

Discovery in the Dorm Room

Evaluation and Redesign of Introductory Undergraduate Physics Series for Use with

USB Devices

Leah Parsons

Advisor: Professor Bedrosian

Second Reader: Professor Poynor

Table of Contents

Title Page	1
Table of Contents	2
APS Abstract	3
Introduction	4
Background	4
Theory	13
Methodology	14
Results	15
Discussion	20
References	23
Appendix A	24
Appendix B	28
Appendix C	29

APS Abstract: *Evaluation and Redesign of Introductory Undergraduate Physics Series for Use with USB Devices^a*

The introductory physics laboratory series at many colleges suffer from several problems, including a large time commitment, inflexibility of lab set-ups, and lack of accommodation of multiple learning styles. It is difficult in a conventional lab set-up, in which students follow a carefully specified series of steps, to be able to generalize findings to more than one specific case. In this project, we propose changes that will allow students to form the labs to their own learning styles to better study the phenomena of interest as well as to address the other issues. To test our ideas, we have reduced the current introductory physics labs at Allegheny College to their basic principles in order to apply them to a new, more flexible, lab paradigm. Using a USB device designed by Rensselaer Polytechnic Institute, labs that reflect the core concepts of introductory physics will be able to be performed in a more agreeable environment: the student's own home, at a time of their choice, with use of a personal computer and simple additional materials. This project will present the method of lab design as well as proposed testing of lab effectiveness.

^a The complete text from the American Physical Society 2009 March Meeting poster presentation session is available in Appendix A.

Introduction

The purpose of this project is to research methods by which the current lab-based introductory physics series at Allegheny College can be improved. Issues that have arisen as part of the series include the amount of time that must be devoted to a prescribed laboratory period as well as the restrictive nature of the labs that disallow student innovation and discovery. To address these problems, I intend to assess the experiments that are currently being conducted and to reform them for use with a USB device, which would allow for a less restrictive experimental environment for students. Some of the issues that could arise from a new set-up will also be addressed. Labs will be created to work with the USB device and consequently compared to the basic lab sessions that are currently in use. Additionally, testing the manner in which the new experimentation set-up affects the amount of material that is learned, and retained, by students is a matter of central interest. In order to do this, testing methods will be designed for both the control (e.g., current) and renovated labs.

Background

In physics education, there are many problems that must be addressed. These issues range from the manner in which physics teachers present their topics, the preconceptions that students bring to the class, and to the laboratory experiments that are difficult for students to approach. However, one of the most prevalent is the presentation of laboratory type experimentation to students in introductory courses.

The lab setting offers a very stiff and unforgiving environment in which students can only complete prescribed experimental procedures and cannot engage in work that

may better favor their personal learning styles. By reforming the current lab design to a more student friendly set-up, including a device that can be used in a student's home during his or her own time and with much more flexibility, I propose that students will be able to learn more about the physical concepts that are the main focus of the introductory physics series in many undergraduate programs. Using studies concerning physics education as well as its integration with new technologies, it will be possible to see that by changing the way in which material is presented, students will be able to gain a better understanding and a more complete education.

In a 2002 paper, Francisco Esquembre states that new technology could contribute a great amount to physics education. Specifically, the paper lists technology as being able to “bring exciting curricula based on real-world problems to the classroom”, “give students and teachers more opportunities for feedback, reflection, and revision” as well as to “build local and global communities that include teachers, administrators, students, parents, practicing scientists...” Additionally, the author suggests that allowing students to see graphical representations of their lab data will better connect the concepts that they study with the concrete results that they obtain.¹ When it is possible to relate the abstract to the tangible, students have an easier time understanding why their material of study is important and applicable to their everyday life. Moreover, by focusing on the experimentation early in the students' physics careers, students will be able to establish a connection between physics and the daily experiences of the students. This would, in turn, offer incentive for students to remain involved and interested in their physics curriculum.

While bringing new technology may have positive implications for students, it must also be considered in terms of teaching staff. In one study of e-Science labs, it was found that a typical hour of lab required 15 hours of preparation by the teacher.² With this amount of preparation, the implications of the labs must be judged on more than the impact on students. If educators are required to spend a vast amount more time preparing the required materials for each lab, time may be taken away from classroom teaching preparation, which would not suit the student better, instead it would deprive them of another integral part of their education: the lecture.

While the 15 hour time commitment would not be precisely what would be experienced in the laboratory sessions suggested for Allegheny College because faculty would not necessarily be directly involved in the completion of the labs, there will be some additional time commitment. Because students would have fewer opportunities to have the concepts explained to them while they were completing the lab; it would be necessary for professors to devote more time to lab concepts during class periods. This would not only change the way that classes would be run, because student questions about the labs would have to be addressed in class, but also the way that professors would prepare for class. Because the new classes would have to be run in a more seminar-like format, where input from students would be encouraged, the lecture would become less of an educator-controlled set-up for some amount of time and more of a student-directed endeavor.

These issues could possibly be addressed by using the 3-hour lab periods that are assigned when students register for classes. The periods, which are normally when students come to the lab to complete their experiments, could instead be used as times

where instructors would be available for student questions. Although this may seem senseless, because one issue that the USB labs are meant to address is the question of student time commitment, having professors available during this time would not require students to finish their labs in the prescribed period. Instead, this allotted time would act as a safety net for students who anticipate misunderstandings and complications. By maintaining the lab period, those students who would like to could work on their labs where a professor could offer guidance, but those who would rather work on their own could do theirs in the comfort of their own homes. It may also be beneficial for students to begin their lab during the assigned period in order to guarantee that they understand the material before completing the experiment at home. In allowing this flexible period, some amount of the traditional lab will be maintained, offering students and professors a level of comfort while still working to reform the lab sessions for a better use in physics education.

In the same e-Science study, the authors suggest that another way to support the labs based on new technologies would be to involve scientists who are specialists in the fields that were being studied.³ This interaction with specialists gives students a better sense of why the material that they are studying is of significance to the larger picture of physics. While this type of interaction may be more difficult in an introductory setting, due to the simplified nature of the concepts, it could be beneficial because contact with professionals would give students a reason to study the basic concepts. If specialists are available to undergraduates, this interaction may grant some encouragement to students just beginning to study the field, in terms of how they could progress in their studies and what research they could eventually do. Interaction of this type could be useful at

Allegheny College because faculty members rotate the responsibility of teaching the introductory courses, meaning that each member of the physics department will eventually teach the courses. This type of rotation may allow professors to give each other instances in which the topics of introductory study are useful in their own specialized fields, which could be introduced to students as a motivating factor for their continuing interest in physics. This type of material could also be given in the laboratory manuals that describe the basic principles and reasoning behind the experiments. This is an additional way that updates to the introductory series could be made.

