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| Harvard Project Physics |
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**Introduction**

 *Harvard Project Physics* is arguably one of the most influential physics curriculums. It has served to reshape the way educators think about developing a curriculum. This project was not a small undertaking, and through the foresight of F. James Rutherford, it became an amazing teaching tool that was tested and tweaked over several years. “It is estimated that in the 1970's, as many at 15% of American High Schools used the curricular program” (Lange, 2005, p. 6). Although this program is not in use today, its impact is evident in the field of science education and its materials are still adaptable in useful to teaching high school physics to today's youth.

**The Authors**

 Before delving into the project, it is necessary to discuss the three creators of *Harvard Project Physics*. F. James Rutherford, Gerald Holton, and Fletcher G. Watson worked together to create the original framework and aims for the project.

 F. James Rutherford was born in California in 1924. Shortly after the attack on Pearl Harbor, he joined the Navy. After the war ended, Rutherford completed his bachelor's degree at Berkeley, and then continued on to obtain a master's in Science Education from Stanford. After teaching for a few years, he went to Harvard where he received his doctorate in Science Education in 1961. Rutherford returned to teaching in California for a few years, but departed for Harvard in 1964 to become a professor.

 Gerald Holton received his bachelor's degree from Wesleyan University in 1941 and a masters in 1942 before continuing on to obtain a doctorate in physics from Harvard in 1948. He was a professor at a number of universities before he ended up at Harvard, where he worked in both the Physics and History of Science departments.

 Fletcher G. Watson graduated in 1933 from Pomona College and went on to receive his doctorate in astronomy from Harvard in 1938. Fletcher did post-graduate work in the Harvard observatory and served in the Navy during WWII. After the war, he returned to Harvard where he became a faculty member of the Science Education department.

 Although this is a very brief history of their lives, it serves as a basis to understanding the motivations behind creating this project.

**Aims**

 When the authors set out to create *Project Physics*, they first put together a set of concise goals for the course. They were as follows:

“Aim of the Course

1. To help students increase their knowledge of the physical world by concentrating on ideas that characterize physics as a science best, rather than concentrating on isolated bits of information
2. To help students see physics as the wonderfully many-sided human activity that it really is. This meant presenting the subject in historical and cultural perspective, and showing that the ideas of physics have a tradition as well as ways of evolutionary adaptation and change.
3. To increase the opportunity for each student to have immediately rewarding experiences in science even when gaining the knowledge and skill that will be useful in the long run.
4. To make it possible for instructors to adapt the course to the wide range of interests and abilities of their students
5. To take into account the importance of the instructor in the educational process, and the vast spectrum of teaching situations that prevail” (Rutherford, Holton, & Watson, Project Physics: Text, 1975, p. vi)

 These aims contain many of the goals of any physics instructor, but then go above and beyond. The first item that jumps out after reading the aims is that the students are the focus. This goes along with a student centered course, which is now commonplace in curriculum development. However, unlike most courses, there are also aims that discuss the teacher, and imply that they are skilled professionals that can shape the materials as they see fit. The authors wanted to make sure that the course they were going to create would be able to be adapted by any teacher to fit their students. Every classroom is different, and it is important that the instructor can easily alter the materials to better fit the students without destroying the integrity of the course. Starting with these goals in mind would help the authors to focus their efforts to create the best course possible.

**Development**

 The *Project Physics* curriculum was developed in three main phases. In the first phase,

The three authors collaborated to lay out the main goals and topics of a new introductory physics course. They worked together from 1962 to 1964 with financial support for the Carnegie Corporation of New York, and the first version of the text was tried out with encouraging results" (Rutherford, Holton, & Watson, Project Physics: Text, 1975, p. v).

 In the second phase, the authors examined the preliminary results, and worked to receive several major grants from U.S. Office of Education and then NSF starting in 1964. Additionally, there was financial support from the Ford Foundation, Alfred P. Sloan Foundation, Carnegie Corporation, and Harvard University. It was at this time that the project was officially titled *Harvard Project Physics*. With a great deal of funding for the project, there was a large number of staff and consultants that were hired. These collaborators consisted of physicists, astronomers, chemists, historians, philosophers of science, college and high school teachers, science educators, psychologists, evaluation specialists, engineers, filmmakers, artists and graphic designers.

 In the third phase of the project's development, the team concentration on developing and then later conducting training programs. Additionally, a great deal of time was spent on analyzing data and writing reports on their findings and the successes of the course. This is also the time at which the project started to hit the fourth aim and evaluate how to "reshape the course for special audiences" (Rutherford, Holton, & Watson, Project Physics: Text, 1975, p. v).

