilitators of Northfield
Contact Person: The Honorable Friar Jay, Secretary
email:jtasson@carleton.edu

Our organization has seven professionally trained facilitators, some even with advanced degrees in the physical sciences, who can help your group function at its optimal potential. If you're having trouble dividing up tasks, getting group members to assume responsibilities, setting realistic deadlines and goals, please contact us. We're a privately funded organization and our services are absolutely free and confidential. Just give our secretary, Friar Jay, a call or send him an email. We guarantee prompt, confidential, and courteous service. Remember, a cooperative and friendly group is as good as it gets.

Miscellaneous Comments on Organization and Structure

1. The technical consultation sessions with TTA will go better if you submit questions to King Jay a day in advance of the scheduled meetings.

2. View this special project experience as an experiment. Don't stress out. If everything doesn't get done, it's OK. Put in an honest effort; think in terms of about 30 hours of work on the project over the course of the term.

3. Let the Royal PC know immediately if you have a problem with the date and time of the conference.

4. Keep the lab areas picked up. You need to make sure you stuff is safely put away when you're not working on it. This is both to make sure you don't interfere with the lab's space, and to make sure they don't break your Treb.

5. You are likely to have a more successful and less stressful experience with the project if you begin tasks significantly before they are due. This provides time to seek help if needed as well as time for your back brain to work on things.