In a paper discussing the merits of using virtual laboratory set-ups for physics instruction, it was found that physics simulations, such as Java applets, can help students to understand concepts when presented by instructors, but not when students use them at home. The paper also says that, when given the choice, students will prefer open-ended experiments to book study, but prefer already made materials (such as prepared labs) to computer-based examples. Additionally, the paper suggests that students were motivated to work in the open-ended labs was because they had the opportunity to investigate different aspects of the subject that the educator would not have included.⁴ With this in mind, having a more open-ended lab that still provided some suggestions could be more attractive to students. This coupled with the idea that students are more engaged when they can go beyond the expectations of the teacher creates a structure that can be used in tandem with the redesigned labs to encourage student learning. The use of open-ended labs can be a tool to motivate students to engage in activities that are more like actual scientific experimentation, in that the students are able to adjust the parameters of the lab as they go in order to change the way that they are studying the subject. This

will allow them the flexibility of a real lab while still allowing them to learn about the subjects that they are required to in order to pass the course.

While each of the previous concepts certainly contributes to the effective implementation and use innovative lab strategies, one study has been completed that addresses the idea of implementing new lab technology from start to finish, the VenDASys project. This study follows the German project from creation of the hardware and software that were used to the realization of labs with the equipment to the feedback of teachers and students, giving a comprehensive view of each aspect of the process. The hardware includes a computer with software which connects via USB to an electronic platform which, in turn, connects to various sensors (see Figure 1). The platform is designed to include power supplies, analog and digital inputs and outputs, relays and counters (see Figure 2). The front page of the software is meant to mimic the setup of the hardware (see Figure 3) in order to make it easily understandable for users.⁵

The sensors, which are of the most interest in terms of the system's interaction with the subject of study, are also very specialized for their individual purposes. This system includes four sensors that can connect to a device for measurement of mechanical signals, control the separation of vehicles carrying solvents, measures acceleration and measures atmospheric conditions.⁶ In terms of what would be most applicable to the undergraduate physics labs, the acceleration sensor is most interesting.

The acceleration sensor is used in a crash scenario to demonstrate how changes in acceleration can be detected and the measurement of the changes in acceleration can be applied to realistic situations (see Figure 4). In the simulations when the acceleration exceeds a certain cut-off a series of LEDs are activated, indicating that airbags would

have been deployed. Students using this lab set-up would also be able to experiment using different materials that the vehicle can impact in order to examine the changes in acceleration associated with each.⁷

While the sensors are important for the direct interaction of students with the phenomena that they are studying, there are other aspects that must be addressed. One important factor that is addressed in this study is the manner in which teachers were educated about the system. In the study, teachers were introduced to the system in a very general setting and then had experiences that became more and more specific. The training sessions, which were ongoing, eventually became peer led endeavors where experienced teachers were teaching less experienced teachers, a system that is similar to the suggestion that specialists become involved in course materials.⁸

Using a similar approach could be useful in the undergraduate arena as well. Because the current manner in which faculty members teach the introductory lab series at Allegheny College is based on a rotational system, having professors who have already used a technology based lab system may have a positive impact on those who are new to the method. Because not all problems with the system can be anticipated, instructor input is absolutely necessary in order to create a lab system that is agreeable to both educators and students.

Keeping these suggestions in mind, creating a new laboratory system has several main requirements. Included in these are the use of new technology, allowing flexibility for students, addressing educator commitment, involving specialists and creating an environment where educators can have support from peers. Discussed within the review

were ways in which labs within the undergraduate education system, specifically at Allegheny College, could be adjusted and issues could be addressed.

The use of technology is meant to be addressed by introducing USB devices to students so that they could experience a more advanced piece of equipment that could feasibly be used for other purposes. Flexibility would also be addressed in the use of the USB device because it would be available to students whenever they are ready to complete their labs and, with the lab periods still available, there would still be allowance for interaction with professors. Also in terms of the lab period, professors could use this time to decrease the amount of commitment outside of work hours that they would have to assign to the preparation for each lab. Much of the time would be set aside for understanding the new lab system and preparing students for the new labs, the actual set-up time that must be devoted to each lab would be decreased. Because professors would be devoting more time to intellectual preparation rather than to physical preparation, the time devoted could be done over longer periods and would not require a great investment of time in one session.

Another issue that needs to be addressed is the way that educators would engage in this system. By offering knowledge about what aspects of the field of physics as a whole are influenced by the basic concepts, educators will be able to make the introductory series seem more relevant and useful to their students. Additionally, educators can act as advisors to other educators by sharing their experiences while teaching the courses. Having this kind of support and interaction will allow for more advances to be made in the future, once the proposed lab system has been put in place.

While the issues discussed do not encompass all of those that will be faced in the future, they give a sample of some that must be addressed in the creation of the system.

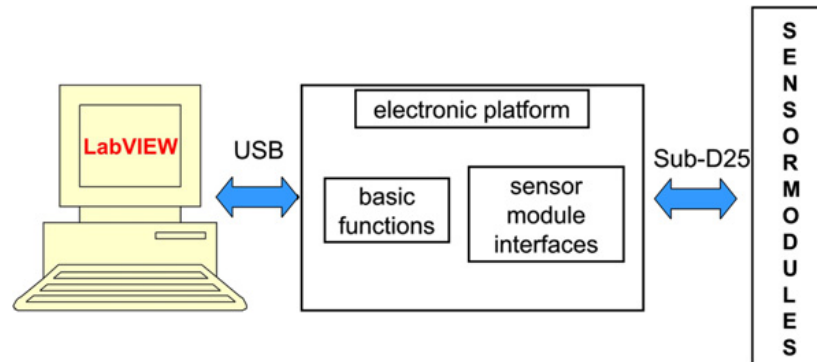


Figure 1: The basic set-up of the VenDASys system.

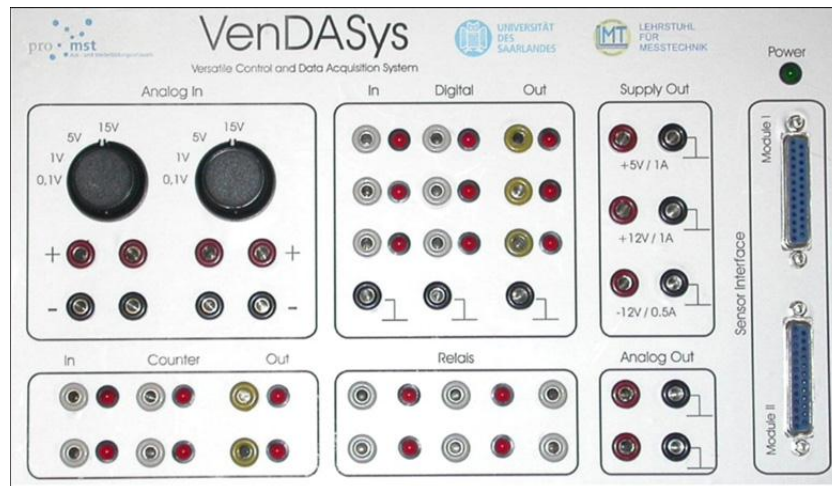


Figure 2: The front view of the electronic platform.