**Textbook**

 The text starts with a brief story involving the Curie's and Fermi. This is not the typical beginning of a textbook, however it also makes it very clear that the authors do not intend for this book to be like anything that has be printed so far.

 The next section details relative orders of magnitude. This shows students the overall size of items in our universe from distance between galaxies to size of a human, all the way down to a nucleus. Next to the order of magnitude chart there is a chart titled “Our place in time”. This chart gives relative times of events using the time between heartbeats as the base unit. This is an important section, especially where it is placed. Many students, and even adults, have very little conception of the relative size of objects or of relative times. These two charts set the tone for the textbook. The authors have a clear understanding of the basic skills that students will need entering the physics course. Understanding these simple charts will allow students to evaluate answers to see if they made sense, and make quick order of magnitude calculations.

 Within the opening chapter, there is an integration of graphing skills, and how to properly interpret the graphs. These are skills that will be essential in future chapters, and developing them early is a wise choice by the authors.

 The text is written in a casual style that is a pleasant change from the stuffy formal feel of many textbooks. The authors presenting experiments, and then discuss the relevant physics that the experiments demonstrated. Additionally, the notes in the margin are exceptional in terms of clarifying what was written in the body of the page. The first few experiments attempt to describe motion and the author explains why they are unsuccessful. Then, revisions are made until the experiment successfully describes motion. This is a brilliant way to start a textbook. This will get students thinking from the onset that physics is not just all cookbook activities, and that science in general requires revision to reach the desired result.

 The example problems that are given within the text are laid out extremely well. The equation is given, the conceptual names applied, values with units, and then answer with units. In addition, the analysis of the answer is clear and in as simple terms as possible. This allows students to see each step clearly, making it easier from them to complete similar problems on their own.

 At the end of each chapter, there is a study guide. This contains a list of all of the experiments, activities, and reader articles that apply to the chapter. The authors also include an example problem for each of the sections in the chapter. This allows students to identify an area in which they are struggling, and give them specific problems to practice once it has been identified.

 There is a great deal of history that is included within the text. This is not surprising knowing that Rutherford studied in the History of Science department at Harvard (Lange, 2005, p. 4). The history allows students to see how ideas developed, as physicists tried to piece together, many of the concepts that now seem to be common knowledge. This is also another opportunity to see physics as a human activity. In addition, the authors have included a time line, which neatly lays out the major historical events, and influential people of the times divided into six categories: government, science, philosophy, literature, art, and music. This allows for students to get a better understanding of what events were taking place and who was influential at the times that various scientists were prominent.

 There is a chapter entitled *Understanding Motion*. This first section of this chapter involves going to the moon. The section takes the physics that has been discussed in the preceding chapters and shows how it was applied to traveling to the moon. This analysis is divided up into easy to swallow chunks, and is a great example to show students how what they are learning about in the classroom is applicable to the real world.

 The most obvious conclusion after glancing through the text is that it is unlike any other I have ever come in contact with. The main reason is that each chapter starts with an idea, which is then talked about in historical terms and an experiment that display this idea is discussed long before formulas are presented. The concept is being introduced well before any equations or numerical problems. Today, it is rare to be able to flip the first five pages of a text and not find the necessary equations in bold typeface. In the *Project Physics* text, it is not uncommon to go ten or more pages in a chapter before seeing the equations that are typically associated with the topic. Instruction following this philosophy allows students to grasp the ideas and the physics before being overwhelmed with the mathematics. Since many students often do not like mathematics and freeze when doing basic algebra, this is a better approach to teaching physics. However, when the formulas are introduced they are clear and explained with example problems that also often have real world applications. Overall, this textbook is phenomenally written, the included materials that branch beyond purely physics (i.e. historical context, applications) are second to none. This is the type of resource that all teachers should have in their possession for a new perspective on how to introduce physics to their students.

**Handbook**

 The handbook boasts itself as the “guide to observations, experiments, activities, and explorations, far and wide, in the realms of physics” (Rutherford, Holton, & Watson, The Project Physics Course: Handbook, 1970, p. 4). The book urges that physics is not to merely be read, but to be experienced. There are an extraordinary number of activities and the author notes, “you will need to pick and choose” (Rutherford, Holton, & Watson, The Project Physics Course: Handbook, 1970, p. 4). The introduction also urges students to complete any activity that interests them, even if they are not specifically assigned it by their instructor.

 There are three main sections: *Experiments, Activities, and Film Loop.* The Experiments “contain full instructions for the investigations” (Rutherford, Holton, & Watson, The Project Physics Course: Handbook, 1970, p. 4) and are meant to be done as a class. The activities are a much wider range and include projects, demonstrations, and activities that the students can perform on their own. The film loop notes give instructions on how to use the film loops that were specifically designed for use in the Project Physics curriculum.

