Authors Note: This document was prepared by David Jackson for distribution to students at Santa Clara University enrolled in an Explorations in Physics Course. This will have to be modified to conform to your own course management philosophy and local conditions. You are welcome to use/modify it as you wish.

Explorations in Physics: Course Overview

OVERVIEW OF SCIENCE

Today, science is an integral part of our technological society, and people are often inundated with information on issues such as global warming, nuclear waste disposal, ozone depletion in the atmosphere, combating deadly diseases, finding new sources of energy, or the prediction of earthquakes and violent weather systems. A basic understanding of scientific principles and concepts is essential if today's citizens are going to be knowledgeable enough to comprehend and make informed decisions about these and many other difficult issues. In order to arrive as such an understanding, it is helpful to have some idea as to what science is all about.

There are about as many different definitions of science as there are scientists in the world. Perhaps the simplest way of defining science is as *an investigation into the workings of nature to try and understand how the world works*. Typically, this involves setting up some kind of experiment, making careful observations, and then attempting to explain these observations by coming up with an idea that describes what is going on. If the idea cannot successfully explain the observations, then it will not be very useful. On the other hand, if it *does* explain the observations, then one can try applying this idea to new situations in an attempt to predict what might happen. New experiments can then be done to test whether the predictions from this idea, or theory, accurately describe what is observed. If it doesn't, the theory has been *falsified*, and is generally discarded in the search for a more accurate one.

Now, it is often the case that a theory may not accurately describe the world in one situation, but it is very accurate in many other situations. In this case, the theory is only an *approximate* description of the world, but may still be very useful in those cases where it is known to be accurate. In fact, all scientific theories are only approximate descriptions of nature. It is impossible to ever say for absolute certainty that a given theory is true or correct. However, it only takes one experiment to show that a theory is incorrect. That does not mean that progress cannot be made. Indeed, each experiment that is done adds some new piece of information to our understanding of the world. Occasionally, these advances have a dramatic effect on the public, such as when penicillin was discovered or after the first transistor was developed. Such revolutionary scientific breakthroughs are rare and unpredictable, and makes the process of science an interesting, albeit sometimes chaotic, endeavor.

The late physicist Richard P. Feynman gave an interesting and surprisingly accurate description of the scientific process. Imagine that you are watching a game of chess and you don't know the rules. If you sit there and watch long enough, chances are you will notice some things that seem to happen over and over again. After observing these events enough times, you might be able to make a guess about one of the rules of the game. Then, to see if you are right, you could watch very carefully, paying particular attention to whether or not your "rule" worked in every situation. If it does, you might get a small feeling of pride that you were able to "discover" how a certain aspect of the game worked. You might even discuss it with someone sitting next to you and see if they came up with the same "rule." It's possible that they might have discovered something different, and it's even possible that their idea works just as well as yours. In this case, you would have to watch even more closely for a clue that would help you determine which of you has the better rule, or if some new idea is needed altogether.

Of course, it is entirely possible (and quite likely) that your rule doesn't work in every situation. If this were the case, you might study these situations very carefully to see if you could recognize a pattern of some kind. If you did, you might try to incorporate that pattern into a "new and improved" rule, altering your old one to account for the new observations. On and on you would go, slowly trying to understand the rules of the game, one step at a time. If the game was simple enough, you might be able to figure out all the rules in a relatively short time. However, if the game was extremely complex, you might *never* be able to figure out all the rules just by watching.

The process of science is very similar to the situation just described. In this case, nature is the game and we are the observers. Although nature turns out to be an extraordinarily complicated game, we have a slight advantage over the passive game watchers just described. You see, we can actually manipulate the "game pieces" into particular situations that we want to look at more closely. These *experiments* allow us to examine specific events as often as we like, which helps us figure out the rules more quickly than might otherwise be possible. This course is designed to give you a chance to try and "discover" some of the rules of nature on your own. Because there will be no one there to "tell" you the rules of the game, there is the possibility that you might have to change your ideas from time to time. This may seem a little foreign at first, and can be frustrating at times. However, going through such a process will help you develop a deeper understanding of the concept under study and what the process of science is all about.