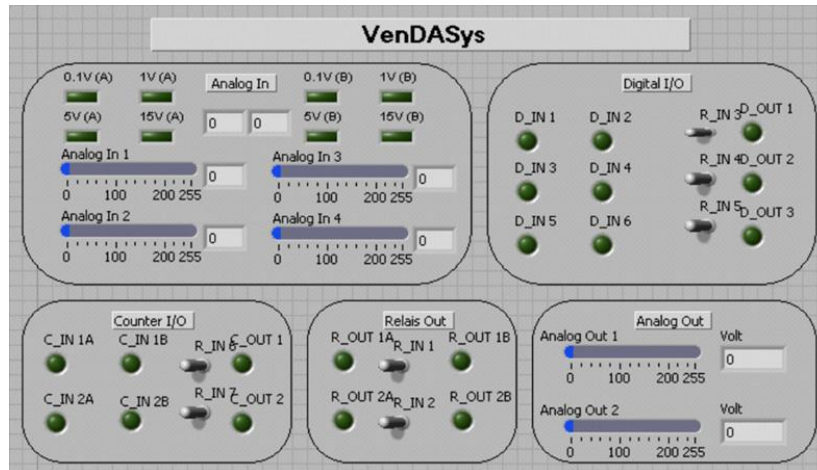


Figure 3: The front page of the software, modeled after the electronic platform.

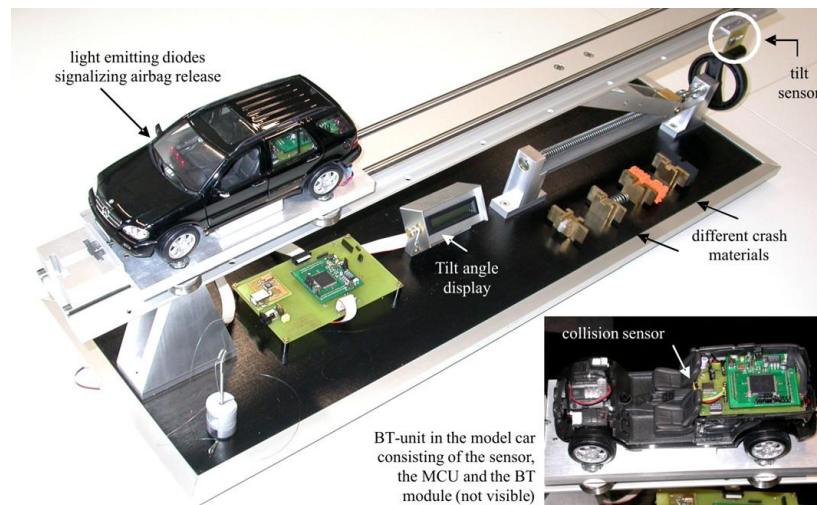


Figure 4: The acceleration set-up from VenDASys represents a realistic use for accelerometers.

Theory

The theory underlying this project is that students will learn more from their physics laboratory experiences if they have the ability to expand the parameters to study more of the phenomena of interest. This means that the traditional, restrictive lab environment is not the most conducive to student education. Instead, the typical labs require students to focus only on particular aspects of physics and disregard any curiosity

that they may have about other features. To better allow the students to fulfill their own learning goals, a more flexible lab system must be designed.

Methodology

In order to complete this project, it will be necessary to complete several steps. These include reducing the labs to their basic principles and physical occurrences of study, designing new lab set-ups that test the phenomena of interest while still remaining flexible and testing the design with the USB device (see Figures 5 and 6). The material will be left open ended with minimal student testing because of time restraints. However, there will be the option for continuing research on this topic in the form of subsequent projects which would evaluate the effectiveness of the laboratory procedures as compared to the ones that are currently in use.

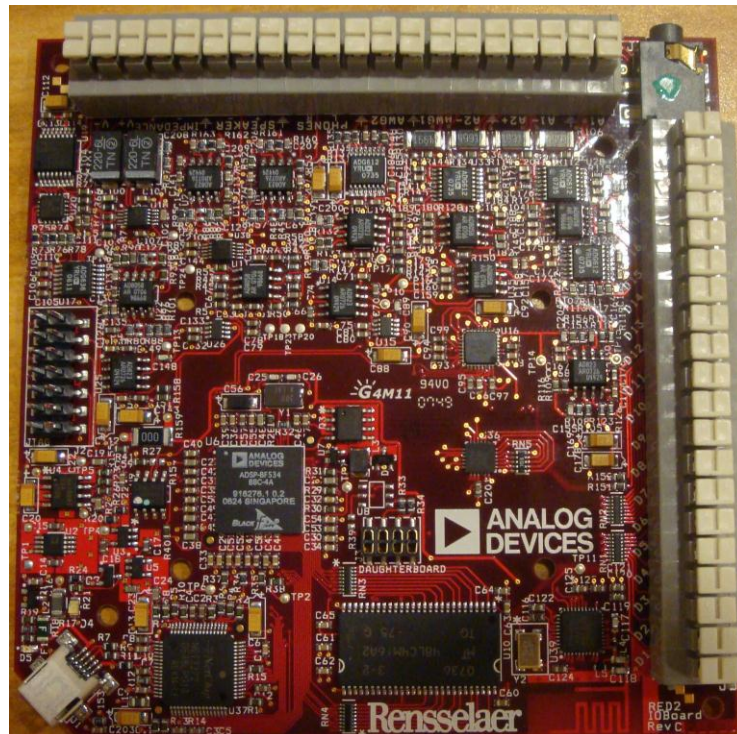


Figure 5: The USB device designed by Rensselaer Polytechnic Institute will be used in this project. The USB cable connects in the upper left corner.

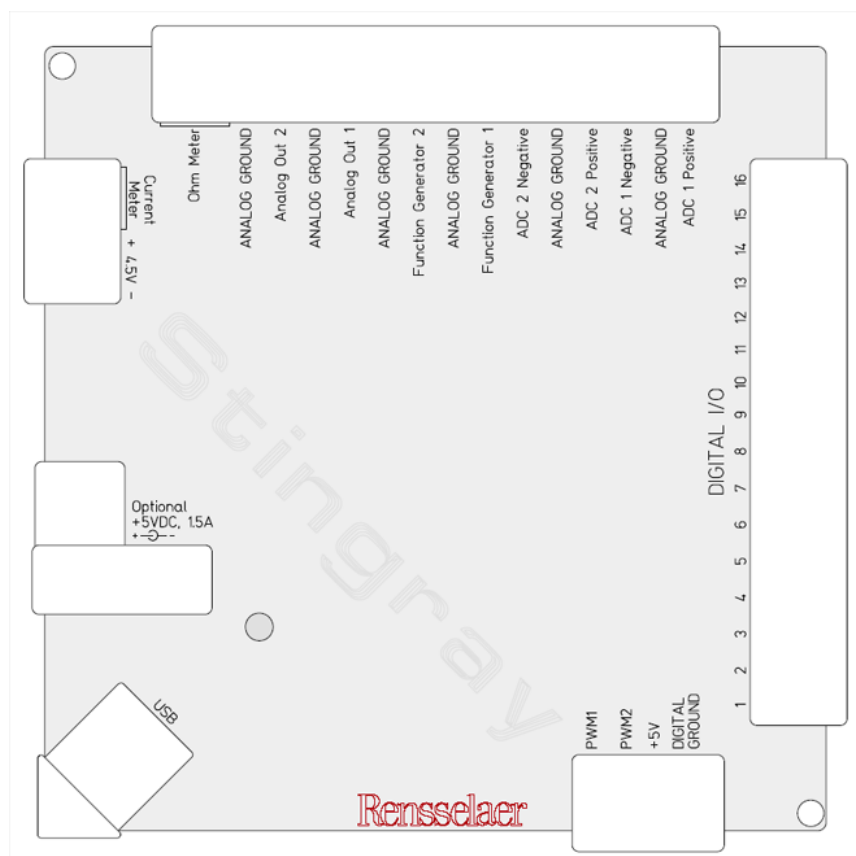


Figure 6: The reference diagram for parts of the Board, set-up in the same orientation as Figure 5.⁹