 In the introduction of the handbook, there is a section titled “Keeping Records”. This details exactly how students should keep their laboratory notebook. Keeping a proper laboratory notebook is a skill that students are expected to have in college, yet there is little instruction on it. By addressing this issue at the start of the school year, it will set students up for success for the rest of the year and beyond. If the students are unclear about what the authors are attempting to describe, there is an example of an experiment and the accompanying notebook entries. The authors even go as far as to mention that “in general, it is better to record more rather than less data” (Rutherford, Holton, & Watson, The Project Physics Course: Handbook, 1970, p. 5). Students often only want to record the “right” data. Although this may be a minor note in the handbook, it is a great example of the thought that the authors put into each aspect of the curriculum.

 Each of the experiments includes detailed sketches of all of the apparatuses to be used, and also of any apparatus that is discussed in the notes. Periodically, there are cartoons that are semi-relevant to the topic at hand which serve to break up the material.

 Overall, the handbook is an outstanding resource that guides students and teachers through the various activities. Since a number of the activities can be done by students on their own, this makes the book and invaluable material to help if they are struggling. The intention of the handbook is to take the material that the textbook discusses, and have the students experience it instead of just reading about it. In this aspect, the handbook is a complete success.

**Readers**

 The purpose of the readers is to go beyond the typical classroom materials. The authors mentions that

"Your teacher will not often assign reading in the *Project Physics Reader*, but you are encouraged to look through it for articles of interest to you. … Since different people have very different interests, nobody can tell you which articles you will most enjoy" (Rutherford, Holton, & Watson, The Project Physics Course: Handbook, 1970, p. 9)

 The readers are designed to supply the students with a variety of supplemental materials either to enrich the material in class, or to delve deeper into the physics. "For those seeking a deeper understanding of mechanics, we particularly recommend the article from the *Feynman Lectures on Physics*" (Rutherford, Holton, & Watson, The Project Physics Course: Handbook, 1970, p. 9). These lectures and the other articles that are considered for those looking for a deeper understanding are at a collegiate level, with some of them involving calculus. For those that may find reading lectures from Feynman daunting, there are many articles involving arts, sports and practical applications. Several of the articles involve the historical aspect of physics. This gives famous scientists, like Galileo, explanation on motion. This affords students the opportunity to put themselves in the shoes of famous scientists and read how they describe concepts that are now seen as elementary. Interestingly, there is an article titled *Four Pieces of Advice to Your People* giving students advice for their future, which opens with the author stating that he is aware that those reading this article will ignore his advice. This casual style makes this and many of the articles intriguing to read. These readers also made the physics seem more accessible and personal. When students can see how the physics they are learning about is applied in the real world, it makes it seem more of a human activity, rather than just a bunch of information the students will never use again. This was achieved by the authors, as it was one of their aims for the course. Additionally, in schools today, there is a great emphasis on literacy and that it is integrated into all subjects. The reader was truly ahead of its time because it was incorporating reading and literacy into the physics classroom before schools started to require it.

**Materials**

 *Harvard Project Physics* is most noted for the readers, textbook, handbook, transparencies, and film loops. However, there were a few other creations of the project that are often overlooked. The first was a circular slide rule, seen in the picture below:



 This slide rule was made out of plastic and “has two circular logarithmic scales for multiplication and division...also are linear scales of inches and centimeters” (Harvard Project Physics Circular Silde Rule). However, shortly after this slide rule was created, inexpensive pocket calculators became the norm in classrooms.

 In addition to the slide rule, “There were films produced including an award winning film on the life of Enrico Fermi” (Lange, 2005, p. 5). The film on the life of Enrico Fermi is an astonishing account of his life and work, and has clips of the great physicist at work in his laboratory. Without the initiative of the *Project Physics* staff, this footage would have never been taken and many of the interviews would not have occurred. The foresight of the project to create such a film is yet another testament to their dedication to the field of physics.

**Conclusion**

 The *Harvard Project Physics* curriculum is a masterpiece. Although this was created in the 1960's and mainly in use during the 1970's, this curriculum could easily be used in classrooms today. The adaptability of the materials would allow teachers incorporate new teaching idea while still using the framework of *Project Physics.* With a great deal of hands-on activities and a focus on literacy, the curriculum would meet the goals set forth by most school districts today. *Harvard Project Physics* is a course that altered how all future science curriculums would be developed. Its applicability to today is a testament to the authors' dedication to the field of physics education.

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