THE EXPORATIONS IN PHYSIC PHILOSOPHY

Traditionally, the primary learning activities of science courses involve attending lectures, reading a textbook, and solving problems. These activities are usually supplemented by a weekly laboratory session taught by an instructor other than the lecturer. The emphasis in traditional courses is on *what* you know, and the student is often driven to memorizing a bunch of facts and formulas. In this course, everything you learn will be built up from direct observations that you will make in class. This kind of in-depth study will provide you with more than just knowledge about the particular concept under study. It will give you a chance to understand why a particular scientific definition is made and will make it easier to comprehend the meaning of the "physical laws" that unfold.

The basis of all science is experiments. The theories, laws, and mathematical descriptions of the physical universe that have been created during the past 3000 years are based on experiences and observations of our ancestors. In this course, the lecture and laboratory elements have been integrated to help improve your understanding of the scientific process. To help accomplish this, you will participate in a variety of activities that attempt to expose you to the full scope of scientific inquiry. You will help design and carry out experiments, participate in classroom discussions, and also carry out your own personal observations, predictions, and reflections. Your ability to perform observations, take data, analyze results, and write reports will be enhanced by the use of a computer. The computer, when equipped with sensors and software, can be used for data collection and display, mathematical calculations, graphing, drawing, the simulation of physical events, mathematical modeling, and word processing. All of these activities help to build a thorough understanding of the phenomena under study.

The use of direct experience, new computer tools, and active participation will enable you to achieve an enriched set of learning goals. In addition to beginning to master an important body of knowledge and learning how to solve traditional problems, you should be able to develop your reasoning ability and computer and laboratory skills to a much greater extent than you would in an ordinary science class. In fact, in this course your powers of observation, reasoning ability, and the depth of comprehension of scientific concepts and methods are considered to be *far* more important that any memorized facts, theories, or laboratory procedures. The critical question in this course is not "*what* do you know?" but rather "*how* do you know what you know?"

This course will also involve an independent project that will put you at the helm of a scientific investigation. You, along with your partners, will decide what project to undertake and what you hope to learn. In addition to carrying out the necessary experimental measurements and data analysis, you will be expected to give a short presentation of your project and results to your classmates. This should give you a feel for the kinds of problems scientists encounter when they undertake investigations. Additionally, you will need to answer your classmates' questions regarding your methods and results and will thus be in a position of "defending" what you have done. This introduction to scientific peer review and critical analysis will be an excellent test of the question "*How* do you know what you know?"

OBJECTIVES

- To give you direct experience with some of the phenomena studied by scientists.
- To provide you with a coherent picture of the nature of science.
- To increase your interest in science and provide you with the skills needed to make sound judgments on scientific matters that affect the general public.
- To provide direct and in-depth experiences with observations and experiments and the building of conceptual frameworks to explain observed phenomena.
- To give you direct experience with experimental uncertainty and instrumental sensitivity.
- To provide you with the computer skills needed to collect and analyze scientific data using various computer tools.
- To provide you with cooperative learning experiences and give you a better feeling for the climate of scientific research through the use of open ended independent projects.
- To improve your written and verbal presentation skills by setting up a mini-conference setting for you to present your results to your classmates.

REQUIRED MATERIALS

All required materials will be handed out in class. To help defray the costs of printing, you will be charged $30.00 for the materials, payable by check or cash by the end of *the second week of class*. In addition, you should come prepared to think, debate, brainstorm, evaluate, listen, analyze, plan, experiment, hypothesize…

STRUCTURE OF THE COURSE

Explorations in Physics is divided into *units.*. We will spend approximately half of our time studying the "core material" for a particular unit and the other half on related projects. The core material consists of completing activities in an Activity Guide, which involves some independent work, and also working with a partner and participating in class discussions. After completing the core activities, you will work on a small-group project. These projects will be independent investigations that your (randomly assigned) team chooses to work on. Your group will be responsible for the content of the project as well as gathering or creating the necessary experiments, taking the appropriate data, drawing conclusions, and presenting the results to your classmates. As you work on your projects, you will have ample opportunity to discuss problems you encounter with your classmates as well as with the instructor.

WHAT'S EXPECTED: CLASS WORK

The Activity Guide this is used in this course has been developed to support the *Workshop Physics®* approach to learning. Your in-class work will consist of undertaking various experimental activities, participating in discussions, solving problems, and documenting your work in the Activity Guide. It is important that you fill in the activity guide as you go. It will be assumed that you have completed all of the previous sections each time we begin a new section. Your instructor will make periodic checks to see that you are answering the questions in your Activity Guide. It is in your best interest to think carefully about the questions in your activity guide before answering them.