Results

Initially, the Physics 102/112^b labs were the focus of this project because the component that is currently available can be used for labs involving electricity (e.g., 102, 112 topics) but not force or acceleration (e.g., 101, 111 topics). In terms of progress, the 102/112 labs¹⁰ have been reduced to their component parts, as listed below:

- Electric Fields – electric field lines, equipotentials
- Ohm's Law – resistors, color coding, $\Delta V = IR$
- AC Signals – familiarization with lab equipment, AC signals, circuitry
- Time-Constant in an RC-Circuit – capacitors, RC constant (resistance*capacitance), circuitry

^b Although the laboratory procedures are given as 102/112, Physics 112 is not currently in existence. The 102 lab course is an introductory course for non-Physics majors.

- Helmholtz Coils and the Experimental Determination of the Charge to Mass Ratio of an Electron – charge to mass ratio of an electron
- Geometrical Optics – diverging and converging lenses, focal length, virtual images,

Of these topics, not all are applicable to the kind of labs that are being designed, such as the optics lab and the charge to mass ratio lab. These labs cannot be translated to the USB device because they involve specialized equipment (e.g., Helmholtz coils) that would not reasonably be accessible to students due to excessive cost^{11,c}. On the other hand, the optics lab will not work because it is based on distance measurements and focusing, both of which must be done using the judgment of the experimenter in order to find the best results.

Initially, the AC Signals lab was chosen because it can be used as an introduction to the equipment for 102/112 students. Additionally, this laboratory is similar to a Physics 120^d lab which is problematic in terms of allowing student flexibility. Ideally, the 102/112 lab was meant to serve as a trial run, or a simplified version, of the equivalent 120 lab.

The goals of the current AC Signals lab are similar to what they would be used for in the new system: to introduce new hardware and become familiar with electricity. With the lab software, Mobile Studio Desktop, an oscilloscope will be displayed (see Figure 7) and will display the wave resulting from the AC signal. An introduction, background and equipment list has been designed for this lab (see Appendix B) although the entire lab

^c As a point of interest, the website which was used for research the price of Helmholtz coils sells drivers for LabVIEW, the software that is associated with the VenDASys lab system.

^d This is the second course in the introductory series for Physics majors. It is preceded by Physics 110 which cannot be address due to its focus (i.e., force) similar to the 101 labs.

was not revamped to work with the board. Instead, these basic parts of the lab were written in order to gain a better idea of how to approach the 120 labs, which were of more interest to this project. The one change that was made to the 102/112 lab was to add a background portion which was not previously included. Although this minor adjustment was not intended to be part of the overall project, the lab seemed to be lacking some of the explanation that is present in the 120 labs. While this may be because the 102/112 labs are less advanced, some background may add to student understanding of the general concepts as well as the purpose of the lab. In other labs, relevant information could be suggested by faculty specialists.

The equivalent lab for the Physics major introductory series is currently called *Fun with Oscilloscopes*¹². This lab focuses on the use of the oscilloscope and function generator as well as understanding the use of resistors and capacitors. In order to complete this lab, it was necessary to identify which aspects of the procedure would be best suited to conversion into new forms to be used with the Board, much like the AC signals lab which was previously discussed.

Because the 120 lab is of more interest to this particular project, the procedure of creating the lab will be discussed in more detail. In order to complete the goals that were prescribed in the original lab, it was necessary to introduce both the oscilloscope and function generator tools that are available in the Mobile Studio Desktop software. These tools are available to the user after the Board has been connected to the computer via the USB cable. Explanations including accessing and adjusting the controls of each of these tools were given in the procedure, as was the use of the Help tool included in the software

which offers a simple explanation of each control in the event that students become confused or cannot remember the purpose of each control.

In the redesigned brief introduction about the use of the Board and Mobile Studio Desktop as well as the overall purpose of the lab was given in order to clarify to students what was involved in the experiment that they would be performing. However, in order to pertain to the material discussed in class, the discussion of alternating currents which was already in place in the original labs was kept, as was the Pre-Lab Assignment and the structure of the lab report. Additionally, similar goals for the lab procedure were kept in mind in order to cover the material as completely in the newly designed lab as in the original one.

In order to fully incorporate the ideas of the previous lab into the new one, it was necessary to understand what was integral to the lab and which portions would be necessary to maintain the usefulness of the USB lab as compared to the traditional lab. Through careful examination of the principles being studied in the *Fun with Oscilloscopes* lab, I determined that core concepts, such as understanding the meaning of the oscilloscope trace, being able to manipulate the function generator and oscilloscope to provide useful information, could be used in much the same way that they are in the original lab. This allows for students to be able to use the Board while still gaining the knowledge that they would need in order to use a traditional oscilloscope or function generator in their future studies. It was similarly found that the section of the original lab titled *Playing with Patterns* could remain useful because the modes discussed (Y-T and X-Y) were available on the Mobile Studio Desktop oscilloscope as they would be on its traditional counterpart.

While the *Using an Oscilloscope* and *Playing with Patterns* portions of the procedure were able to be converted to their new forms to interface with the new hardware and software for this project, the section called *Resistors and Capacitors* created a more difficult situation. In order to accomplish the goal of the *Resistors and Capacitors* part of the lab, it was necessary to employ a breadboard. While the breadboard is the traditional way to perform this section of the lab, it is also the easiest way to create an interface between the resistors, capacitors and the Board. By using the Help function included in Mobile Studio Desktop, it was possible to determine which analog ports (located on the upper portion of the Board in Figures 5 and 6) were linked to the output from the function generator. These ports, labeled A1+ and A1- allow the user to connect wires to the Board and to display the results on the computer screen. After connecting the wires to the Board, they are connected to the breadboard in such a way that the current being supplied by the Board runs through the resistor or capacitor that the user has selected. It is then possible for the student to observe the different phenomena that result when resistors and capacitors are connected to voltage sources.

The completed *Fun with Oscilloscopes* lab includes an introduction, explanation of alternating currents, pre-lab assignment, equipment list, procedure, and lab report. As previously discussed, the procedure contains three sections, Using an Oscilloscope, Capacitors and Resistors, and Playing with Patterns, which were the focus of this project. The complete lab is available in Appendix C.

