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A Virtual Physics Laboratory for Remote/Online Learning

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RCEU 2022 Project Proposal

Project Title

A Virtual Physics Laboratory for Remote/Online Learning

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I. Project Description

The goal of this proposal is to reverse-engineer and model Java-based classic Newtonian mechanics experiments for the purpose of online and remote/distant learning. In particular:

The student will become familiar with an already widely used existing Java-based collection of libraries that provide real-time animations and graphical solutions of mechanical systems that can be very challenging, if not impossible, to replicate in an actual laboratory setting. Examples will span (but not limited to) from explosions to multiple object interactions (e.g. springs and frictionless pulleys), perfect collisions etc. Under the guidance of the advisor (Chronis) the student will design and implement different experiments of various difficulty levels (i.e. introductory, intermediate and advanced), run the simulations and export the related data in an ascii-based format. The next step is to solve the specific problem analytically and use the data to corroborate the solution accuracy. The final product is to incorporate a number of similar experiments it in a collection of a Physics-based web-based portal. Additional guidance on how to implement the solution will be also given as a general pseudo-coding implementation (e.g. on Matlab). This portal will become a vital tool to students who cannot physically attend laboratory experiments, but providing them them the opportunity to study real experiments with real data and analytic solutions. This portal will address high school/introductory college level up to higher level mechanics. Chronis has already started this initiative by developing a similar online portal (see here).

II. Student Duties, Contributions, and Outcomes

a. Specific Student Duties

The student should first become familiar with the SimPhy (clickable link) graphical user interface (code and manual provided by the advisor). The GUI contains various elements such as e.g. rigid objects (defined by e.g. moment of inertia, surface material etc), joints (e.g. pulley, ropes, strings etc.). This is a drag-and-drop menu that is student friendly and intuitive. The advisor has already built up experience and will help the student become familiar. With the advisor's guidance the student will configure and simulate experiments that in a real laboratory setting may be challenging to set up e.g. projectile motion with air drag, 2-dimensional collisions, explosions, multi-joint interactions (pulleys, springs etc) in oscillatory behavior etc. The student will run the simulation and target key graphical and data output such as e.g. angular velocity of a rolling sphere down an inclined plane, kinetic energy, angular momentum etc. The data acquisition will be also achieved via the SimPhy environment. The next step will be to analytically solve the experiment at hand and finally compare/fit the acquired data to the theoretical solution. The student will then upload the description of the experiment, data and

solution on a web-based portal that is interactive, allows the introduction of widgets and video instructions (Genially, see here).

b. Tangible Contributions by the Student to the Project (10% of Review)

The end goal is the development of an immersive online environment where the remote user/ student will be able to sharpen his/her analytical and problem-solving skills based on real data and real physics problems. The remote user will be able to gradually enrich their knowledge of Newtonian mechanics on a portal which will entail a virtual laboratory setting. This will incorporate videos/animations of (Java-based on SimPhy) simulated experiments, collection of the relevant data, ability to reproduce the experiment with different variables and a step-by-step analytical solution based on the UAH's curriculum of PH-111 (Physics I with Calculus) as well as more advanced topics that are covered in 200 or 300 level courses. The student will further adapt the analytical solution to a pseudo-code (not necessarily related to one particular computer programming language).

c. Specific Outcomes Provided by the Project to the Student (30% of Review)

The involved student not only will improve his/her engineering, data analysis and problem-solving skills but also delve into the educational aspect of teaching Physics. Each simulated exercise will be addressing a gradually higher skill level e.g. start from basic projectile motion, getting into air drag, terminal speeds, oscillations (e.g. via springs, flotation), coupled oscillators, resonance and so forth. The involved student not only will design and realize these simulations on SimPhy but more importantly will make sure that the derived simulated data are corroborated by the analytical solution which will also be derived. These tasks will help the involved student deep-dive into a comprehensive modeling approach to mechanical systems, sharpening these important skills that are important to any scientist or engineer. Finally, the student, with Dr. Chronis' supervision and mentorship will develop the outline that best serves the purposes of an online Physics-based course curriculum. This approach will put the student in the place of the actual teacher/instructor which is deemed as a paramount step towards learning (Feynman's "If you want to learn something, teach it!").

III. Student Selection Criteria

The selection criteria that the student must meet entail strong background in Newtonian mechanics, mathematics/computational Physics, computer coding but more importantly (than any GPA), passion for deep-dives in Physics, teaching and out-of-the-box thinking.

IV. Project Mentorship *(30% of Review)*

Dr. Chronis has build from the bottom up the Physics undergraduate laboratories which enrolls more than 1,000 UAH students per year. Dr. Chronis also developed the online versions for more than 150 virtual experiments that have been the basis of the online course curricula during the period of the COVID-19 restrictions. The student will meet with the mentor (Dr. Chronis) on a weekly basis or as often as is deemed necessary. The mentor will help with the initial laboratory setup but it is the student who will be required to "devise" scientific techniques to carry out the experimental tasks. Dr. Chronis will provide all the laboratory space (Curiosity lab), licenses of the required software, apparatus, although the student's improvisation in effectively designing the experiment will be necessary. Dr. Chronis is a strong supporter of "hands-on" teaching and these experiments are designed in such a way so that students develop their critical thinking, design and reporting skills.