There will be homework problems assigned on a regular basis. Some of the problems may be small activities for you to complete with your partner to help prepare you for the projects you will be undertaking at the end of each unit. Some of the problems will involve calculations and some will be more conceptual. We feel it is important for you to have experience with many different types of problems. These homework problems will be graded and must be handed in on time.

You will work with a partner and also in small groups, depending on what type of activity you are doing. When working in a group, make sure that everyone gets a chance to take part in the activities, including working with the computer. Don't have the same person do the computer work for every single activity. This is a great opportunity to get comfortable with computers and computer-based measurement devices, but you must be willing to "get your fingers dirty." Some of the exam questions may involve the computer, so it is important that everyone be comfortable with it.

There will also be class discussions from time to time and you may be called on to answer questions or give your opinion. It is important that you participate in class discussions, which means being quiet and listening to what others say as well as contributing your own thoughts and ideas. Your willingness to discuss ideas with classmates, devise clever ways to measure or observe things, and make brief presentations using the board at the front of the room are important aspects of your participation in the course and will have a large effect on what you learn in the course. *You are expected to participate actively in the class sessions at all times.*

Lastly, when answering the questions in your activity guide, adhere to the following guideline. When asked for a prediction, we are looking for what *you* think, not what your partner thinks. It is essential that you investigate your own ideas about a phenomenon before you can build a more comprehensive understanding of it. Therefore, although you are encouraged to discuss things with your partner, it is also important for you to answer many of the questions on your own. It should be fairly obvious from the context of the question whether you should discuss it first or not. When in doubt, answer it on your own!

WHAT'S EXPECTED: PROJECTS

Roughly one-half of the time you spend on this course will be on your independent projects. For each project must submit a project proposal that outlines what you want to investigate and what measurements you intend to make *before* embarking on your project. This proposal will be read over by the instructor who may decide that you are attempting something too easy or too difficult. If needed, you will be asked to submit a revised proposal. One of the main purposes of the project proposal is to get you to think through the project critically so that you don't run into too many unforeseen problems. (There are *always* unforeseen problems when you undertake an investigation.) The project proposals should be about one page in length and should address what you want to investigate, why you want to investigate it, what measurements you intend to make, and a breakdown of your plan of action, including a preliminary time schedule. Because it is important to write a good proposal, 10% of your project score will be for your proposal.

Your projects will be done in groups of three that will be assigned randomly, so don't ask if you can work with your friends. You will also get the opportunity to make an oral presentation to the rest of the class. You will have 10 minutes to present your project, which will be followed by a 5-minute question and answer session. These presentations will count for almost half of your project grade and will provide a good opportunity for you to assess the strengths and weaknesses of your knowledge. In addition to the presentation, *each* person will be required to hand in a written summary of your project. This written summary will also account for about half of your project grade. Some of the main issues that should be addressed include:

- The goal of your project (what are you investigating?)
- How you accomplished your task (what experiments did you do?)
- What your results were (what data did you obtain?)
- What the results mean (what did you learn?)
- Any conclusions you can draw (putting it all together)

These summaries should be written for someone who knows nothing about your project. The reader should, after reading your report, be able to understand exactly what was done and should be able to reproduce the project if they so desired. There is no set format for these written summaries, as long as the information is presented in a concise and coherent manner. One of the most important goals is for you to show competence of the project you undertook. This means having a *solid* understanding of the material as well as understanding why you made any measurements and what this data tells you. These project proposals, presentations, and summaries, as well as the scientific soundness of your projects, will count for a large portion of your grade and should not be taken lightly. A rough draft of this summary needs to be turned in and will count for 10% of your project grade.

EXAMINATIONS

There will be an in-class exam given after you complete the core activities for a particular unit. There will also be a number of small quizzes given periodically throughout the quarter to make sure you are working through your Activity Guide. Some of the exam questions may require you to use the computer equipment and some might involve take-home activities. Because we will be giving project presentations on the final exam date, there will be no final exam in this course. (Hurray!)

POLICIES

Coming to Class—This institution specifically states that "students are required to attend all classes." Because of the activity-based nature of the work in this class, it is extremely difficult to "catch up" if you happen to miss a class. Therefore, your grade will be adversely affected if you miss classes. In addition, each class begins promptly. Because of the detrimental effect of disruptions on the rest of the class, no one will be allowed to enter after this time. That means that the door will be locked at the time the class starts, so make certain you arrive on time.