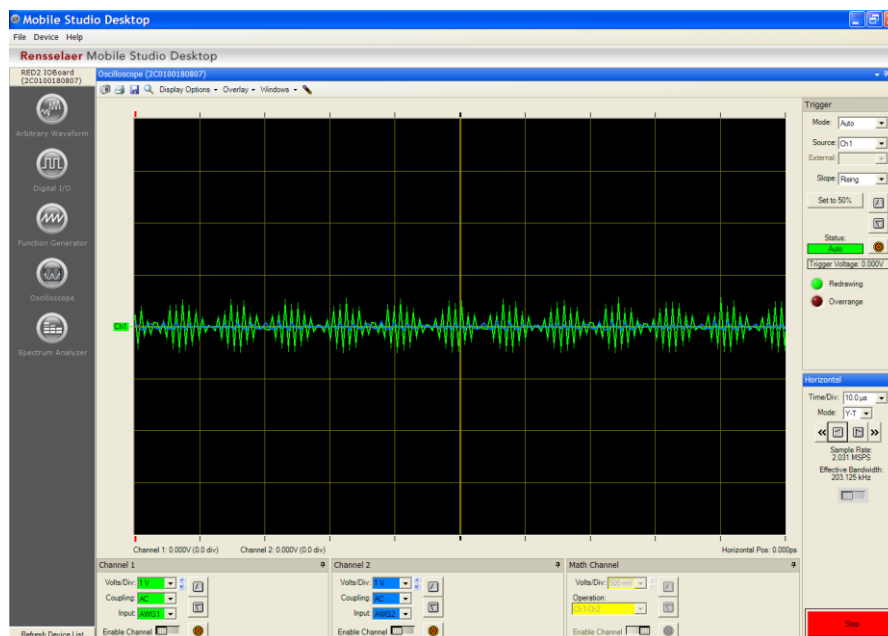


Figure 7: Oscilloscope function from Mobile Studio Desktop.

Discussion

Although a new version of *Fun with Oscilloscopes* was designed during the course of this project, it is necessary to address some other aspects that have not been previously discussed. The inclusion of the explanation of alternating current, the pre-lab and the lab report structure from the existing *Fun with Oscilloscopes* lab will be explained along with the use of the Digital I/O application in Mobile Studio Desktop. Additionally, an explanation of what will be required to determine how effectively the new lab addresses student learning will be discussed, especially with respect to the requirements for further study.

While creating an alternate version of the *Fun with Oscilloscopes* lab was the primary goal of this project, there were concessions made. For example, the procedure that was the main area of the lab that was changed with no additions to the explanation of alternation current, the pre-lab or the structure of the lab report. This was done in order to maintain the same format as well as to be sure that the lab would coincide with the

material that would be taught during the regular class period. Additionally, for future research into the effectiveness of the USB lab with respect to the current lab, the information provided in the introduction and explanation as well as the structure would remain fixed and therefore would not influence the student perception and use of the lab.

In order to understand whether or not the new lab set-up is as effective in terms of student learning as the one already in place, it will be necessary to do a comprehensive study over the course of several semesters. To do this, it will be necessary to design tests or surveys that students can take before and after each lab, gauging what information they were aware of before having completed the lab and what they learned during the course of the experiment. By comparing the data collected from students who used the new labs to that of students who completed the existing labs, it will be possible to obtain information as to how using the USB Board has affected the way that students interact with the material that they study in their introductory physics courses.

However, before it will be possible to study the effectiveness of the labs on a large scale (i.e. that of an entire class) the College will need to obtain the materials required to do so while also enlisting the assistance of researchers to conduct the lengthy study. Initially, either the institution or the students will be required to purchase USB Boards as well as the software required to use them before it can be established that the redesigned labs have had any impact on the way that students learn. Also, the College will have to recruit people who are willing to devote their time to creating surveys or tests for the study of student learning.

Because the knowledge that would be required for this type of research would not be primarily that which Physics majors would have, it would be necessary to work with

other departments, namely the Psychology department, to develop research strategies. While it would most likely be possible to enlist the effort of Allegheny College senior Psychology majors, additional oversight may be required because knowledge of physics would also be necessary when designing a way to study the manner in which student learning is effected by the new labs. Additionally, it may be necessary to study student preference for the redesigned labs with respect to the current labs. This factor would be important because if students prefer one set-up to the other, it could have some impact on how they learn, for instance, because they are more comfortable with one set-up or because one is more engaging.

References

- ¹ F. Esquembre, Computers in Physics Education, Comput. Phys. Commun. **147**, 13 (2002).
- ² J. Underwood, H. Smith, R. Luckin and G. Fitzpatrick, E-Science in the classroom – Toward viability, Comput. & Educat. **50**, 535 (2008).
- ³ Ibid.
- ⁴ D.W. Heermann and T.T. Fuhrmann, Teaching physics in the virtual university: the mechanics toolkit, Comput. Phys. Commun. **127**, 11 (2000).
- ⁵ T. Conrad and A. Schütze, A contribution for increasing the interest of high-school students for MEMS technology, engineering, and physics, Measurement **40**, 224 (2007).
- ⁶ Ibid.
- ⁷ Ibid.
- ⁸ Ibid.
- ⁹ Rensselaer Mobile Studio, <http://mobilestudio.rpi.edu/Hardware.aspx>.
- ¹⁰ *Physics 102 and 112 Lab Manual*, Allegheny College [Fall 2008].
- ¹¹ GMW Associates,
http://www.gmw.com/electromagnets/Uniform_Field/5451/5451_pricing.html.
- ¹² *Physics 120 Lab Manual, Fun with Oscilloscopes*, Allegheny College, Spring 2009.

Appendix A:

Evaluation and Redesign of Introductory Undergraduate Physics Series for Use with USB Devices

Leah Parsons and Gary Bedrosian

Introduction

Undergraduate students taking introductory physics courses face many problems in one particular aspect of their education, the required series of labs. Some examples of these issues include the time commitment, the inflexible nature of each experiment, and the lack of real world applicability. It may be that these problems not only create a tedious and uninspiring set of courses for students devoted to continuing their physics education, but also that they drive away students whose potential interest has not been cultivated. For these reasons, it is necessary to redesign a system that will both engage students and address the other problems that plague the laboratory series.

One of the options that are available to both students and the institutions that they attend is the personal computer. The fact that every student either owns or has access to a computer allows for the creation of labs that can harness the availability and simplicity of the traditional user interface. This type of interaction has the potential to allow students to have a wider variety of experiences with physics by placing the laboratory in an available, and unintimidating, environment; the students' own dorm room or their favorite computer lab. By creating physics labs that students can finish on their own time, outside of the traditional laboratory setting, it is possible to foster the interest of the student in the material of study while also preparing them for further study where laboratory sessions will be more open-ended and less supervised, making the transition to higher level learning seamless and unintimidating.

Background

Similar ideas have been discussed and consequently developed into learning systems by other groups. One such group specifically focused on the high school setting and creating a set-up that revealed the real world uses of physics study. Using Micro-Electrical-Mechanical Systems (MEMS) to create laboratory setting which mimicked realistic uses for physics knowledge was the goal of a research initiative funded by the German Federal Ministry for Education and Research which created and implemented a computer based system which could be brought into classrooms for use by students. The system, called VenDASys, and its software, called LabView, was designed to be used with any computer that was equipped with a USB port, making them almost universally acceptable to computers that are currently available to students. The system itself relates to the material of study by using sensors that are able to be used for more than one purpose. This allows students and educators to reduce the amount of equipment used for an entire lab series into a few basic components, creating a more manageable situation.

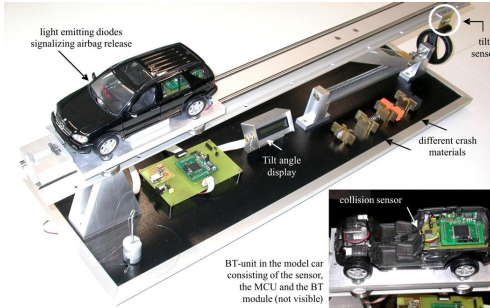


Figure 1: The acceleration set-up from VenDASys represents a realistic use for accelerometers.

One of the set-ups that were discussed in some depth in the paper featured an accelerometer and its potential uses outside of the lab. By placing a sensor set-up as an accelerometer into a toy car fitted with an LED which interfaced with the sensor, it was possible for students to see how an accelerometer could be used in a vehicle to determine whether an airbag should be deployed (Figure 1). By using change in acceleration to determine this, a simple physical concept is given a real world application, transforming it from being simply an abstract concept and instead into a useful idea that could possibly serve the student in a future career as an automotive engineer.

Instrumentation

A MEMS system created at Rensselaer Polytechnic Institute (Figure 2), which interfaces with a computer via USB port, and software designed to work with it, called Mobile Studio Desktop (Figure 3), will be used to update physics labs. Other materials that will be used include the personal computers of the students and various materials for individual lab sessions including transistors, etc.

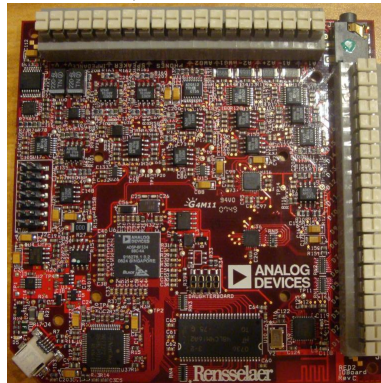


Figure 2: The USB device designed by Rensselaer Polytechnic Institute will be used in this project. The USB cable connects in the lower left corner.

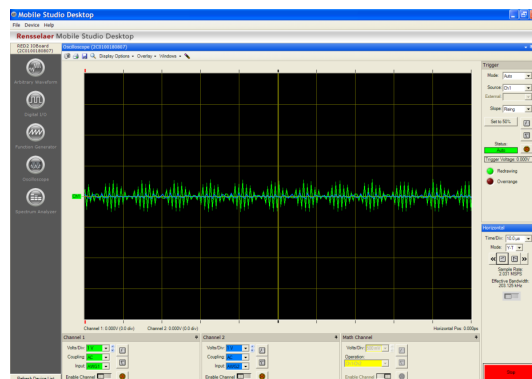


Figure 3: Oscilloscope function from Mobile Studio Desktop.

Completed Work

In order to work within the constraints of the introductory physics laboratory series at Allegheny College, it was first necessary to become acquainted with the materials involved. To accomplish this, time was spent accessing the various functions of the Mobile Studio Desktop. It was expected that by better understanding the manner in which different functions operated it would be possible to create more effective and fulfilling laboratory sessions. This is because by understanding the user interface, where students would actually be observing the results of their experimentation, an opportunity for creating more effective educational vehicle.

The first accomplishment of this project was a comprehensive study of the secondary laboratory courses in the introductory series. This consisted of two separate courses, one meant for students who intended to major in physics and another for those who did not. By studying the current laboratory procedures, it was possible to distill the topics of study that were most important to the courses and the professors who taught them. The isolation of these subjects allowed for new laboratory sessions to be designed by instilling the same subject matter into the new set-ups and procedures.

Initially, the course for non-majors was used because the study in this course was at a more basic level and it would be an ideal test case because fewer factors would have to be considered in its creation. The experiment that was chosen initially dealt with alternating and direct currents and used a function generator. By connecting the USB board to a computer, it is supplied with power and the Mobile Studio Desktop is equipped with a function generator. Because these aspects of the lab were already in place, it was possible to create a basic laboratory procedure. A procedure was created, including background information and equipment list, in order to replicate the previous lab.

Currently, a similar process is occurring for the course designed for physics majors. The equivalent lab, called 'Fun with Oscilloscopes,' has been reduced to its basic principles and goals and has been revamped in order to attain a similar level of ease of operation as the simpler lab. In this lab, students are asked to explore the uses of the oscilloscope and function generator that are included in the Mobile Studio Desktop software that works with the USB Board. Within this exploration, they are directed toward understanding the relationship between frequency and time between cycles as well as how their manipulations of various parameters affect the behavior of their trace. Additionally, they are given the opportunity to study the different operational modes of the oscilloscope. While it has yet to be completed, the lab is also going to include

portions that involve students using both capacitors and transistors with the Board in order to understand the ways in which these additional components affect both the flow of electricity and the visible trace.

Conclusion

Although testing of the laboratory series as designed has yet to be completed, parts of the testing are in place. There is currently a trial of the oscilloscope and alternating current lab in place for early April 2009. During this period, students will be introduced to the board and its interactions with the computer for the first time. While there are not currently enough boards for all the students, by gauging the response of the class it will be possible to determine whether or not the project is worth pursuing further. In the event that it is, students in the following semesters will continue to work on physics education research in order to better develop the program and to allow it to become fully integrated into the Allegheny College physics curriculum.

While developing the labs and the program further is a major concern, it will also be necessary to complete studies about whether the proposed lab designs are significantly more effective in helping students learn than the current labs. A joint effort with the psychology department would be ideal in order to study the way that learning processes are affected and involved in scientific learning as well as in the way that students become engaged in their learning. With this effort, it will be possible to understand the student interaction with physics on a more complete level as well as to work toward improving the lab set-ups that they work with in order to maximize student interest and learning while also creating an environment in which faculty can collaborate with their students to best suite undergraduate learning.

Sources

- MEMS Exchange, <http://www.memsnet.org/mems/what-is.html>.
- *Physics 102 and 112 Lab Manual*, Allegheny College (Fall 2008).
- *Physics 120 Lab Manual*, Allegheny College (Spring 2009).
- T. Conrad and A. Schütze, A contribution for increasing the interest of high-school students for MEMS technology, engineering, and physics, *Measurement* **40**, 224 (2007).

Appendix B:

AC Signals

Introduction:

The purpose of this experiment is to become familiar with the Rensselaer USB board and accompanying software as well as AC signals.

Background:

Alternating current (AC) is commonly used throughout the world because it can be efficiently transferred from one location to another. However, alternating current cannot be used to power devices and must instead be converted to direct current (DC). For example, the boxes-like structures that are built into the power cables for notebook computers are AC to DC converters.