Classroom Hours—You may want to come in and work at times other than the normal class times. This is particularly true while working on your projects. The classroom will be open an hour before class each day so that you can come in if you feel like you need some extra time working on things. This is also an excellent opportunity to try and make up work if you happened to miss a class.

Respect for Equipment—We expect you to be careful with the lab equipment. At the end of every class session, your table should be left with the equipment arranged neatly, computer equipment off, and any scrap materials thrown away. If you need equipment outside of class for your project, you must have your instructor sign it out to you. **Make sure that you bring it back and have it signed in, or else you might be held responsible for replacing it!**

Late Work—In general, late work will not be accepted. You *must* consult with your instructor *before the work is due* if you believe you deserve an exception to this rule. Be aware, however, that very few (if any) exceptions will be given.

Academic Honesty—You are encouraged to discuss and debate the ideas in any of your assignments and projects with your instructor, TA's, lab partners, and other classmates. If you work on assignments cooperatively, rather than independently, you may share ownership of spreadsheets, graphs, and diagram files based on data you have taken with your partners. However, any other spreadsheet or written assignments must be expressed in your own words and reflect your own format details. This includes your project summaries! Thus, you may not copy (even with some modifications) problem, solutions, or spreadsheet assignments, activity guide entries, project summaries, or material on examinations. If there is reasonable evidence of copying, it will be construed as an act of plagiarism. *Anyone found cheating will immediately receive a penalty grade of "F" for the entire course!*

GRADING

You will be graded on a professional judgment of your work using the following weighting scheme as a guide:

Component	Percentage
Activity Guide	10%
Homework	15%
Quizzes	20%
Exam	20%
Project	30%
Effort/Participation	5%
Total	100%

Note that 5% of your grade will be determined by your "effort/participation." This will be determined by an evaluation of your homework, Activity Guide, in-class participation, overall effort on your project, and steady improvement throughout the quarter. Please note that simply showing up in class every day is expected and does not constitute a high degree of "effort/participation." On the other hand, missing a number of classes does indicate a low degree of effort.

FINAL REMARKS

Have Fun—We hope your experience in this course will be stimulating. Take the time to have some fun and try not to get overly stressed if you run into problems while working on your projects. Part of the process of science is learning to deal with the unexpected problems you run into. Try to be resourceful and develop creative solutions to any problems that arise. Science is very much an artistic endeavor and scientists derive tremendous satisfaction by solving seemingly impossible problems in elegant ways.

Ask Questions—In this course, the format is designed so that you are actively engaged in discussions and activities with your fellow students. You will find times when everyone seems to be confused and yet it seems perfectly clear to you. Of course, there will be times when you are the one feeling frustrated and everyone else seems to have "gotten it." It is important to be able to explain things to others as well as to be able to understand another student's explanation. This interactive process is intellectually beneficial to both parties and you should engage in discussions whenever appropriate.

Use Your Head—This course is designed on the assumption that you will make an honest effort to answer the questions in your Activity Guide with intelligent thought. You will learn little if you decide to just "whip through" the questions as fast as you can, without giving them much thought. On the other hand, try not get too bogged down on any one question. If you are really having problems with something, it is possible you are interpreting the question differently than anticipated. Ask your instructor!

Talk to the Instructor—If you are having serious problems, come and talk to the instructor. Their job is to help you overcome your difficulties. Your frustration and anger can spread to your classmates and result in a bad experience for everyone. On the other hand, enthusiasm and excitement are equally contagious, so keep that in mind and lend a hand when your partner is having difficulties. Remember that your instructor cannot be held responsible for your learning. If you are having problems, do not wait until you are so lost and frustrated that nothing can be done to help.

ACKNOWLEDGMENTS

The work involved in producing the materials for this course have been supported by funds from the Charles A. Dana Foundation. Additional funding was provided by the Department of Education's Fund for the Improvement of Post-Secondary Education (FIPSE) and the National Science Foundation (NSF). Intellectual support was provided by sources too numerous to mention. However, a number of similar projects provided many wonderful ideas for us to build from. Among these are *Workshop Physics*, developed at Dickinson College, *Physics by Inquiry*, developed at the University of Washington, and the *Powerful Ideas in Physical Science*, developed in conjunction with the American Institute of Physics and the American Association of Physics Teachers. In addition, numerous conversations which led to improvements have taken place with many people, too numerous to mention individually.