Equipment:

- Rensselaer USB Board
- Mobile Studio Desktop (Oscilloscope & Function Generator)
- AC Source
- Connectors/Cables

Appendix C:

Fun with Oscilloscopes

Introduction

During this lab, you will become familiar with the RPI USB board and the functions of the Mobile Studio Desktop software. Additionally, you will gain knowledge of alternating currents through experience.

Alternating Currents

Our discussion of circuits was focused on circuits where the voltage sources always supplied a voltage that did not change in time, i.e. a *constant voltage*. As a result, the *current* flowing in the circuit was also *constant*. Such circuits are called *Direct Current (DC) circuits*. An Alternating Current (AC) is a current that varies in time, usually in a sinusoidal fashion. Such currents are produced by an AC source that supplies a sinusoidal voltage.

Symbol for an AC voltage source: 

The time behavior of an AC voltage is given by:

$$v(t) = V \cos \omega t$$

where

V = amplitude

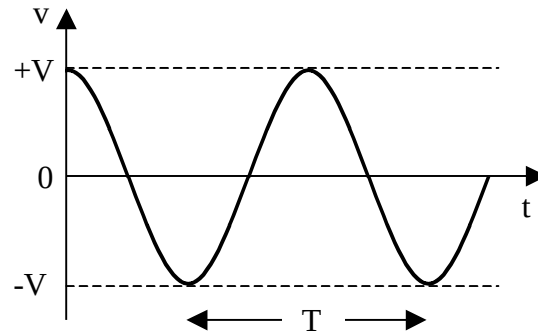
$$\omega = 2\pi f = \frac{2\pi}{T}$$

f = frequency of the voltage source

T = period

N.B.: time-varying voltages and currents are represented by lowercase letters: e.g. a time-varying voltage is given by $v(t)$ and a time-varying current by $i(t)$.

We can plot $v(t)$ vs. time to get the following graph:



The peak-to-peak reading on the voltage axis is equal to $V_{pp} = 2 \times V$, giving us the value of the amplitude of the voltage, and the peak-to-peak reading on the time axis is equal to the period of the signal: $t_{pp} = T$.

This voltage can be displayed on an *oscilloscope* to directly get the amplitude and period of the voltage source. Such a voltage can be generated by a *function generator*. *Please consult the extra handout to learn more about the operation of these two devices.*

RMS Voltage: when measuring a voltage using an AC meter, we always measure the root-mean-square (rms) value. The rms value of the voltage is related to the voltage amplitude by:

$$V_{rms} = \frac{V}{\sqrt{2}}$$

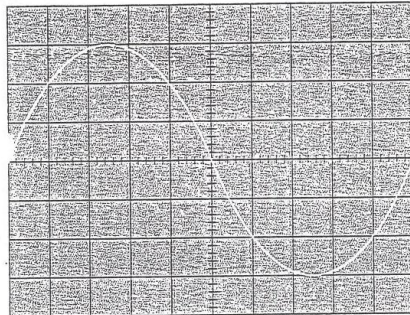
In the same way, the rms value of an AC current is given by: $I_{rms} = \frac{I}{\sqrt{2}}$.

Pre-Lab Assignment

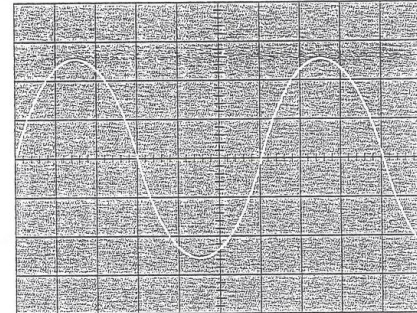
Name: _____

Please read the handout on oscilloscopes before attempting this assignment.

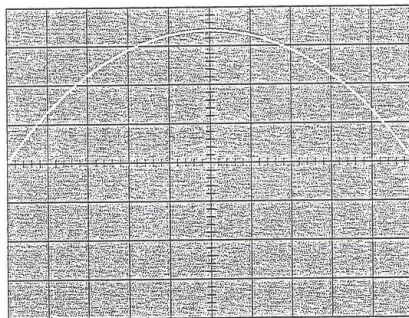
Determine the amplitude, period and frequency for each of the AC signals from the oscilloscope displays shown below:



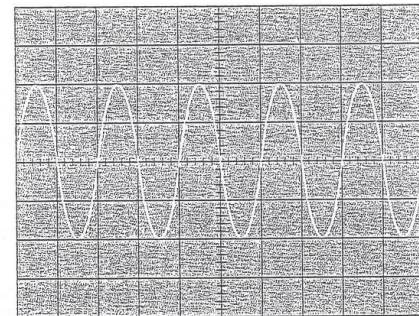
(a) VOLTS/DIV = 0.5 V
SEC/DIV = 2 ms



(b) VOLTS/DIV = 50 mV
SEC/DIV = 0.1 ms



(c) VOLTS/DIV = 2 V
SEC/DIV = 10 μ s



(d) VOLTS/DIV = 5 V
SEC/DIV = 2 μ s

(a) V = _____
T = _____
f = _____

(b) V = _____
T = _____
f = _____

(c) V = _____
T = _____
f = _____

(d) V = _____
T = _____
f = _____

Pledge: _____

Equipment:

Mobile Desktop Studio software (Oscilloscope, Function Generator, analog)
 RPI Board
 USB Cord
 Capacitors
 Resistors
 Breadboard
 Wires

Procedure

Part 1: Using an Oscilloscope

1. Attach your Board to a USB port using the USB cable.
2. Open Mobile Studio Desktop and the Oscilloscope
 - a. Channel controls will be in the lower portion of the screen. These can be used to adjust the scale of the divisions (Volts/Div) on the oscilloscope output as well as the type of current being supplied (Coupling) and the input that is being read (Input). Channels must be enabled for the output to be displayed.

On the right side of the screen, other controls are available. The Trigger window allows you to select which source(s) you would like to have displayed (Source) and what type of display you would like (Mode). In this case, choose Auto under Mode.

The control panel labeled Horizontal allows you to change the scale of the horizontal axis using the Time/Div bar.

- b. Choose Channel 1 as your input and enable this channel, also chose it as your source on the Trigger panel. After pressing start and stop, adjust your divisions (Volts/Div and Time/Div) so that a trace is displayed, it will be shown in green. **What parameters did you set to see this trace? What do you think this represents?**
3. Open the Function Generator application in the Mobile Studio Desktop.
 - a. This is the tool that was creating the function that you observed in step 2b. **Do the settings that are displayed in the Function Generator seem reasonable for what you observed? Why or why not?**
 - b. Using the available panel, adjust the frequency of Channel 1 to the frequency of your choosing and adjust the peak-to-peak amplitude (labeled Pk-Pk on the function generator). Once again, adjust the scales on the oscilloscope so that when you press start, a function is displayed. Use the horizontal scale to determine the frequency of the function and the vertical scale to determine its peak-to-peak voltage. **Are these values the same as what you set in the function generator? What could account for any discrepancies?**

4. Keeping the peak-to-peak voltage the same, vary the frequency. **What do you observe? What is the relation of the frequency to the amount of time between the peaks? What do the units of frequency have to do with this relationship?**

Part 2: Capacitors and Resistors

1. Locate the input and output ports on the upper edge (considering the USB connection in the lower left hand corner) of the Board. Use wire to connect to ports AWG1 and $\perp$ which can be located by reading the markers along the row of ports. AWG1 will be the output from the function generator and $\perp$ will be the negative terminal.
2. Open the oscilloscope window and adjust the controls so that the Channel 1 controls accept input from AWG1 which will allow the oscilloscope to display the information that is filtered through the breadboard.
3. Attach the resistor to the breadboard so that the prongs are inserted into two different columns. Next, attach the connector wires from the board so that one is in each of the two columns which are attached to the prongs of the resistor.
4. Set the frequency to 10 Hz and observe the pattern displayed on the oscilloscope set to detect DC (direct current). **What similarities and differences do you observe with respect to the patterns from the *Using an Oscilloscope* section?**
5. Replace the resistor with a capacitor and repeat the observation. If there is no reading, reverse the capacitor so that its prongs switch places. **What similarities and differences do you observe with respect to the patterns from the *Using an Oscilloscope* section?**
6. Next, attach the resistor and capacitor in series (so that one wire coming from the Board is in the same column as the first of the resistor's prongs, the second prong of the resistor is in the same column as the first of the capacitor's, and the second prong of the capacitor is in the same column as the second wire to the Board).
7. Observe the output from the oscilloscope. **Report the peak wave value as V_p .**
8. Observe at what time division this peak takes place, this will be time zero.
9. Divide V_p by e ($= 2.718$) to find V_τ , **record this value. At what time does the voltage drop to this value after the peak? Record this time as τ .** To do this, use the time divisions as markers and V_p as the zero point.
10. Estimate the uncertainty based on how well you can read the scope output. **Record the uncertainty.**
11. **What do you expect would happen if you were to increase and decrease the capacitance? What about the resistance?**
12. Choose whether you want to hold the resistance or the capacitance constant and repeat your observations while changing your variable quantity. **Are the results consistent with your predictions? How does varying this quantity change τ ?**
13. Now vary the other quantity and repeat the observations. **Are the results consistent with your predictions? How does varying this quantity change τ ?**
14. **What values of resistance and capacitance will give you the same results as your initial trial?**
15. Predict that value of τ for a capacitance and resistance that you did not try together. **Record the prediction** before trying the resistor and capacitor together.

What is the actual value for τ ?

Part 3: Playing with Patterns

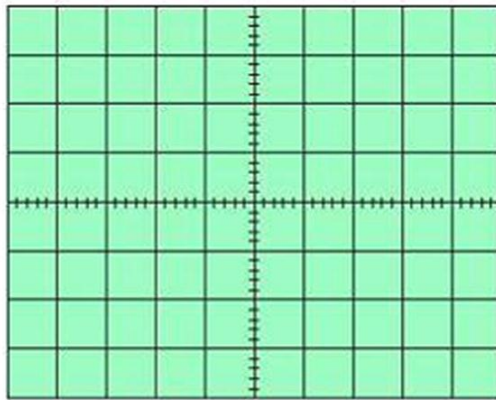
1. In the Oscilloscope pane, change the Horizontal mode from Y-T to X-Y. Make sure that the function generator is in units of Hz and adjust it to 100 Hz. **What is different about this display? Sketch the display and explain why it is different from the previous display of the functions.**

Lab Report

Names: _____

Part I

1. (b) Oscilloscope trace:



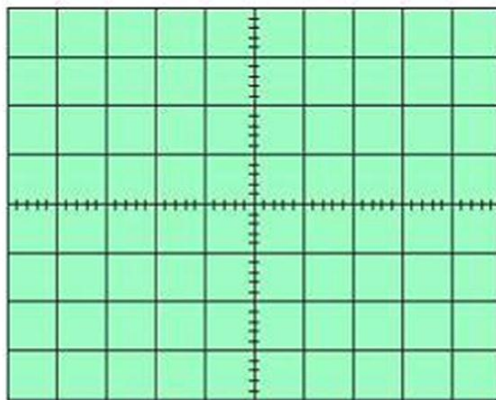
Settings:

VOLTS/DIV = _____

SEC/DIV = _____

Voltage = _____

2. Oscilloscope Trace



Settings:

VOLTS/DIV = _____

SEC/DIV = _____

f = _____ (oscilloscope)

f = _____ (freq. counter)

3. V = _____ (amplitude)

V_{pp} = _____

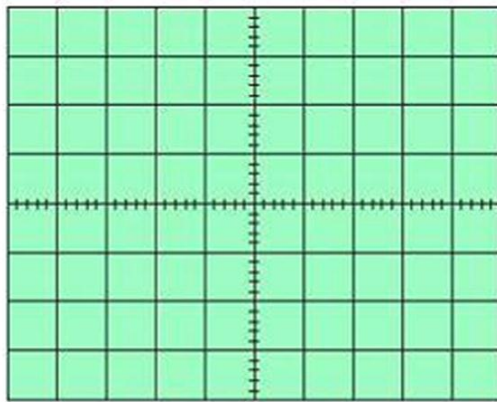
V = _____ (DMM)

Discrepancy (explain):

4. Observations:

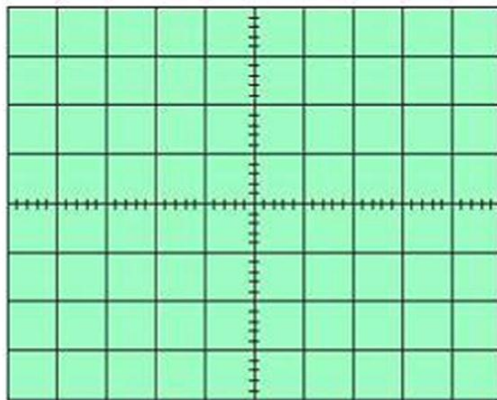
Part II:

1. Observation of oscilloscope trace with resistor:



2. Similarities and differences to *Using an Oscilloscope*:

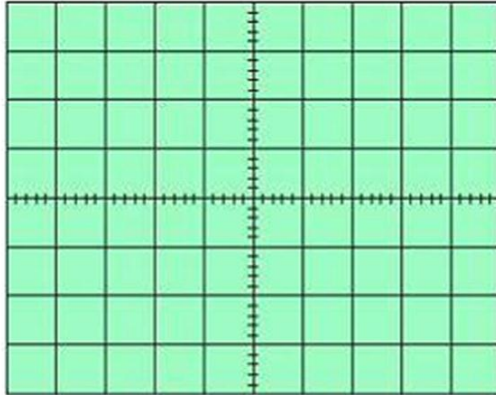
3. Observation of oscilloscope trace with capacitor:



4. Similarities and differences to *Using an Oscilloscope*:
5. As you increase the capacitance leaving the resistance unchanged what happens to the time τ ?
6. As you increase resistance the leaving the capacitance unchanged what happens to the time τ ?
7. Do any combinations of R and C give the same time τ ?
8. Prediction for τ with R= _____ k Ω and C= _____ μ F.
9. Measured τ with R= _____ k Ω and C= _____ μ F.

Part III:

1. Oscilloscope trace:



Explanation: