2011

Scaffolding with video prior to sophomore physics lab: The addition and resolution of vectors

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Recommended Citation

Sitar, David J., "Scaffolding with video prior to sophomore physics lab: The addition and resolution of vectors" (2011). *Master's Theses and Doctoral Dissertations*. 341.
http://commons.emich.edu/theses/341

Scaffolding with Video Prior to Sophomore Physics Lab: *The Addition and Resolution of Vectors*

by
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Thesis

Submitted to the Department of Physics and Astronomy
Eastern Michigan University

in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE
in
General Science
Concentration: Natural Science Education

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June 10, 2011
Ypsilanti, Michigan

DEDICATION

In memory of Robert Justin –

you are missed and remembered….

ACKNOWLEDGEMENTS

My loving wife; Shelley Sitar and my family, for their patience and support

Norbert Vance, for his friendship and sharing his knowledge of the night sky with me

Department of Physics and Astronomy, for the education and support

The Graduate School's staff

Committee Members, for their guidance and time

The Astronomy Club at EMU, good friends at a great location

Thomas Cocco, for his help with video editing and media technologies

Cynthia Marlatt, for all her help with uploading and keeping track of the online video files

and lastly, the Grateful Dead – "…nothing left to do but smile, smile, smile…"

ABSTRACT

This work examines the efficacy of pre-lab video tutorials for the sophomore physics labs offered by the Department of Physics and Astronomy at Eastern Michigan University. In particular, investigation involves Lab 3 "*The Addition and Resolution of Vectors.*" Students, in tangent with the PHY221/223 Mechanics, Sound, and Heat lecture, take a lab course. Past results show that students often do not complete the pre-lab assignment before coming to Lab 3. Online tutorials for an experimental group were designed for students to view two days before the assignment was due. Results and student comments support the belief that that the videos were helpful in explaining content. Our conclusion is that these free online tutorials should be considered in the future of this lab across all sections.

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Introduction

Laboratory components of university science courses provide essential learning opportunities where students can engage in the science they are learning about in class using the tools of science. Much of the purpose of such labs is to provide students the opportunity for hands-on engagement with such tools to better understand science principles as well as the endeavor of science. However, time in the lab is limited. Preparing for the lab prior to the experiment itself could increase the efficiency of instruction while allowing the students to spend more time investigating the science using the tools, rather than being bogged down in the technical aspect of the laboratory. As the tools become trickier to use, preparation becomes even more important. An example of such a lab would be an examination of the vector nature of forces in a typical introductory physics course using a force table. Traditionally, students might read the lab assignment before class. However, with the availability of other media, I suggest that video might provide more specific support to prepare the students for the upcoming lab.

Background and Literature Review

Over the past two years I have observed that students struggled with the pre-lab assignment for the composition of forces lab in our PHY221/223 (Lab 3, see Appendix F). I felt that, as an educator, an intervention was necessary and scaffolding was the way to go. According to Anita Woolfolk, "Scaffolding is to support learning and problem solving. The support could be clues, reminders, encouragement, breaking the problem down into steps, providing an example, or anything else that allows the student to grow in independence as a learner" (2004, pp. 50-51). I believe that the use of video will support student learning and will provide an example to enhance student lab results and understanding. The impact of scaffolding with video will not only help directly with the vector addition pre-lab, but will also better prepare students

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for the lab write-up. "Current research in physics education focuses on developing techniques that actively engage students in their own learning" (Lloyd, 2000, pp. 365). By having the students view the videos as part of their pre-lab activity the students will be more engaged in the actual mechanics of setting up the lab and be more prepared for instruction.

Research about scaffolding lessons in the classroom is evident, such as modeling how to do an activity. The difference with my approach is that the modeling can also be done outside the classroom with the use of video, which is a new way of thinking and may be equally effective as the traditional way. Brunvand and Fishman stress the usefulness of video in supporting teachers before teaching a given activity or concept in a classroom (2006). This is not dissimilar to preparing students to do a lab. Both are preparing the observer to take action using the tools presented in the video. Moreover, Bates and Poole found it useful to distinguish the five primary educational media as "direct face-to-face, text, audio, video, and digital multimedia" (2003, p. 53). Incorporating a variety of strategies in instruction, we increase the opportunity for student learning. Installing a variety of these five elements into pre-lab videos should result in outcomes such as better understanding of how to set up equipment during lab and how to use the equipment to solve problems. This is a great opportunity to increase the integrity of the lab and student achievement (Yager, 1996). This is a great opportunity to increase the integrity of the lab and student achievement. Thus, in addition to having written lab materials, having videos available might provide more support.

Providing students with additional resources for supporting their lab is one approach to improving instruction. But how might students utilize these videos? Would these be useful? In order to study the impact of having videos supporting laboratory, I examine the following research questions:

1. What are the impacts of having tutorial videos available on student learning?
    a. Does the addition of support videos produce better lab scores?
    b. Do students gain a better understanding of what is expected of them in the pre-lab?
2. Do students value the use of video?
    a. Are students motivated to use the video?
    b. Do students find the video helpful?

In order to examine these questions in depth, I identified a laboratory that required the students to do a pre-lab component and included challenging content and set-up. The *Addition and Resolution of Vectors* lab has two procedures/activities that students must perform outside of the laboratory. This pre-lab portion is worth one point, or 8.3% of the student's grade on this report, which is addressed on the rubric (see Appendix G); successful completion of this activity has to be shown to student's lab instructor in the first ten minutes prior to lab beginning. In past discussions at graduate student meetings, led by Professor Diane Jacobs, graduate students discussed a concern about students not being prepared to do Lab 3 upon entrance into this lab, despite the fact that the pre-lab component was required. Students did not seem to have the prior knowledge to perform the task, possibly because they had not reached the topic of vectors in lecture, or perhaps they just did not care enough to take the time to engage in the pre-lab exercises. Focusing on these problems is a never-ending process.

One of our goals as instructors is to motivate students to become engaged in this way, and an important step is to get the students to do the pre-lab activities. Students are more likely to become engaged if they see value in what they are doing. Videos supporting the lab are one way to accomplish this. With the aid of videos, students will now have an opportunity to see what is being asked of them in order to meet the pre-lab requirements. These videos were available to students online two days before their lab date, so they could watch them on their own time and have ample time to complete the pre-lab assignment. The intent of the videos supporting the lab set-up is to provide students with information that will help them mechanically complete the lab. This will improve the lab experience, which ultimately would motivate the students to do future pre-labs. In addition, the Lab 3 videos also guide students to a better understanding of how to construct vectors via the *Parallelogram Method* and how to calculate vectors using the *Analytic Method.* These videos were available to the comparison group through their emich.edu accounts and they could view them in a YouTube video.

Lab grades for this particular lab have been observed as generally low, which in turn frustrates the students not only in lab, but also with physics in general. Another observed issue is students do not have the background information regarding vectors so it takes them a long time to complete the experiment. One reason for this challenge is that their pre-labs are not complete and they struggle with the force table apparatus used in the *Experimental Method* portion. Therefore, this issue is threefold: 1) students' grades reflect lower scores because of the missed points from the pre-lab, 2) students have difficulty with the content, and 3) there is a lack of student engagement. So, by installing on-screen text, tutorials, examples, and different interactions that provide students with the essential vocabulary and the "how to use" the equipment, students will have a higher degree of success (Brunvand and Fishman, 2006).

Justification and Significance

Studies have shown that scaffolding subject matter leads to stronger student success (Woolfolk, 2004). I have used video in the classroom in the past and found it to be useful. For example, during a chemistry course I made three different videos and posted them online through EMU i-Tunes to help students with calculator use, lab safety, and how to properly use a pipette.

These videos are now used in the College of Arts and Sciences to help identify lab safety protocols in chemistry courses and by the College of Education to have students evaluate the efficacy of the tutorials (http://www.emich.edu/itunesu/index.html). I believe that by incorporating videos in a systematic way I can improve lab instruction as a whole. In this research study, I examine the specific impact of such an intervention. This is a study of the impact of having additional resources in the form of videos available to assist students in preparing for lab and not a study of the specific characteristics of the videos themselves. [1]

First, in the Methods section, I discuss the experimental methodology used to conduct the research and describe the analytical technique used to empirically examine the research questions discussed above. Next, I describe the data collected for the study. In the Results section, I describe the findings of conducting the analysis to answer the research questions above. Finally, in the Discussion section, I synthesize the results from the research questions on laboratory practice and future research.

Method

I first got permission from the Eastern Michigan University's (EMU) Institutional Review Board (IRB; see Appendix A and B). Since I was using undergraduate physics students as my subjects, it was only ethical that I do so and was University protocol. The consent forms and questionnaires can be found in Appendix C and D.

To establish the comparison and control groups for this study, I semi-randomly assigned the lab sections that had access to the videos and those that did not. To avoid personal bias, the

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[1] One of the major challenges of this type of research is the fidelity of implementation (meaning we do not know who is watching what part of the video and when: exposure or participant's responsiveness (Dane & Schneider, 1998)). That is why the claims are limited to students who had the option of watching the videos.

sections that I taught did not have access to the videos, thus assignment was not completely random. Without my students having access, I avoided biasing the students to say the videos were useful. Since all TA's plan and work together putting a great deal of effort towards using a common grading rubric, created by Prof. Jacobs, the labs are graded consistently. The videos were filmed on the campus of EMU using an HD Flip Camera, and all of the equipment used by the students is present in the videos, along with an explanation about how to use each of the items. Students could watch the videos as many times as they wanted between the second and third lab[2], but only needed to watch once while they do their pre-lab assignment.

Video 1 – Procedure A: The Parallelogram Method

- Time: 7 minutes and 24 seconds
- This video highlights the terms used in the lab and how to construct the Parallelogram Method from the data given.

Video 2 – Procedure B: The Analytical Method

- Time: 7 minutes and 50 seconds
- Students can see how to step by step calculate the magnitude and direction of the resultant force.

Video 3 – Procedure C: The Experimental Method

- Time: 8 minutes and 49 seconds
- The last video discusses the use of the equipment that will be used in Lab 3.

Each of the three videos lasts about seven to eight minutes, so total viewing time is approximately twenty-three minutes and is accessible from the physics lab's website

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[2] During traditional Fall and Winter semesters, this might be a week since labs met once a week. During Spring and Summer semesters this could be two day to five days, since labs met twice a week, such as Monday and Wednesday.

(www.emich.edu/physics/course_labs/phy2xx/index.php) using any Internet capable device. Spier remarks, "With the advent of computers there has been a shift from traditionally stable organizational structures towards more flexible working arrangements" (2002, p. 167).

Data were gathered and analyzed to see if this approach was beneficial to both the sophomore physics lab and to the students; the outcomes are discussed below. An assessment in the form of a survey was administered to see how many students used the videos, if the videos were effective, and if students felt the videos were a benefit to them.

The videos were available to the lab students for two days (videos can be found for viewing in the back of this paper). The time to gather our data took one week, and this timeframe took into account the grading that had to be done by the other lab-teaching assistants (TA's). From the start of the research (allowing students to access the videos and gathering the consent forms) to the end (grading the labs) took approximately one week. For a complete description of the video, please see Appendix E.

Quantitative and Qualitative Methodology

I compiled data and comments among eight different lab sections – a comparison group of four sections had access to the videos and the control group of four sections did not. The lab seats up to 18 students, and 110 students participated in the study: 56 who had access to the videos and 54 who did not have access to the videos (Table 1). Students did have the right not to participate without penalty, and those who were under eighteen years of age could not participate. Of those students, 51 from each condition completed the survey. All data were collected during the spring 2011 semester.

Table 1

Participants (2011) N=110

	NUMBER OF STUDENTS	NUMBER OF SECTIONS
CONTROL	54	4
COMPARISON	56	4

Data

Pre-lab Scores

The lab instructors recorded just the students' pre-lab activities as part of the lab assignments to determine if students who had the opportunity to watch the videos were more likely to complete the pre-lab assignment and if the quality of the pre-lab assignment varied (completed, partial, or no pre-lab).

Student Survey

Once students completed the lab and report, they answered a survey. The survey for those who had access to the videos examined the students' perception of the efficacy of the videos and if the students found them helpful. The control group also completed a survey to determine if they thought the use of a video would have been helpful to them in the completion of the pre-lab assignment and in understanding of the content.

Video Usage

I collected data on the number of hits to the video to look at the distribution of students using the various videos.

Lab Scores

I collected anonymous lab score data for each section for each of the three labs: labs 1 and 2 to determine if the control and comparison groups were equivalent, and Lab 3 to look at student learning.

Analysis

First, I examined the claim that we had equivalent groups. Although the assignment to the control and comparison conditions was random (with the caveat that my sections did not get the comparison), students' self-selection into each section was not. Therefore, to test the premise that the conditions were equivalent, I conducted an unpaired sample T-test comparing the total score of the first two labs between the two groups. I included only those students who completed all three labs to avoid the exaggerated impact of "0" on the lab on the data. I then controlled for the lab scores for Labs 1 and 2 and tested for statistical significance.

What are the Impacts of the Tutorial Videos on Student Learning?

Do the videos produce better lab scores? To study the impact of having the video available as part of the pre-lab, first I examined the impact on students learning as represented by their lab grade. In order to do this, I collected the lab scores of the students and conducted a pair sample T-test to determine if there is a statistically significant difference between the control and the comparison groups. This was done using PASW, a new version of SPSS.

Do students gain a better understanding of what is expected of them in the pre-lab? I quantitatively analyzed the students' pre-lab component of the lab comparing comparison and control groups using Mann-Whitney Rank Sum test for ordinal data. Students earned a 3 for a completed pre-lab, 2 for partial and 1 for no pre-lab. This was done using PASW, a new version of SPSS. I also quantitatively compared students' answers to survey Question 3 (Q3) and qualitatively analyzed the survey comments of the students in the control and comparison groups.

Do Students Value the Use of Video?

I used the survey to examine students' value of video. I calculated the percentage of students who reported using the videos and whether they found them of value. In addition, I surveyed the control students to determine if they thought a video would be a valuable additional resource. This research identified if students had the prior knowledge to complete the pre-lab or if they had an idea of what was being asked of them to even complete the activity.

Are students motivated to use the video? Students in the comparison group were given the option of using the videos to help them with the pre-lab, but it was not required. Thus choosing to view the video represents motivation, which shows initial expectations of value. To examine this question, I turn to the answer to Question 4 on the survey data. I also look at the log data from the video viewing to see if there is a difference between students use of the various videos.

Do students find the video helpful? To investigate this question, I turn to Question 5 (Q5) on the survey to find the percentage of students who report finding the video helpful, and also to the comments on the survey (Table 6).

Results

First, I tested the assertion that the control and comparison groups were equivalent by comparing the scores of each group on the prior lab. The mean score for the sum of the first two labs for the control group was 12.9 (standard deviation 2.7), and the mean score for the comparison group was 12.9 (standard deviation 2.3); these values are not statistically significantly different using an unpaired sample T-test. These numbers suggest that the groups are equivalent based on the results using the common grading rubrics used to grade labs by the teaching assistants.

I then examined the pre-existing/background knowledge of the students coming into the class. Table 2 shows the survey results. Question 1 (Q1) from the survey asks students to circle yes or no to indicate if their lecture section had reached the topic of vectors prior to lab. Question 2 (Q2) asked students if they knew a pre-lab activity was due at the beginning of the lab, and once again, circle yes or no. Question 3 (Q3) asked students if they were familiar with the vocabulary used in the pre-lab assignment and to circle yes or no. The last item on the survey was for students to make any comments they had about the pre-lab.

In Tables 2 and 6, Q1 shows that nearly all the students in all sections had reached the topic of vectors in class. Q2 shows that nearly all students knew they were required to do a pre-lab. This was an expected result because students see a note posted on the chalkboard the week before Lab 3, it is presented in the lab manual at the end Lab 2, and a mass email is sent to the students the week prior to the lab. Q3 shows that most students were familiar with the vocabulary used in the lab manual. In each case, there was no significant difference between the control and comparison groups in this area. Students coming into the class had sufficient background to complete the lab in both groups and were aware that they needed to prepare for the lab before class. Now I address the research questions specifically.

Table 2

*Survey data from control/comparison groups (n=51)**

Question	Control (answered yes) n= 51	Comparison (answered yes) n= 51
Q1 - Vectors reached in class	49	49
Q2 – Knowledge of pre-lab	49	51
Q3 – Familiar with vocabulary	47	50
Comments	14	29

*51 students were available the beginning of the following lab to complete the survey.

What are the Impacts of the Tutorial Videos on Student Learning?

Do the videos produce better lab scores? In order to investigate the impact on students' learning, I compared the lab report scores, including the pre-lab points, to determine if there was a statistically significant difference between the control and comparison condition. Analysis of the data shows there was no statistically significant difference in the Lab 3 scores between the control and comparison groups (at $p<0.05$ level). Initially this is cause for concern, because one of the goals of the video was to improve student learning, but what this suggests is that maybe students in these isolated instances are still learning to create the lab reports, and that skill set is bounded by their knowledge of the content, ability to write lab reports, and motivation. In hindsight, the instructional practice was consistent across conditions, so change in scores might not be expected. Another possibility is that 61% of the students watched the video, which may not be enough to find a measurable difference in the learning of the comparison group as a whole.

Although the students who used the videos did not get better overall lab scores, the data collected in Table 3 do show that those students who did have access had greater success in completing the pre-lab assignment. Moreover, I believe that this does show that the instructional practice of using video tutorials could be an effective teaching and learning tool, but without change in practice the lab score might not measure this impact.

Do students gain a better understanding of what is expected of them in the pre-lab?

Students' pre-labs were collected and recorded (Table 3). Making the no credit column equal to 1, partial credit equal to 2, and full credit equal to 3, I compared the pre-labs of the students in the control and comparison group on the specific pre-lab component of the lab scores (Lab 3) using a Mann-Whitney test.

Table 3

Credit distributions between groups

Comparison groups

Section A	No	Partial	Full
	0	1	15

Section B	No	Partial	Full
	0	1	12

Section C	No	Partial	Full
	0	0	12

Section D	No	Partial	Full
	1	2	12

Control Groups

Section E	No	Partial	Full
	2	3	11

Section F	No	Partial	Full
	2	3	9

Section G	No	Partial	Full
	2	4	3

Section H	No	Partial	Full
	0	3	12

The mean is 2.93 for the comparison group and 2.53 for the control group. I determined that students in the comparison group were much more likely to do the pre-lab ($p<0.001$). Thus, students who had the option of viewing the video were much more likely to complete the pre-lab assignment (see Table 4).

Table 4

Descriptive statistics for pre-lab portion of the study (2011)

	Group	N	Mean	Std. Deviation	Std. Error Mean
Score*	Comparison	55	2.93	0.262	0.035
	Control	53	2.53	0.696	0.096

*$p < 0.001$

Do Students Value the Use of Video?

In addition to Questions 1-3 discussed above, I added two more questions to the comparison group survey. Question 4 (Q4) was investigating if students had watched and used the video tutorials to guide them through the procedures. Question 5 (Q5) asked if they circled yes to Q4, then did they find the videos helpful and to explain.

Are students motivated to use the video? The results show that just 61% of the comparison group actually used the video tutorials. This is not a great number to draw conclusions from, all of those who did access the videos found them helpful (Table 6). The comments are positive, and I strongly believe that if lab partners reported that the videos were helpful, then their peers would view them or more students might consider viewing future videos if they were part of other labs. The value of the videos for those who watched them is clear. The next step is to find a way to motivate more students to watch the video. One approach might be to make it required as part of the pre-lab assignment.

Do students find the video helpful? Based on log data, many of the 31 students who watched the videos went back to them numerous times to complete the pre-lab. However, fewer students watched the video for Procedure C, and one could also infer that the videos were too long and the students lost interest.

Table 5

Student use of videos

Proc. A	Proc. B	Proc. C
69	48	36

For Q4, 61% of the students who had access to the videos watched and used the videos to guide them through the pre-lab assignment (See Table 6). Of the 61% who answered yes on Q4, all of those students said that the videos were helpful. As for the 61% who said the videos were helpful, 57% of them gave insightful comments to support my research question and hypothesis; this is solid evidence of positive reinforcement. There were two "not applicable" answers for Question 4 because no answers were given for this question.

Table 6

Survey data from comparison group (n=51)

	Yes	No	No feedback	Not applicable
Q4	31	18	0	2
Q5	31	4	14	2
Comments	29	0	17	5

Students were prompted in the survey to comment on Question 5 (Q5), which asks students who if answered yes on (Q4) to explain why they found the videos helpful. Although students stated from Questions 1-3 that they were familiar with the content, based on comments from the control group, coverage and confidence do not appear to be the same thing. Students stated that they wished they had more support using the methods taught. Here are several of the 14 comments made by students who did not receive the intervention (control group):

- “Had a hard time doing the Parallelogram Method since no tutorial was given.”
- “Lab manual could’ve been worded better and shown more detail on how to do the Parallelogram Method.”
- “Make the vocabulary more straight forward.”
- “I wished I had an example to let me know if I was doing it correctly.”
- “The pre-lab was difficult to grasp.”
- “The example of the Parallelogram Method was confusing.”
- “The explanation of the Graphical Method was very hard to understand.”

The videos appeared to have an impact, from the students’ perspective, on their learning and preparedness. Here are several comments made by the 29 students that support my idea of scaffolding with video prior to lab:

- “The videos guided me step by step on how to complete the pre-lab.”
- “Made it easier to do the vector calculations.”
- “I did not know how to do the pre-lab at all from lecture or the lab manual, so it helped a lot.”
- “Very helpful – I felt prepared for lab after watching videos.”
- “The videos were very demonstrative of what was going on in the diagrams. Great demos. Thanks a lot for the videos.”
- “Well, the videos made sure I did not miss any steps in the lab manual.”
- “The videos made it VERY clear how to fill in the tables.”
- “Awesome! Dude is great!”

- "I would have been lost without them."
- "They were very easy to follow and I liked that I could pause and then continue as I worked through each part."
- "The videos were VERY clear and helpful."
- "I would not have known how to do it if I did not see them."
- "The videos eliminated any confusion about what needed to be done."

By looking at the difference in comments, some of those who did not have access struggled with what they needed to do to complete the pre-lab and wished they had something to use as a guide. As for those who did have access, all of the 31 students gave positive feedback to the guidance the videos gave them.

Limitations

Like any experiment, there were limitations to this one. The first to address was that I do not know whether students watched the videos when looking at their lab scores, so I cannot conclude definitive impact of the videos on learning, but rather just option of watching the videos. This might be thought of as fidelity of implementation, which is always a challenge in social science research. Thus, my claims are limited to availability of the treatment. A second issue was keeping students who did not have access from watching the video even when they were not supposed to. An example of this would be if a student from the control group knew someone in the experimental group and they gave access to that student while working on the pre-lab. Even though the videos were password protected, I could not control what students did during their free time or outside of lab. However, the positive feedback from the comments section on the questionnaires (see data in Table 6) leads me to conclude that there was still a positive gain in the intervention.

Another limitation was grading bias; there is a grading rubric used by all graduate assistants, but we do have some academic freedom in our grading, so some TA's may be concentrating more on different aspects of the rubric than others. However, we limited the impact by determining that there was not a significant difference between the control and comparison group in Labs 1 and 2.

The last limitation that comes to mind is that because the data was collected in the accelerated spring semester and students have to produce two lab reports per week, there could have been a time constraint. However, in the fall and winter semesters, students get an entire week to compete the pre-lab and write one lab report per week.

Discussion

Impact

The measure of the impact of the video on student learning is varied. First, the overall Lab 3 scores were not significantly different for students in the control and the comparison groups. This might first suggest that the videos did not impact student learning; however, this might not be the case. Recall, only 61% of the students watched the videos and I was not able to identify which scores came from those who watched the video and those who did not. However, if I am interested in how having the videos as a resources impacts class scores, I determined that there was not a statistically significance between the two groups.

The videos may have an impact of the students individually, but not on the class has a whole. I do not have the data to determine the individual impact. It may also be that the impact of the video resulted in improved efficiency or mechanical understanding of the processes. Since the set-up of the labs was the same, and instructors' expectations were the same, the scores might be the same. But possibly the real value of the use of videos is that it can alter the instructor's approach to teaching by allowing the instructor to attend to different issues, such as the content in the lab versus how to continuously set up the force table during the lab. This was not something I was able to measure during this study, but something that should be considered in future work.

Observations of an Instructor

Although empirically not a finding, the following are my own reactions as an experienced lab instructor. These are not to be presented as "findings" but rather musings based on my two years of experience. I taught several lab sections each semester as a graduate student and noticed that with the *Addition and Resolution of Vectors* lab, it took us lab instructors a great deal of time to discuss not only how to perform the lab, but also what was going on in the pre-lab assignment.

Because of the extra time discussing these topics, it was difficult to get everything in, including completion of the lab. Besides the time lost in the beginning of class due to answering pre-lab questions, students also struggled with the three set-ups of the force table. I, and the other lab instructors, had to constantly go from group to group and assist. Even though this was not much of a problem because it was part of our responsibilities as lab instructors, it was the fact that after groups finished with their first set-ups, lab instructors then had to review it again from group to group, and then a third time. I found it so interesting that a majority of the groups needed this explained to them over and over; why were they not understanding? I believe that the videos eliminated some these set-up issues.

Future Research

A topic for future research is to have lab-teaching assistants keep a running record of the time that it takes students to complete Lab 3. This information would be useful because if half of the lab sections had access to the videos and the other half did not, efficiency in lab could be gauged.

Another possibility is that video presentation of information is more useful to different types of students, majors, gender, age, or other demographic characteristics. Future study might include looking at the impact across these different groups. Although not the focus of this paper, future studies should include this information.

It is clear from the qualitative analysis of students' comments from the survey that they valued the information from the videos and felt they were better prepared to do the lab. The caveat to this finding is that students had a choice to watch the videos. Those who did clearly have the predisposition that doing so would be of value. Future study should include requiring the viewing of the video to see if the findings remain the same.

Conclusion

I believe that my results show that scaffolding with video prior to the sophomore physics lab, *The Addition and Resolution of Vectors*, enhanced students' understanding, even though only 61% of the students viewed the videos. This suggests that if more students watched the videos, the improvement would even be greater. Students who used the videos found them helpful, but not as many students used the videos as I would have liked. Thus, the challenge of getting students engaged in pre-lab remains. However, from the students' comments, the video intervention had an overwhelming positive effect on the students who did access them; therefore, the videos should be considered for future semesters.

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Appendix A

Human Subject Module Completion Report

CITI Collaborative Institutional Training Initiative

Investigators, Students, and Faculty Mentors Curriculum Completion Report
Printed on 5/13/2010

Learner: David Sitar (username: dave12string)
Institution: Eastern Michigan University
Contact Information Department: Physics and Astronomy
Email: dsitar@emich.edu
Investigators, Students, and Faculty Mentors:

Stage 1. Basic Course Passed on 05/12/10 (Ref # 4381841)

Required Modules	Date Completed	Score
Belmont Report and CITI Course Introduction	05/05/10	3/3 (100%)
Students in Research - SBR	05/06/10	9/10 (90%)
History and Ethical Principles - SBR	05/06/10	4/4 (100%)
Defining Research with Human Subjects - SBR	05/06/10	4/5 (80%)
The Regulations and The Social and Behavioral Sciences - SBR	05/08/10	5/5 (100%)
Basic Institutional Review Board (IRB) Regulations and Review Process	05/09/10	5/5 (100%)
Assessing Risk in Social and Behavioral Sciences - SBR	05/09/10	5/5 (100%)
Informed Consent - SBR	05/09/10	5/5 (100%)
Privacy and Confidentiality - SBR	05/09/10	3/3 (100%)
Records-Based Research	05/09/10	2/2 (100%)
Research With Protected Populations - Vulnerable Subjects: An Overview	05/09/10	4/4 (100%)
Research with Prisoners - SBR	05/09/10	4/4 (100%)
Research with Children - SBR	05/09/10	4/4 (100%)
Research in Public Elementary and Secondary Schools - SBR	05/09/10	4/4 (100%)
Vulnerable Subjects - Research Involving Pregnant Women and Fetuses in Utero	05/12/10	3/3 (100%)
International Research - SBR	05/12/10	3/3 (100%)
Internet Research - SBR	05/12/10	4/4 (100%)
Group Harms: Research With Culturally or Medically Vulnerable Groups	05/12/10	3/3 (100%)
HIPAA and Human Subjects Research	05/12/10	2/2 (100%)
Hot Topics	05/12/10	no quiz
Conflicts of Interest in Research Involving Human Subjects	05/12/10	2/2 (100%)
EMU Page	05/12/10	no quiz
Genetic Research in Human Populations	05/12/10	2/2 (100%)
FDA-Regulated Research	05/12/10	2/5 (40%)
Human Subjects Research at the VA	05/12/10	3/3 (100%)
Workers as Research Subjects-A Vulnerable Population	05/12/10	4/4 (100%)

For this Completion Report to be valid, the learner listed above must be affiliated with a CITI participating institution. Falsified information and unauthorized use of the CITI course site is unethical, and may be

Appendix B

Human Subject Approval Form

EASTERN MICHIGAN UNIVERSITY
Education First

January 31, 2011

David Sitar
c/o Beth Kubitskey
Physics & Astronomy

Dear David:

The College of Arts and Sciences Human Subjects Review Committee (CAS HSRC) of Eastern Michigan University has reviewed and approved your proposal (#1024) titled, "Scaffolding with video prior to sophomore physics lab, The addition and resolution of vectors." The CAS HSRC determined that the rights and welfare of the individual subjects involved in this research are carefully guarded. Additionally, the methods used to obtain informed consent are appropriate, and the individuals participating in your study are not at risk.

You are reminded of your obligation to advise the HSRC of any change in the protocol that might alter your research in any manner that differs from that upon which this approval is based. Approval of this project applies for one year from the date of this letter. If your data collection continues beyond the one-year period, you must apply for a renewal. Please specify in your consent form that approval is from 1/31/2011 to 1/30/2012.

On behalf of the Human Subjects Committee, I wish you success in conducting your research.

Sincerely,

Alissa Huth-Bocks

Alissa Huth-Bocks, Ph.D.
CAS Human Subjects Review Committee Chair

Note: If project continues beyond the length of **one** year, please submit a continuation request form by **1/30/2012**.

cc: Beth Kubitskey, Ph.D.

University Human Subjects Review Committee · Eastern Michigan University · 200 Boone Hall
Ypsilanti, Michigan 48197
Phone: 734.487.0042 Fax: 734.487.0050
E-mail: human.subjects@emich.edu
www.ord.emich.edu

Appendix C

Consent Forms

Consent for those not accessing videos

The Department of Physics and Astronomy at Eastern Michigan University
Informed Consent for Physics 221/223 Lab Students Involved in Thesis Research

☐ Please check box to the left if you are under eighteen years of age and do not continue.

Title of Project:
"Scaffolding with video prior to sophomore physics lab, "*The Addition and Resolution of Vectors*".

Investigator/Graduate Student:
David J. Sitar

Purpose of this Research/Project:
The purpose of this research is to examine the effects of using a video through the Physics 221/223 pre-lab assignment on student preparation prior to coming to lab. Half of the Physics 221/223 students will have access to the videos, while the other half of the students will not have access to the videos. Therefore, this researcher will be able to examine associations between access to the videos and student success including lab scores. Results may influence the use of the videos in future semesters of this course. Since there will be twelve sections included in this study and each section has room for eighteen students, we can compare approximately 108 student scores (those who have access) to 108 student scores (those who do not access). Thus, the sample size of this study is expected to be 216.

Procedure and Risks:
We are asking that you complete this lab as you have done all of your labs to this point. We are also asking permission to collect your lab scores. There are no known risks involved in participating in this study. Participation in this study is completely voluntary, and refusal to participate will not lead to any negative consequences and will in no way impact your grade. If you choose not to participate, please do not sign the consent form or fill out the final questionnaire.

Benefits:
Benefits involved for participating in this study may include:

a. Improving overall lab scores in the sophomore physics lab.
b. Improving time management of the lab and student productivity.

These benefits are not meant to encourage or persuade you to participate; they are presented to clarify the purpose of this investigation and possible outcomes.

Confidentiality:
There will be no use of your name, Social Security Number, or your student identification number (SIN). There will be no collection or use of any identifying characteristics of participants, and there will be no videotaping of participants in lab. Participant responses will be kept confidential. There are no conditions under which the investigators may break confidentiality. Results of this study will be presented in aggregate form in a final master's thesis paper.

Compensation:
There is no compensation for participating in this study other than the benefit of obtaining the pre-lab points and information on how to use the force table in lab. One pre-lab point is given for the completion of the parallelogram and analytical methods; this is approximately 8.3% of your total grade. Your lab TA will sign off for this point at the beginning of your lab section, once they verify that you have completed both methods correctly. Partial credit can also be given. For example, if only one of the methods is complete, you will receive half the credit.

Freedom to Withdraw:
You are free to withdraw from this study at any time without penalty, and your lab grade will not be affected. You are also free to refuse to answer any questions and/or to respond to experimental situations described above.

Participant's Permission:
I have read the Consent Form and conditions of this project and my questions have been answered. I hereby acknowledge the above and give my voluntary consent:

____ Date__________________
Your signature

Should you have any pertinent questions about this research or its conduct - you may contact:

David Sitar / dsitar@emich.edu
Investigator / e-mail
Graduate Assistant of the Department of Physics and Astronomy

Dr. Beth Kubitskey / 734.487.8798 / mkubitske1@emich.edu
Thesis Advisor and Reviewer / Contact number / e-mail
Department of Physics and Astronomy

This research protocol and informed consent document has been reviewed and approved by the Eastern Michigan University Human Subjects Review Committee for use from 1/31/11 to 1/30/12. If you have questions about the approval process, please contact Dr. Deb de Laski-Smith (734.487.0042, Interim Dean of the Graduate School and Administrative Co-chair of UHSRC, human.subjects@emich.edu).

Consent for those accessing videos

The Department of Physics and Astronomy at Eastern Michigan University
Informed Consent for Physics 221/223 Lab Students
Involved in Thesis Research

☐ Please check box to the left if you are under eighteen years of age and do not continue.

Title of Project:
"Scaffolding with video prior to sophomore physics lab, "*The Addition and Resolution of Vectors*".

Investigator/Graduate Student:
David J. Sitar

Purpose of this Research/Project:
The purpose of this research is to examine the effects of using a video through the Physics 221/223 pre-lab assignment on student preparation prior to coming to lab. Half of the Physics 221/223 students will have access to the videos, while the other half of the students will not have access to the videos. Therefore, this researcher will be able to examine associations between access to the videos and student success including lab scores. Results may influence the use of the videos in future semesters of this course. Since there will be twelve sections included in this study and each section has room for eighteen students, we can compare approximately 108 student scores (those who have access) to 108 student scores (those who do not access). Thus, the sample size of this study is expected to be 216.

Procedures:
You will be asked to watch three online tutorial videos outside of lab. Each video lasts about five to eight minutes long, and the total time you will spend is under twenty minutes. The first video examines how to execute the parallelogram method, which is the graphing of the addition of vectors. The second video concentrates on how to solve vector addition analytically, and the third method focuses on how to use the force table in lab for the following week. You will be asked to watch these videos, complete the pre-lab work, and answer the questionnaire administered at the end of the third lab to see whether you found the videos helpful or not. We are also asking permission to collect your lab scores. Results may influence if this method is adapted to the lab for future semesters. These online videos and pre-lab work will be done over the course of one week, and you will only have to access the tutorials once in order to complete the pre-lab; however, you have unlimited access for the entire week. Once the week is over, the tutorials will become unavailable.

Risks:
There are no known risks involved in participating in this study. Participation in this study is completely voluntary, and refusal to participate will not lead to any negative consequences and will in no way impact your grade. If you choose not to participate, please do not sign the consent form or fill out the final questionnaire.

Benefits:
Benefits involved for participating in this study may include:

a. Improving overall lab scores in the sophomore physics lab.
b. Improving time management of the lab and student productivity.

These benefits are not meant to encourage or persuade you to participate; they are presented to clarify the purpose of this investigation and possible outcomes.

Confidentiality:
There will be no use of your name, Social Security Number, or your student identification number (SIN). There will be no collection or use of any identifying characteristics of participants, and there will be no videotaping of participants in lab. Participant responses will be kept confidential. There are no conditions under which the investigators may break confidentiality. Results of this study will be presented in aggregate form in a final master's thesis paper.

Compensation:
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You are free to withdraw from this study at any time without penalty, and your lab grade will not be affected. You are also free to refuse to answer any questions and/or to respond to experimental situations described above.

Participant's Permission:
I have read the Consent Form and conditions of this project and my questions have been answered. I hereby acknowledge the above and give my voluntary consent:

____ Date____________________
Your signature

Should you have any pertinent questions about this research or its conduct - you may contact:

David Sitar / dsitar@emich.edu
Investigator / e-mail
Graduate Assistant of the Department of Physics and Astronomy

Dr. Beth Kubitskey / 734.487.8798 / mkubitske1@emich.edu
Thesis Advisor and Reviewer / Contact number / e-mail
Department of Physics and Astronomy

This research protocol and informed consent document has been reviewed and approved by the Eastern Michigan University Human Subjects Review Committee for use from 1/31/11 to 1/30/12. If you have questions about the approval process, please contact Dr. Deb de Laski-Smith (734.487.0042, Interim Dean of the Graduate School and Administrative Co-chair of UHSRC, human.subjects@emich.edu).

Appendix D

Questionnaires

PHY221/223 Questionnaire Regarding Preparation for Lab 3: *The Addition and Resolution of Vectors*

Circle answers below for each question to express your pre-lab experience. If you have any additional comments about the pre-lab to better prepare you, please address them on the bottom or back of this sheet.

☐ Please check box to the left if you are under eighteen years of age and do not continue.

1. Did your lecture section reach the topic of vectors prior to this lab?

   Yes / No

2. Were you aware that there was a pre-lab due at the beginning of lab 3?

   Yes / No

3. Were you familiar with the vocabulary used in the pre-lab?

   Yes / No

Comments:

PHY221/223 Questionnaire Regarding Preparation for Lab 3: *The Addition and Resolution of Vectors*

Circle answers below for each question to express your pre-lab experience. If you have any additional comments about the pre-lab to better prepare you, please address them on the bottom or back of this sheet.

☐ Please check box to the left if you are under eighteen years of age and do not continue.

1. Did your lecture section reach the topic of vectors prior to this lab?

   Yes / No

2. Were you aware that there was a pre-lab due at the beginning of lab 3?

   Yes / No

3. Were you familiar with the vocabulary used in the pre-lab?

   Yes / No

Comments:

PHY221/223 Questionnaire Regarding Preparation for Lab 3: *The Addition and Resolution of Vectors*

Circle answers below for each question to describe your pre-lab experience. If you have any additional comments about the pre-lab to better prepare you, please address them on the back of this sheet.

☐ Please check box to the left if you are under eighteen years of age and do not continue.

1. Did your lecture section reach the topic of vectors prior to this lab?

   Yes / No

2. Were you aware that there was a pre-lab due at the beginning of lab 3?

   Yes / No

3. Were you familiar with the vocabulary used in the pre-lab?

   Yes / No

4. Did you use the video tutorials to guide you through the methods used to complete the pre-lab?

   Yes / No

5. If yes, did you find the videos helpful? Explain

   Yes / No

PHY221/223 Questionnaire Regarding Preparation for Lab 3: *The Addition and Resolution of Vectors*

Circle answers below for each question to describe your pre-lab experience. If you have any additional comments about the pre-lab to better prepare you, please address them on the back of this sheet.

☐ Please check box to the left if you are under eighteen years of age and do not continue.

1. Did your lecture section reach the topic of vectors prior to this lab?

   Yes / No

2. Were you aware that there was a pre-lab due at the beginning of lab 3?

   Yes / No

3. Were you familiar with the vocabulary used in the pre-lab?

   Yes / No

4. Did you use the video tutorials to guide you through the methods used to complete the pre-lab?

   Yes / No

5. If yes, did you find the videos helpful? Explain

   Yes / No

Appendix E

Video Treatment

DESCRIPTION OF TREATMENT – THE VIDEOS

Figure 1, below, is the opening scene for the Parallelogram Method; this is also referred to as the graphical method. It begins by introducing what students will need to do in order to complete this first procedure. The scene continues with supplies and items needed to draw the three sets of parallelograms and how to appropriately choose a scale to use. For my example diagram, I chose to use 20cm to be one Newton (N), because I wanted a large enough diagram visible on the video screen. Since students would be using graph paper, they would probably choose a scale something like 5cm for one Newton (N).

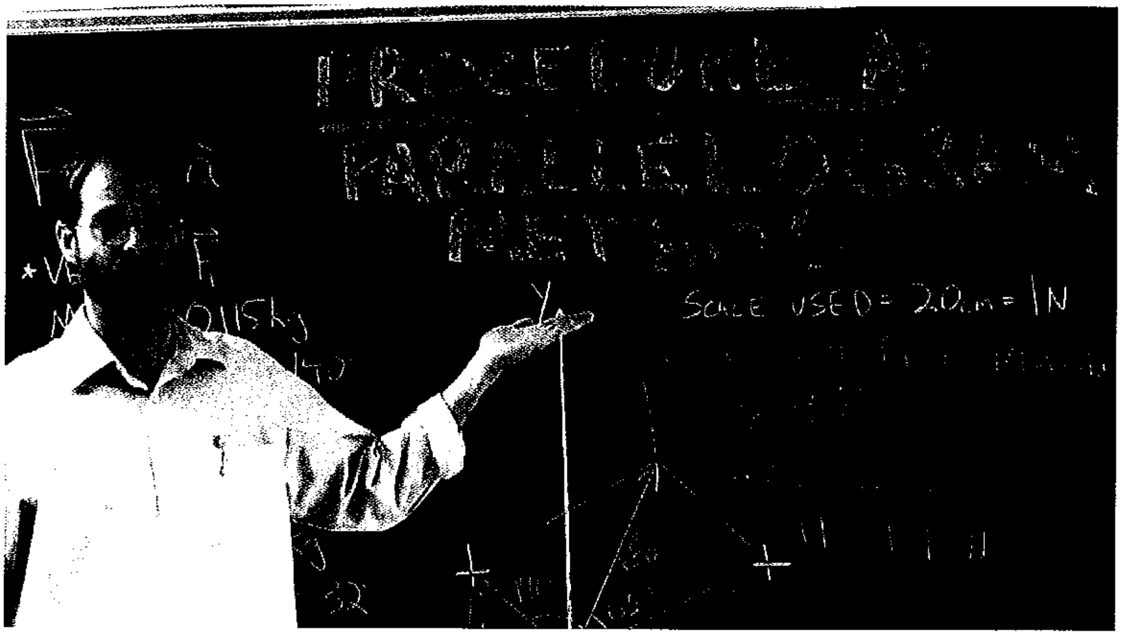


Figure 1: Introduction to the graphical method

The next set of scenes, a still shot shown in Figure 2 introduces some of the vocabulary, such as what a vector is, and how to calculate force. There is a brief discussion of Newton's Second Law on how a force or weight can be computed by multiplying a mass times the gravitational constant ($g = 9.81m/s^2$). Once the students have calculated the forces, it is time for them to draw the vectors that have given variables as F_1 through F_6. F_1 and F_2 are a set as well as F_3 and F_4, and so on. The drawing of the vectors will be discussed in Figure 4 along with how to find the resultant force.

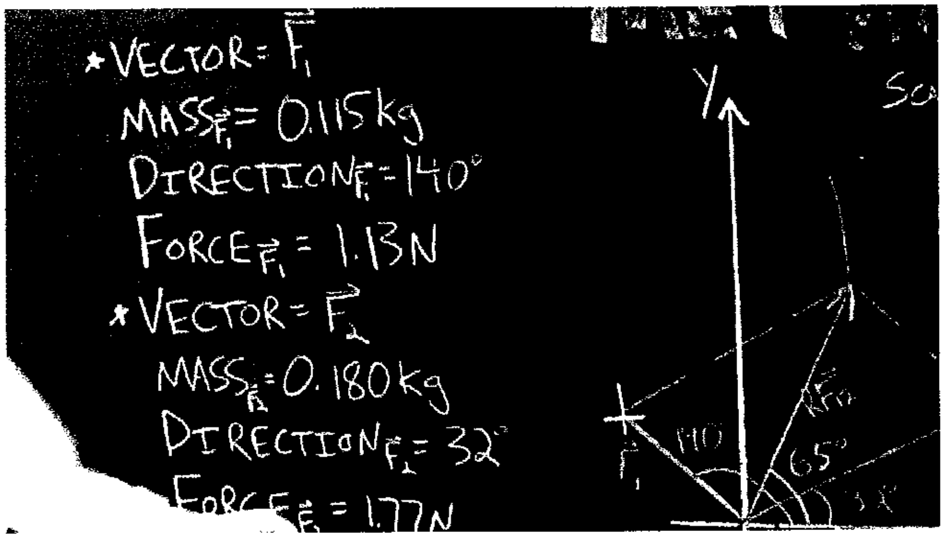


Figure 2: Introducing used variables

In order for students to draw the vectors, they need a force; a discussion on how to attain these was provided in the last section with Figure 2. Not only are force vectors needed, but angles are as well; this information has been given to the students in the lab manual. Figure 3 shows how to put these values to use by drawing a parallelogram. A protractor is used to find the angle, or direction, and a ruler is used to draw out the force vectors to scale, which can be seen in Figure 4.

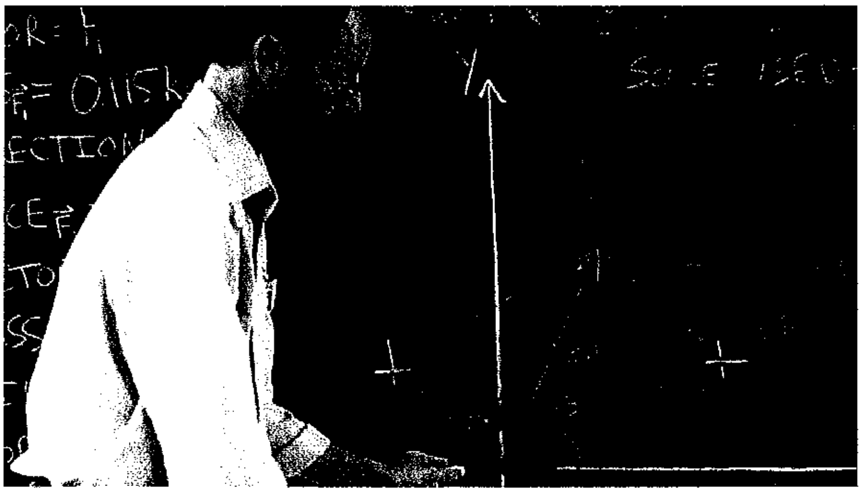


Figure 3: Using a protractor to define angles to be drawn

Notice in Figures 3 and 4 that there are solid lines and dashed lines making up the parallelogram. The solid lines are the force vectors that were calculated for and drawn, and the dashed lines come from drawing the same quantity calculated, but are not drawn from the "true" origin. Instead, the dashed lines are found by using the tip of F_1, which is drawn as a dashed line in parallel to the same length as F_2. This goes for finding F_1 too, the tip of F_2 is used and a parallel line of F_1 is drawn as a dashed line. To ensure the accuracy of being in parallel to each other, notice in Figures 3 and 4, there are "crosshairs" on the tips of each of F_1 and F_2. With the use of these "crosshairs," or another set of x and y-axes, the students can use their protractors again to find the corresponding angles from the horizontal.

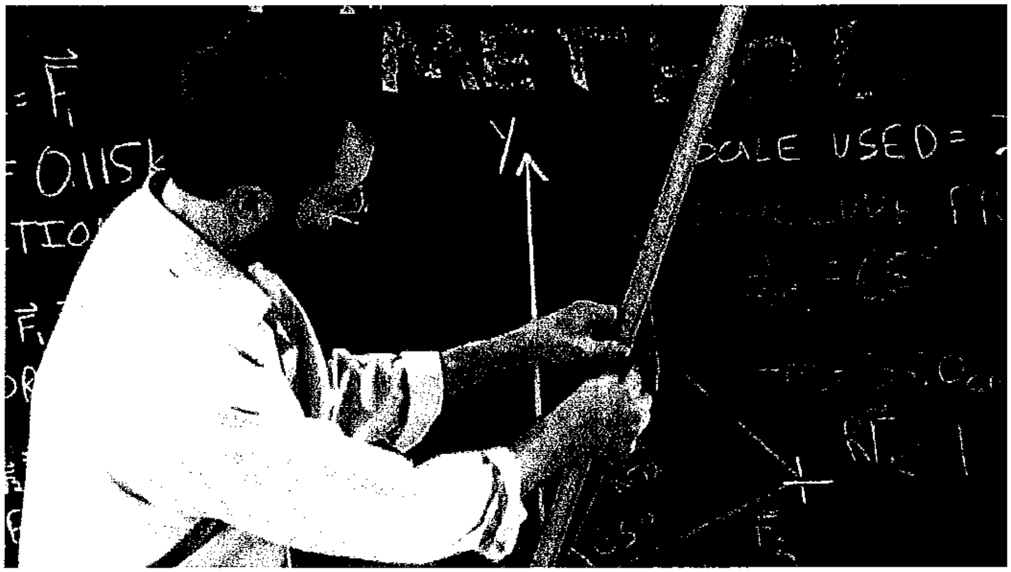
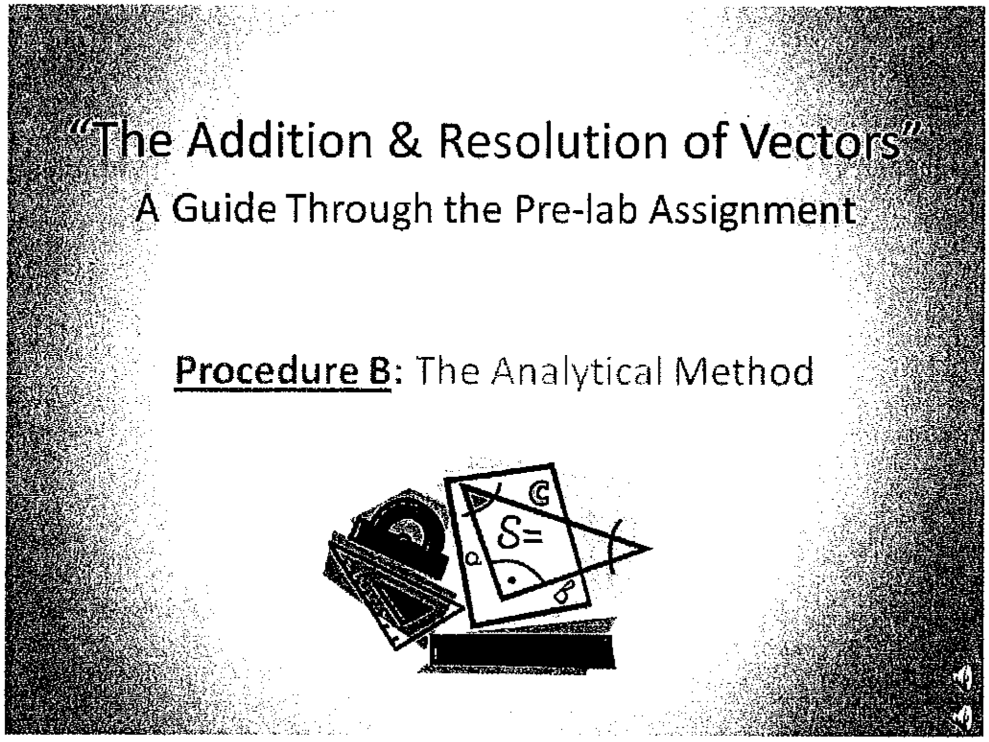


Figure 4: The use of a ruler to obtain magnitude and direction of the resultant force

The last item for the students to do to complete Procedure A is to find the resultant force. By definition, the resultant force is the sum of F_1 and F_2. Now that the parallelogram has been established, the resultant force is simply found by drawing a line from the "true" origin to where the two dashed lines intersect (see Figure 4) and is labeled RF_{12}. In order to find the magnitude and direction, which by definition is what a vector is, a ruler and protractor are used.

The next video, which is in the form of a PowerPoint presentation, demonstrates how to complete the Analytical Method, sometimes referred to as the component method.



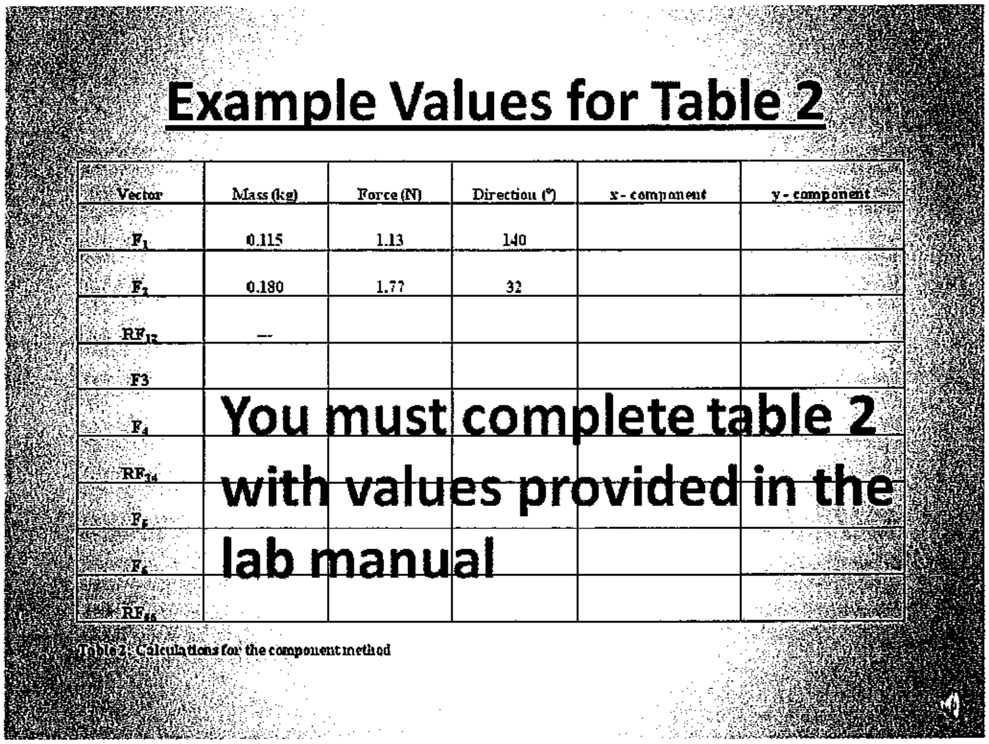
"The Addition & Resolution of Vectors"

A Guide Through the Pre-lab Assignment

Procedure B: The Analytical Method

Figure 5: Introduction to the component method

Figure 6 shows Table 2, which students need to complete to receive full credit for the pre-lab assignment. Once again, an example of F_1 and F_2 are used to demonstrate how to accomplish this, but students have different numbers to use from the lab manual and have F_1 through F_6 to do. The mass and direction have been provided, and the force has already been calculated from Procedure A.



Example Values for Table 2

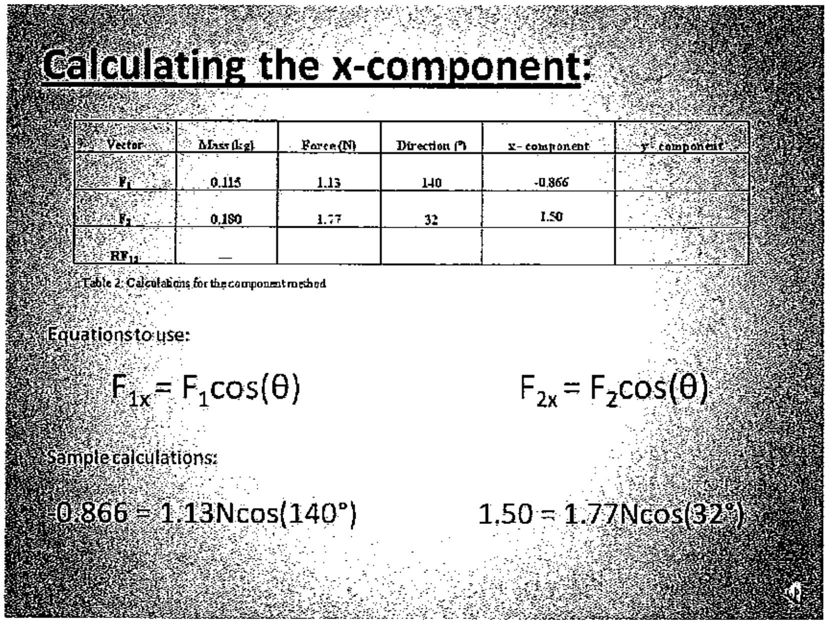
Vector	Mass (kg)	Force (N)	Direction (°)	x - component	y - component
F_1	0.115	1.13	140		
F_2	0.180	1.77	32		
RF_{12}	---				
F3					
F_4					
RF_{34}					
F_5					
F_6					
RF_{56}					

You must complete table 2 with values provided in the lab manual

Table 2: Calculations for the component method

Figure 6: Introducing the table to be completed

The presentation begins by first calculating the x-component. Figure 7 takes the students through this method. The equation used is in the lab manual and is addressed in the PowerPoint slide. I will only do $F_{1x} = F_1\cos(\theta)$, but note that $F_{2x} = F_2\cos(\theta)$ is done the same way and can be seen in Figure 7. The force for F_1 is 1.13N and is multiplied by cosine of some angle. The angle for F_1 in our case is 140°. Calculators must be set to degrees under the MODE function in order to obtain the correct answer; once computed, students should find that this approximately equals -0.866 (value is rounded). This numerical value is then entered into the x-component column. After this step is finished, F_2 is done in the same fashion, but different numerical values for force and direction will be used. This calculated answer can be found in the row labeled F_2 column x-component.



Calculating the x-component:

Vector	Mass (kg)	Force (N)	Direction (°)	x- component	y- component
F_1	0.115	1.13	140	-0.866	
F_2	0.180	1.77	32	1.50	
RF_{12}	—				

Table 2: Calculations for the component method

Equations to use:

$F_{1x} = F_1\cos(\theta)$

$F_{2x} = F_2\cos(\theta)$

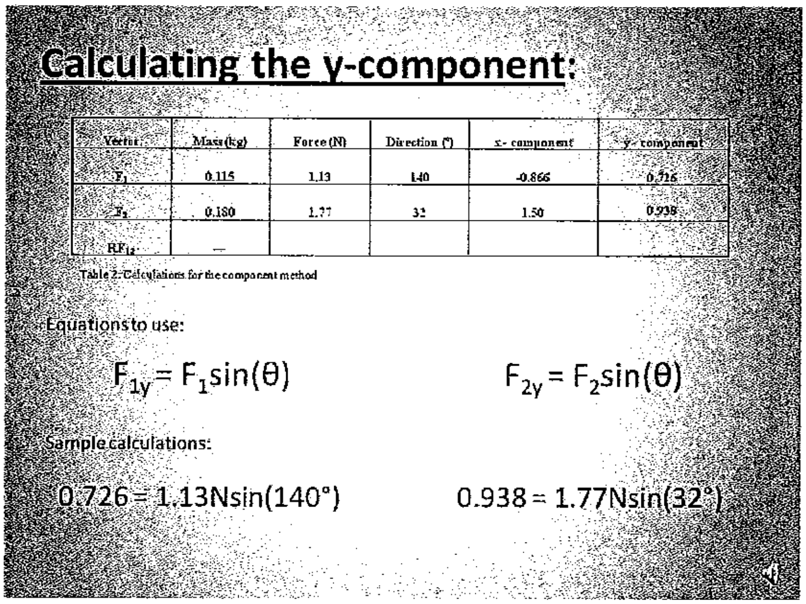
Sample calculations:

-0.866 = 1.13Ncos(140°)

1.50 = 1.77Ncos(32°)

Figure 7: Calculating the x-component

In Figure 8, the y-components are calculated. By following the same protocol discussed in Figure 7, these values can be derived the same way, but once again, F_{1y} and F_{2y}'s values will be used.



Calculating the y-component:

Vector	Mass (kg)	Force (N)	Direction (°)	x- component	y- component
F_1	0.115	1.13	140	-0.866	0.726
F_2	0.180	1.77	32	1.50	0.938
RF_{12}	—				

Table 2: Calculations for the component method

Equations to use:

$F_{1y} = F_1\sin(\theta)$

$F_{2y} = F_2\sin(\theta)$

Sample calculations:

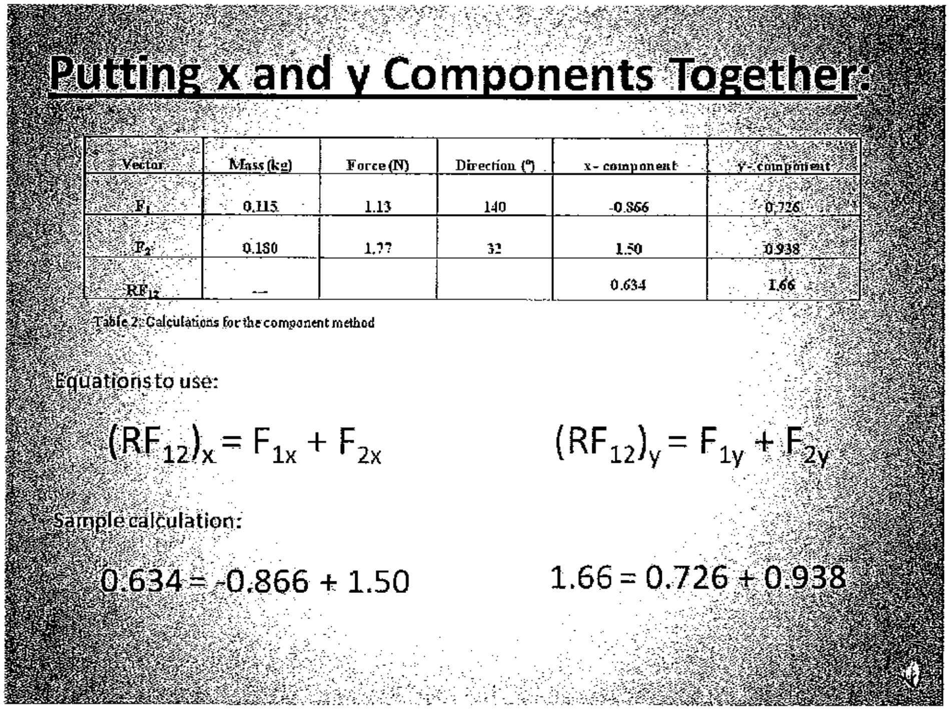
0.726 = 1.13Nsin(140°)

0.938 = 1.77Nsin(32°)

Figure 8: Calculating the y-component

As mentioned earlier, the resultant force (RF_{12}) is the sum of F_1 and F_2. These are achieved by putting the x and y-components together. The slide below labeled Figure 9, takes the students through this method. As seen below, both the x and y-components are computed, but only the process for the resultant force for the x-component will be discussed, but $(RF_{12})_y$ is done the same way.

By adding F_{1x} to F_{2x}, $(RF_{12})_x$ can be found. Notice that the values are F_{1x} is -0.866 and F_{2x} is 1.50; therefore, $(RF_{12})_x$ is 0.634N. This value is then written in the row labeled RF_{12} and column labeled x-component. Now, $(RF_{12})_y$ can be computed; see in Figure 9 that the process is the same as $(RF_{12})_x$.



Putting x and y Components Together:

Vector	Mass (kg)	Force (N)	Direction (°)	x - component	y - component
F_1	0.115	1.13	140	-0.866	0.726
F_2	0.180	1.77	32	1.50	0.938
RF_{12}	---			0.634	1.66

Table 2: Calculations for the component method

Equations to use:

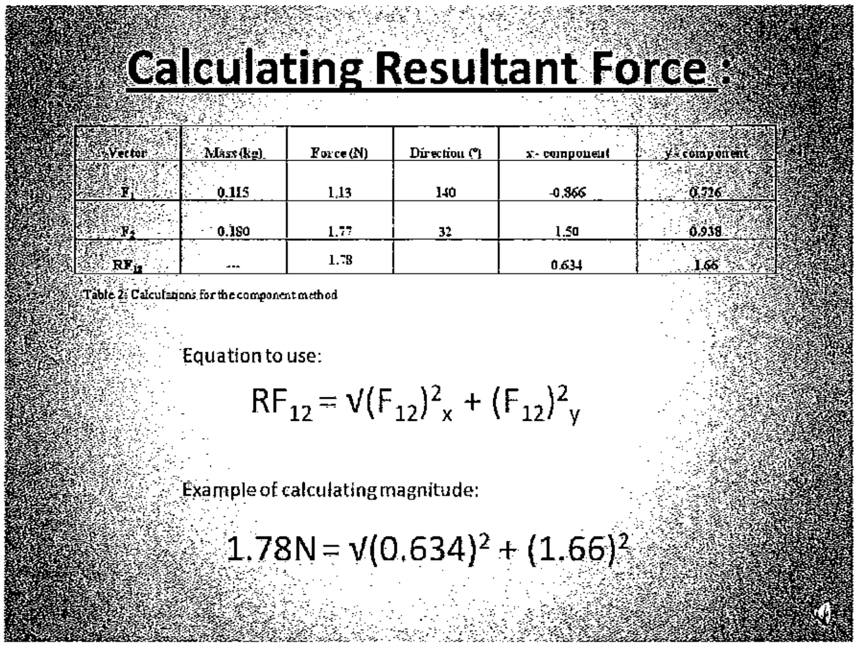
$$(RF_{12})_x = F_{1x} + F_{2x} \qquad (RF_{12})_y = F_{1y} + F_{2y}$$

Sample calculation:

$$0.634 = -0.866 + 1.50 \qquad 1.66 = 0.726 + 0.938$$

Figure 9: Calculating the x and y components together

These are the x and y components, so to find the resultant force, more mathematics are needed. The equation used is somewhat more involved, but notice the similarity for RF_{12} and how close it is to that of the Pythagorean Theorem ($c^2=a^2+b^2$); it is also treated and computed the same as this Theorem. The square of 0.634 plus the square of 1.66 equals 0.412 and 2.16; the square root of the sum of these two numbers equals 1.78N. See in Figure 10 how this answer is then inserted into the force column and row RF_{12}.



Calculating Resultant Force :

Vector	Mass (kg)	Force (N)	Direction (°)	x- component	y- component
F_1	0.115	1.13	140	-0.866	0.726
F_2	0.180	1.77	32	1.50	0.938
RF_{12}	---	1.78		0.634	1.66

Table 2: Calculations for the component method

Equation to use:

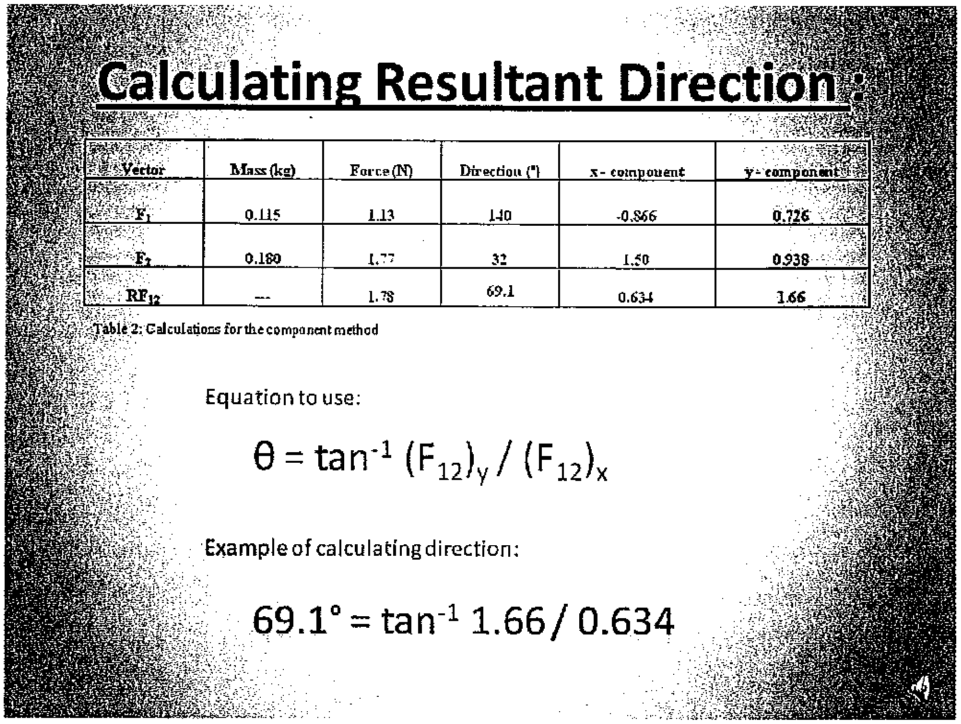
$$RF_{12} = \sqrt{(F_{12})^2_x + (F_{12})^2_y}$$

Example of calculating magnitude:

$$1.78N = \sqrt{(0.634)^2 + (1.66)^2}$$

Figure 10: Calculating the resultant force

There is one last calculation to make before F_1 and F_2 are done, and that calculation is for the direction of RF_{12}. Figure 11 shows these last steps. By taking the inverse tangent of $(F_{12})_y$ divided by $(F_{12})_x$, the angle or direction (in our situation) can be found. The vale for $(F_{12})_y$ is 1.66 and $(F_{12})_x$ is 0.634, which equals approximately 2.62 when rounded accordingly, and the inverse tangent of 2.62 equals 69.1°. A victory dance may be performed at this point since Figure 12 shows; an example of what Table 2 looks like when F_1, F_2, and RF_{12} are completed. Students are still required to finish the calculations for F_3 through F_6, and then the entire Table 2 in the lab manual and the pre-lab are complete.



Calculating Resultant Direction :

Vector	Mass (kg)	Force (N)	Direction (°)	x - component	y - component
F_1	0.115	1.13	140	-0.866	0.726
F_2	0.180	1.77	32	1.50	0.938
RF_{12}	---	1.78	69.1	0.634	1.66

Table 2: Calculations for the component method

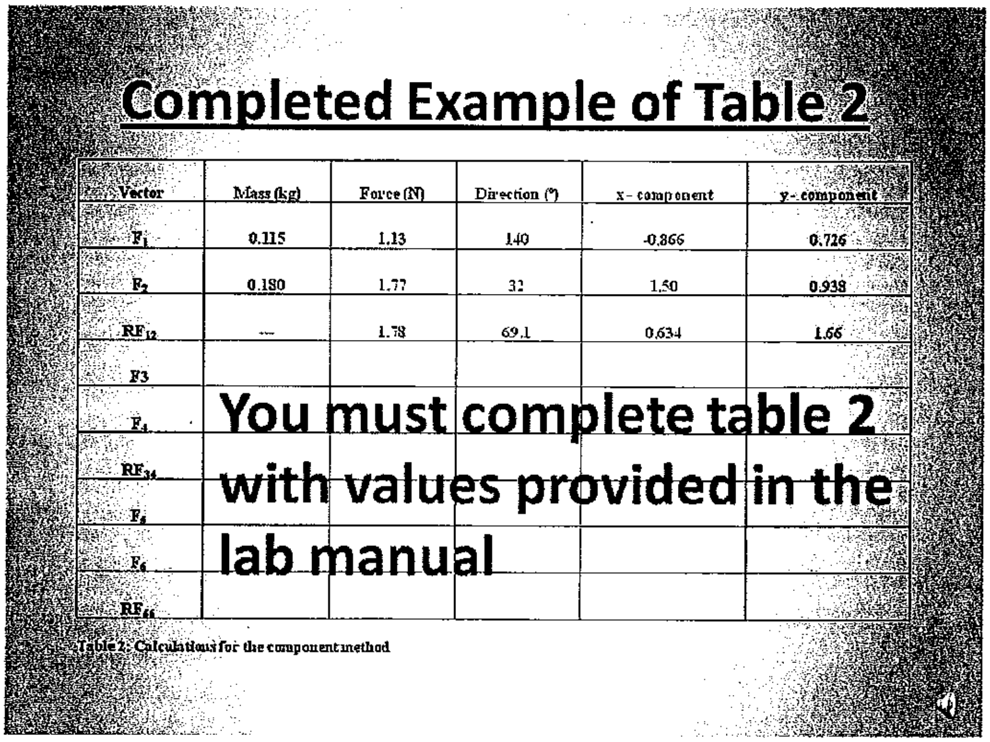
Equation to use:

$$\theta = \tan^{-1} (F_{12})_y / (F_{12})_x$$

Example of calculating direction:

$$69.1° = \tan^{-1} 1.66 / 0.634$$

Figure 11: Finding the direction



Completed Example of Table 2

Vector	Mass (kg)	Force (N)	Direction (°)	x - component	y - component
F_1	0.115	1.13	140	-0.866	0.726
F_2	0.180	1.77	32	1.50	0.938
RF_{12}	---	1.78	69.1	0.634	1.66
F3					
F_4					
RF_{34}					
F_5					
F_6					
RF_{56}					

You must complete table 2 with values provided in the lab manual

Table 2: Calculations for the component method

Figure 12: Completed example for F_1, F_2, and RF_{12}

The third and last video prepares students for the in-laboratory experiment. It is in this section where students observe, take careful measurements, keep a running record of their data, and make conclusions or inferences to communicate their results in their final lab write-ups. In theory, by scaffolding the experimental set-up of the lab equipment, the understanding of the content should increase and the time spent in lab should decrease. Figure 13 begins by discussing objectives to be met in lab, how having the pre-lab work completed will lead to less time manipulating equipment, and gaining a better understanding of what is expected of them.

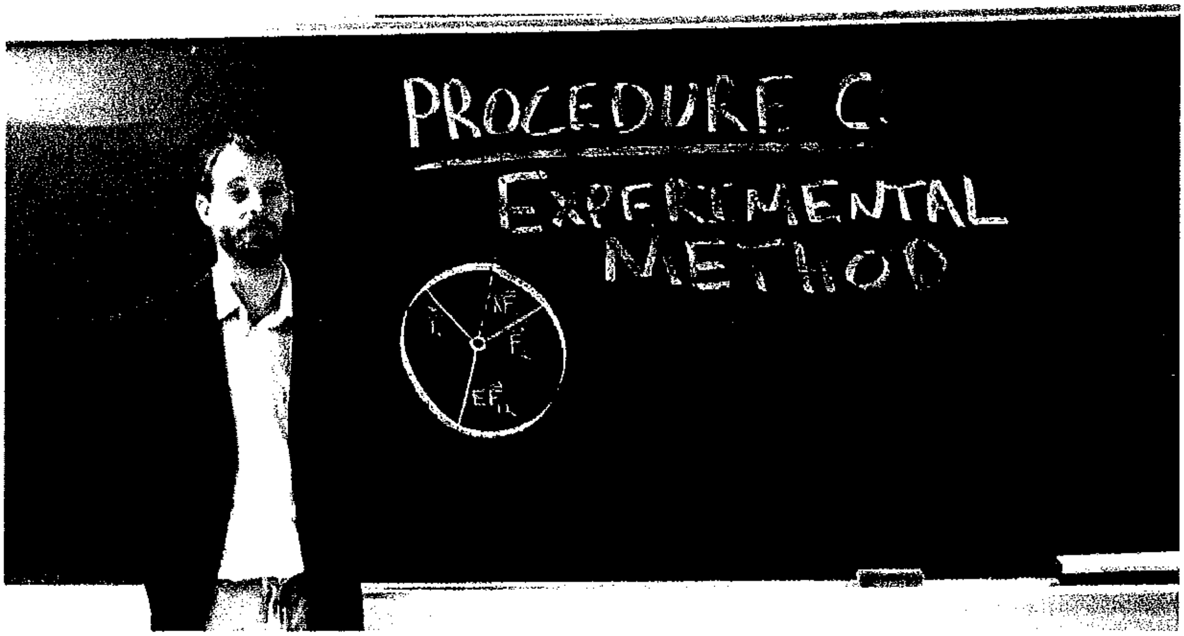


Figure 13: Introduction to the experimental method

Figures 14 and 15 show the students what lab equipment will be used in lab for the coming week during Procedure C. Figure 14 shows the boxes holding the varying masses used and the two different types of paperclips for final adjustments to the hanging mass. Figure 15 is a still image of the force table used. Figures 15, 16, and 17 will be further addressed in this section on how to manipulate pulley systems and the objective of the force table.

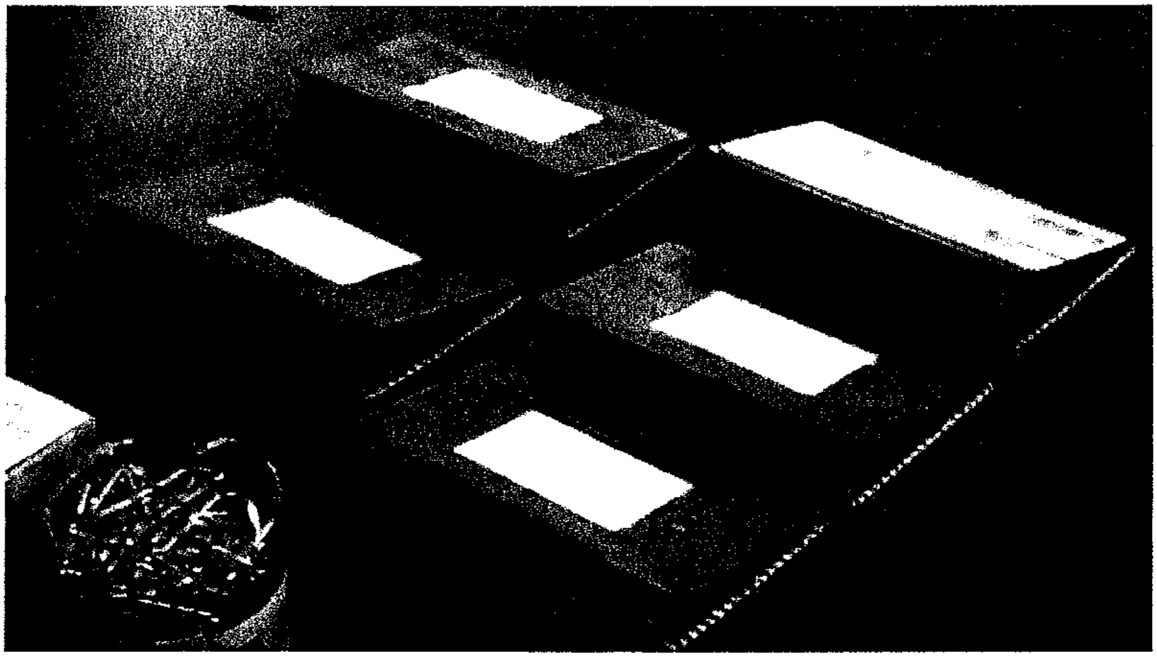


Figure 14: Mass sets used

The force table image in Figure 15 shows a face-on view of the apparatus and needs to be discussed in order to have an understanding of what is to be observed and measured in lab.

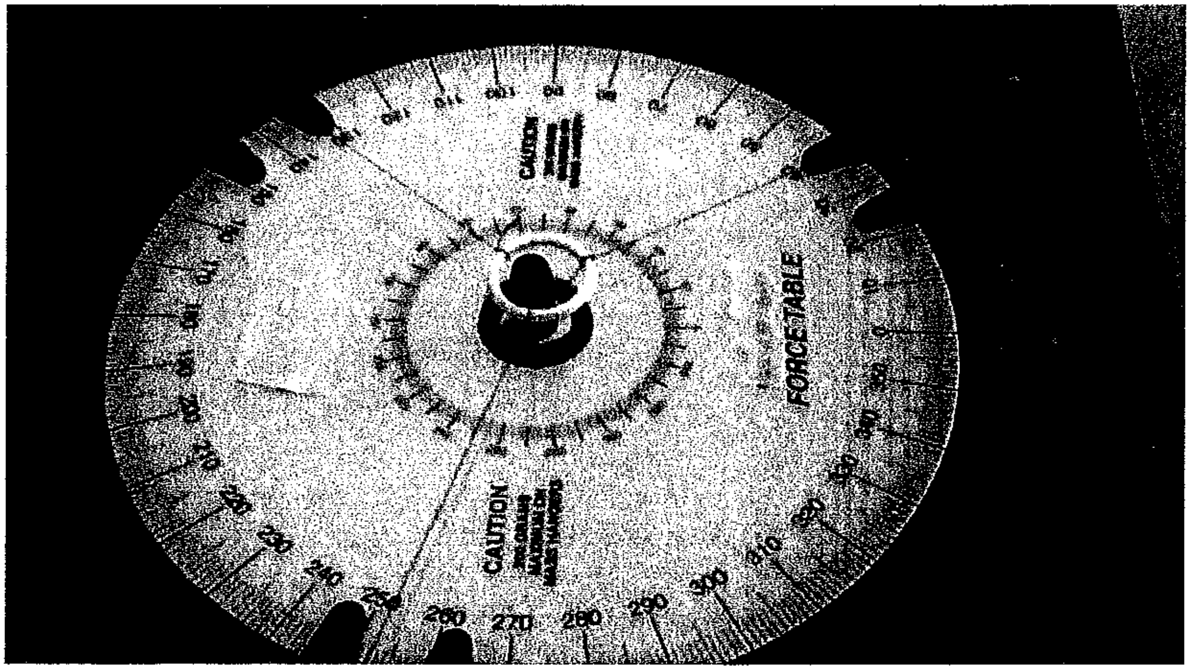


Figure 15: The force table

By looking at Figure 15; notice that along the circumference there are numbers from zero to 360 degrees; this indicates direction. There are three movable pulleys, each with a string that is tied to a center white ring that is placed over the black center post, and the other end of the string is draped over the "frictionless" movable pulley tied to a hanger. The objective for the students is to hang the appropriate amount of mass on the hanger, which is given to them in Table 2 of the lab manual. Students then must find the mass for the resultant force, or as soon to be discussed, the equilibrant force (EF). The resultant and equilibrant forces are the same in mass and force, but differ in direction.

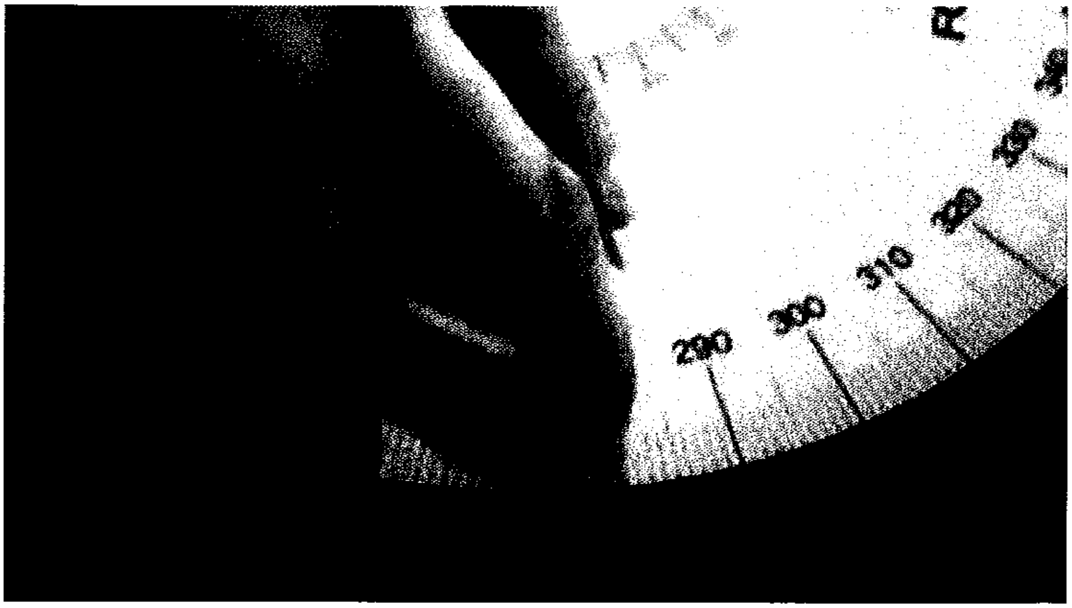


Figure 16: Using the movable pulley to find the direction

Once students have hung the given amount of mass they move the movable pulley system (Figure 16) to gauge the given directions. These too are provided in Table 2 of the lab manual. Now that the given masses, forces, and directions are set, it is up to the students find the equilibrant force. The equilibrant force, as mentioned a moment ago, is by definition the same in magnitude as the resultant but differs in direction. Interestingly enough the equilibrant force is rotated 180° from the resultant force.

Figure 13 shows this relationship on the chalkboard directly behind me. The board has the forces clearly marked as F_1, F_2, RF_{12}, and then 180° of RF_{12} is the EF_{12}. Students actually have an idea of where this should approximately be because they have already theoretically calculated the resultant force in Table 2, so by subtracting or adding 180° from their answer, they have where the equilibrant force (EF) approximately is. After this direction is established, mass is added to the hanger/pulley system (see Figure 17) until the white ring is centered equi-distance around the black center post (Figure 15, image reveals set-up, but not exactly around black center post). Students will use a careful eye in order to make this measurement but will observe that there is some uncertainty in their measurement.

After the empirical observation, the mass and direction data are recorded, and the weight can then be calculated by Newton's Second Law again to find equilibrium, W=mg, where (g) is $9.81 m/s^2$. To complete the experimental method, portion F_3 through F_6 are done the same way as F_1 and F_2; then the students have the data and measurements they need to write their lab reports, which are due five days later in the spring semester. Furthermore, if the results come to fruition as a positive gain, then the videos and data will be reviewed to see about adapting the videos as a permanent fixture on the physics webpage to be used across all sections for future semesters.

Figure 17: Hanging mass for applied force

Appendix F

Lab 3: *The Addition and Resolution of Vectors*

Experiment 3

The Addition & Resolution of Vectors
[You MUST complete some procedures BEFORE coming to lab.]

Objectives

The main purpose of this experiment is to demonstrate the process of the addition of two vectors to form a resultant vector. You will determine the sum of two vectors using a graphical method then you will verify the sum by using a force table. You will compare both these results to the answer you obtain analytically.

Introduction

In physics, the direction an object is moving is just as important as how far it actually moves. A mathematical tool called a *vector* is used to keep track of direction. Vectors represent quantities that have not only a *magnitude* (size/amount) but also have a *direction.* To combine vectors we must accurately keep track of the magnitude and the direction. Many important physical quantities are vector quantities such as displacement, velocity, acceleration, and force. A force exerted on an object can cause the object to move. When more than one force acts on an object special care must be taken to properly account for the directional aspect of each force to obtain the net effect. This process is called the addition and resolution of vectors.

In this experiment we will be using the force of gravity. The Earth is exerting a force on you right now; that gravitational force is also called your weight. This force has a magnitude (how much you weigh) and its direction is straight downward. The force is very different from your mass. Your mass is simply how much stuff you are made of – how many carbon, nitrogen, and oxygen atoms, etc. Mass has no direction and your mass is the same no matter where you are in the universe!

All of our experiments in this lab are done near the surface of the Earth where the force of gravity, which we will call F_g, can be determined by

$$F_g = (\text{mass of object}) \times (\text{acceleration due to Earth's gravity}) = mg.$$

The term g is the acceleration due to Earth's gravity and equals 9.80 m/s^2. The units of force are called Newtons (N). $1\ N = 1\ kg{\cdot}m/s^2$. An object with a mass of 1.00 kg therefore has a weight of 9.80 N.

Theory

There are two common ways to mathematically add vectors. The first method is based on drawing accurate pictures and using a ruler and a protractor. It is called the *graphical* or *parallelogram method.* The second method is purely analytical, and uses algebra and trigonometry to determine the vector sum. It is called the *component method.* Both methods should produce the same answer within experimental limits.

Parallelogram Method: Vectors are represented graphically by arrows drawn on a coordinate system. The arrow has a tail and a head. The *scaled* length of the arrow is proportional to the magnitude of the vector. It is the distance from the tail to the head. The direction of the arrow (orientation relative to the coordinate axes) tells you the direction of the vector. The head points in the direction the vector is acting.

Figure 1 shows you how to add two vectors using this method. To add two vectors $\mathbf{F}_1 + \mathbf{F}_2$, position the tails of both vectors at the origin of the coordinate system. Form a parallelogram with $\mathbf{F}_1$ and $\mathbf{F}_2$ as adjacent sides while maintaining their angular orientations. Draw an arrow along the diagonal of this parallelogram (from the origin to the opposite corner). This arrow is a new vector $\mathbf{F}_{12}$ and it is the vector sum of $\mathbf{F}_1$ and $\mathbf{F}_2$. This new vector is also called the *resultant*. The magnitude and orientation angle (θ) of the resultant are measured directly from the diagram using a ruler and protractor.

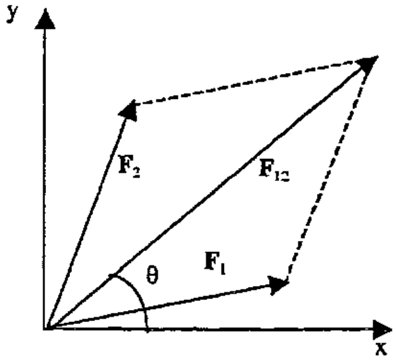


Figure 1

Component Method: When we place a vector in a coordinate system as shown in Figure 1, we see that the vector can be represented by a certain x-position and a certain y-position. To reach the head of the arrow, we must move a certain distance horizontally and a certain distance vertically. These distances are called the (horizontal) x-component and the (vertical) y-component of the vector. Opposite directions are indicated using a negative sign. Typically, a negative x-component indicates that the vector has a component acting to the left, and a negative y-component indicates that the vector has a component acting downward.

To add vectors together using this method, we first must resolve each vector into its components. This is done using basic trigonometry (sines and cosines). The vector sum of any number of vectors can be obtained by adding all the corresponding *x* and *y* components of the individual vectors. In our example, to find $\mathbf{F}_{12} = \mathbf{F}_1 + \mathbf{F}_2$ we must add up the components as shown below:

$$(F_{12})_x = F_{1x} + F_{2x} \qquad \text{and} \qquad (F_{12})_y = F_{1y} + F_{2y}$$

The magnitude and direction of the resultant $\mathbf{F}_{12}$ are found by

$$F_{12} = \sqrt{F_{12x}^2 + F_{12y}^2} \qquad \text{and} \qquad \theta = \tan^{-1}\left(\frac{F_{12y}}{F_{12x}}\right).$$

Note that θ, as determined above, will be the reference angle; you must use the signs of F_{1x} and F_{1y} to determine the vector angle θ. By convention we will always take the vector angle θ to be measured counterclockwise from the positive x-axis.

Example: Let $\mathbf{F}_1$ in Figure 1 be 20 N at and angle of 16° and let $\mathbf{F}_2$ be 23 N at an angle of 57°. We can then find the vector sum:

$F_{1x} = 20\text{ N}\cos 16^\circ = 19.2\text{ N}$ $F_{1y} = 20\text{ N}\sin 16^\circ = 5.51\text{ N}$
$F_{2x} = 23\text{ N}\cos 57^\circ = 12.5\text{ N}$ $F_{2y} = 23\text{ N}\sin 57^\circ = 19.3\text{ N}$

So, $F_{12x} = 31.7$ N and $F_{12y} = 24.8$ N

thus, $F_{12} = \sqrt{(31.7N)^2 + (24.8N)^2} = 40.3$ N

and $\theta = \tan^{-1}\left(\frac{F_{12y}}{F_{12x}}\right) = \tan^{-1}\left(\frac{24.8N}{31.7N}\right) = 38^\circ$

Procedures

A. Graphical Determination of the Components of a Vector

[You must complete this section before coming to lab. Show your TA your drawings and ask your TA to initial your handwritten copy of Table 1.]

1. Use the parallelogram method to find the vector sum for the first pair of vectors listed in Table 1. Draw a vector diagram to scale on a sheet of graph paper using a ruler and a protractor. You will find a paper protractor in Appendix C. Use a scale such that the finished diagram fills **most** of the paper. You must make up a scale. Be sure to record how many centimeters (length of the arrow) represent 1.0 N of force on your diagram. Append your drawing to your lab report.
2. Measure and record the magnitude and direction of the resultant vector with a ruler and a protractor and record the results in Table 1.
3. Repeat steps one and two for the other two pairs of vectors listed in Table 1.

Scale used to draw lines: ________ cm = __________ N

Table 1

Vector	Mass (kg)	Force (N)	Direction
F_1	0.125		145°
F_2	0.175		20.0°
Resultant F_{12}	---		
F_3	0.110		160°
F_4	0.050		35.0°
Resultant F_{34}	---		
F_5	0.175		45.0°
F_6	0.125		270°
Resultant F_{56}	---		

B. Analytical Determination of the Components of a Vector

[You must complete this section before coming to lab. Be sure to ask your TA to initial your handwritten copy of Table 2.]

4. Use the component method to determine the vector sum of each of the pairs of vectors listed in Table 2.

Table 2

Vector	Mass (kg)	Force (N)	Direction	x component	y component
$\mathbf{F}_1$	0.125		145°		
$\mathbf{F}_2$	0.175		20.0°		
Resultant $\mathbf{F}_{12}$	---				
$\mathbf{F}_3$	0.110		160°		
$\mathbf{F}_4$	0.050		35.0°		
Resultant $\mathbf{F}_{34}$	---				
$\mathbf{F}_5$	0.175		45.0°		
$\mathbf{F}_6$	0.125		270°		
Resultant $\mathbf{F}_{56}$	---				

C. Experimental Determination of the Components of a Vector

5. In front of you on the desk is a force table. Three hangers are attached, by strings, to a center ring on the force table. [Note: the mass of the mass hangers must be taken into account]. $\mathbf{F}_1$ is represented using one string by placing a total mass of 0.125 kg (including the hanger) at an angle of 145°. $\mathbf{F}_2$ is represented using another string by placing a total mass of 0.175 kg (including the hanger) at an angle of 20.0°.

6. Now place masses and paper clips on the third hanger to determine the third force, $\mathbf{F}_{E12} = -\mathbf{F}_{12}$, that brings the center ring into equilibrium about the center pin. Record the total mass of the third hanger. Be sure to measure the mass of any paper clips you have used. (Keep track of your significant figures.)

7. Determine the magnitude and the direction of $\mathbf{F}_{E12}$. This is the force needed to balance the two forces $\mathbf{F}_1$ and $\mathbf{F}_2$. It is not the resultant; it is the equilibrant. The resultant of the two forces $\mathbf{F}_1$ and $\mathbf{F}_2$ has the same magnitude as $\mathbf{F}_{E12}$ but is in the opposite direction. Record the magnitude and angle of both the equilibrant and resultant in Table 3.

8. Repeat steps five through seven for the other pairs of vectors listed in Table 3.

Table 3

Vector	Mass (kg)	Force (N)	Direction
$\mathbf{F}_1$	0.125		145°
$\mathbf{F}_2$	0.175		20.0°
Equilibrant $\mathbf{F}_{E12}$	---		
Resultant $\mathbf{F}_{12}$	---		
$\mathbf{F}_3$	0.110		160°
$\mathbf{F}_4$	0.050		35.0°
Equilibrant $\mathbf{F}_{E34}$	---		
Resultant F_{34}	---		
$\mathbf{F}_5$	0.175		45.0°
$\mathbf{F}_6$	0.125		270°
Equilibrant $\mathbf{F}_{E56}$	---		
Resultant $\mathbf{F}_{56}$	---		

9. Take your values from the analytical method as the true values and determine the percent error in the *magnitudes* of the graphical and experimental directions.

10. Take your values from the analytical method as the true values and determine the absolute error in the *angles* you measured in the graphical and experimental methods. Absolute error is just the difference between the true value and the measured value.

Questions for Thought

Q1. Why is the equilibrant of two forces equal in magnitude to their resultant, but opposite in direction?

Q2. Did you expect the graphical or the experimental method to be more accurate? Why? Do your results support this expectation?

Q3. The x-component of a certain force is 65 N and its y-component is -35 N. Find the magnitude and direction of this force.

Q4. How would you use the graphical and the experimental methods to subtract one vector from another (i.e., to find their difference)?

Q5. Take your values from the analytical method as the true values and determine the percent error in the *angles* you measured in the graphical and experimental methods. Reflect on why you were not asked to calculate the percent error for the angles as part of the laboratory procedure.

Appendix G

Grading Rubric for Lab 3

Lab Report Grading Rubric for PHY 221/223 Experiment #3

Poor **Excellent**

Section Pts	Section							Section Score
0	**Cover Page**	-0.5	-0.4	-0.3	-0.2	-0.1	0	
	Includes the five required elements							
2	**Abstract (≤ 75 words)**	0	0.2	0.4	0.6	0.8	1	
	Abstract conveys a sense of the full report -a person should be able to read the abstract (perhaps in a library of lab reports) and understand the objectives and outcomes of the experiment.							
	The abstract should be no more than 75 words long. Please provide a word count.							
4	**Introduction**	0	.20	.40	.60	.80	1	
	Effectively presents the objective and purpose of the lab							
	Successfully discusses the general principles and laws							
	Successfully describes equations and their uses							
	Discusses the role of the equipment							
2	**Results**	0	0.1	0.2	0.3	0.4	0.5	
	Effectively describes, in a couple of sentences before each table or drawing, how the data was obtained or the table was drawn.							
	Presents visuals (tables & graphs) typed clearly and accurately -all tables and graphs should have appropriate titles -briefly describes trends seen in tables and/or on graphs							
	A sample of each required calculation is shown (read the lab manual carefully to identify all the necessary calculations) **-all equations should be typed and appear as they would in a physics textbook** **-used correct units** & significant digits -calculated answers are correct							
	Correctly identifies at least two specific sources of error. Successfully discusses how each error would affect the measured and calculated outcomes.							
1	**Questions**	0	0.2	0.4	0.6	0.8	1.0	
	Questions presented in the lab manual are answered correctly and thoroughly. (This week number your answers.)							
1	**Calculations Using Component & Parallelogram Method**	0	0.2	0.4	0.6	0.8	1.0	
	Student has correctly completed the calculations **BEFORE** coming to lab.							
2	**Excel Calculation & Graphing Homework**	0	0.4	0.8	1.2	1.6	2.0	
	Completes calculations; submits spreadsheet with formulas & graph							
0	**Grading Rubric**	-0.5					0	
	Student has downloaded and attached the correct rubric							
	Penalty for late submission							

Points Earned	

Appendix H

Lab 3 Example

The Addition and Resolution of Vectors

Experiment #3

NAME
SID#
Partner – NAME
PHY 223
Lab Instructor – NAME
Monday/Wednesday, 10:30 AM – 12:20 PM
Lecture Instructor – NAME

Abstract

In this experiment we found resulting vectors graphically, analytically, and experimentally. The parallelogram method gave results that were measured with a protractor while the analytical method relied on mathematical evaluation. During the experiment we used a force table to evaluate what magnitude and direction would produce an equilibrant vector that balanced two given vectors. Both graphical and experimental results proved similar to the analytical method. However, graphical measurements were observed as more accurate than experimental. (75 words)

Good

GREAT

Introduction

In this lab we experimented with vectors; how they are added and how to find resulting magnitudes and angles. We were given the magnitude and direction of two vectors and asked to find the resultant magnitude and direction of the third vector.

Before lab we performed graphical and analytical calculations to determine the values of Resultant $\mathbf{F}_{12}$, Resultant $\mathbf{F}_{34}$, and Resultant $\mathbf{F}_{56}$. Graphically we drew both given vectors using graphing paper and scales that indicated how many centimeters represented how many Newtons. We measured the resulting vectors with a protractor and the conclusions are documented in the handwritten Figure 1. Analytically we used a series of equations to calculate what the magnitude and direction of the resultant vector would be. These equations are listed below:

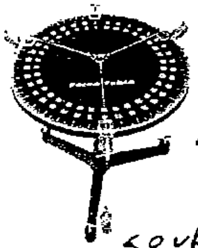
$$(F_{12})_x = F_{1x} + F_{2x} \qquad (F_{12})_y = F_{1y} + F_{2y}$$

$$F_{12} = \sqrt{(F_{12x})^2 + (F_{12y})^2}$$

$$\theta = \tan^{-1}\left(\frac{F_{12y}}{F_{12x}}\right).$$

GOOD

In lab we used a force table similar to the one shown below.



NICE

SOURCE?

The weights we placed on the hangers and the pulleys were moved to the correct angle in the circle. Then we tested the third vector by adding weights one at a time and moving the pulley to different angles until we could find the correct magnitude and direction. The weight of the vectors were converted into magnitudes measured in Newtons by the following equation:

$$F_g = (mass) \times (acceleration) = mg$$

After finding the experimental values we compared the magnitudes experimentally and graphically to the analytical calculations using the percent error equation:

$$\%error = \frac{|true - observed|}{true} \times 100\%$$

We also calculated the absolute error of the angles by comparing the experimental and graphical values to the analytical values using the following equation.

$$Absolute_{error} = true - observed.$$

SUPER

INTRO. MEETS RUBRICS REQUIREMENTS, BUT NOTE THAT MORE BACKGROUND INFO. GOOD BE ADDED

Results

The values for the force in Newtons was obtained by multiplying the mass by the acceleration due to gravity (F=mg). And the direction of the equilibrant vector was obtained experimentally using the force table in lab.

Two of the three hangers on the force table were given the masses and angles of $\mathbf{F}_1$ and $\mathbf{F}_2$ while the third hanger was used to determine the best possible vector to bring the center ring to equilibrium. This process was repeated for $\mathbf{F}_3$ and $\mathbf{F}_4$ as well as $\mathbf{F}_5$ and $\mathbf{F}_6$. The resultant angle was found by subtracting 180° from the equilibrant angle.

Vector	Mass (kg)	Force (N)	Direction
$\mathbf{F}_1$	0.125	1.225	145°
$\mathbf{F}_2$	0.175	1.715	20.0°
Equilibrant $\mathbf{F}_{E12}$	--	1.401	245°
Resultant $\mathbf{F}_{12}$	--	1.401	65.0°
$\mathbf{F}_3$	0.110	1.078	160°
$\mathbf{F}_4$	0.050	0.49	35.0°
Equilibrant $\mathbf{F}_{E34}$	--	0.9016	310°
Resultant $\mathbf{F}_{34}$	--	0.9016	130°
$\mathbf{F}_5$	0.175	1.715	45.0°
$\mathbf{F}_6$	0.125	1.225	270°
Equilibrant $\mathbf{F}_{E56}$	--	1.137	180.5°
Resultant $\mathbf{F}_{56}$	--	1.137	0.50°

Data Table 1 – Magnitude and Direction of Vectors (Analytical Method)

$$F_g = (mass) \times (acceleration) = mg$$

$$F_g = (0.125kg) \times \left(9.8\frac{m}{s^2}\right) = 1.225N$$

Resultant angle = Equilibrant angle - 180°

Finding trends in the collected data isn't very apparent when just looking at this table but when comparing these values to the graphical and analytical values found during the pre-lab, similarities are present. The magnitudes and angles of the Resultant vectors reflect similar values that were obtained graphically and analytically in Figures 1 and 2 of the handwritten, pre-lab analysis.

TRUE

The graphical and analytical values present in Data Table 2 and Data Table 3 were found using the pre-lab processes which are detailed in latter written pages.

	Analytical Values (True)	Graphical Values	Experimental Values	Graphical Percent Error	Experimental Percent Error
Resultant $\mathbf{F}_{12}$	1.43	1.42	1.401	0.699%	2.03%
Resultant $\mathbf{F}_{34}$	0.89	0.885	0.9016	0.562%	1.30%
Resultant $\mathbf{F}_{56}$	1.213	1.20	1.137	1.07%	6.27%

Data Table 2 – Percent Error in Magnitudes

For percent error, graphical values trend (at least) twice as small as experimental values and therefore are more accurate.

$$\%error = \frac{|true - observed|}{true} \times 100\%$$

$$\frac{|1.43N - 1.42N|}{1.43N} \times 100\% = 0.699\%$$

	Analytical Values (True)	Graphical Values	Experimental Values	Graphical Absolute Error	Experimental Absolute Error
Resultant $\mathbf{F}_{12}$	64.7°	66.0°	65.0°	-1.3°	-0.3°
Resultant $\mathbf{F}_{34}$	133°	133°	130°	0.0°	3.0°
Resultant $\mathbf{F}_{56}$	-0.57°	2.0°	0.5°	-2.57°	-1.07°

Data Table 3 – Absolute Error in Angles

$$Absolute_{error} = true - observed$$

$$64.7° - 66° = -1.3°$$

For absolute error, the trends aren't as consistent as with percent error. For Resultant $\mathbf{F}_{12}$ and $\mathbf{F}_{56}$ the experimental errors are smaller but for Resultant F_{34} the experimental error is much larger than the graphical error.

WELL Done

Error Analysis

Parallax is the first of two important sources of error. While lining up the pulleys on the force table, parallax can interfere with the accuracy of the angle measurements. If this difference was large enough, it could change the absolute errors in Data Table 3. For example, if the angle measurements were off slightly on the two given vectors for Resultant $\mathbf{F}_{12}$, and the resultant angle was 66.2°, the experimental absolute error would be larger than that of the graphical absolute error.

$$64.7^\circ - 66.2^\circ = -1.5^\circ$$

If this were also true for Resultant $\mathbf{F}_{56}$, the results of the absolute error analysis would conclude that the graphical measurements are always more accurate than the experimental ones.

Another source of possible error lies in the accuracy of the weight measurements. In the experiment we used disk weights as well as paperclips and the hanger itself which was measured to be 0.5 g. If these measurements were slightly incorrect it could affect the magnitude of the given vectors and the resulting vectors. The following percent error calculations could be thrown off by these incorrect weights. For example, if the magnitude of Resultant $\mathbf{F}_{12}$ was 1.44 instead of 1.401, the percent error would have been much different:

STRONG SUPPORT

$$\frac{|1.43N - 1.44N|}{1.43N} \times 100\% = 0.699\%$$

This percent would indicate that the graphical and experimental values were equal but opposite in error and it would have made it more difficult to construct trends.

Conclusion

Through our experiment we found the equilibrant and resultant angles for two vectors and although their magnitudes were equal, their angles differ by 180°. This is because the equilibrant angle is the one that balances the two vectors in the opposite direction while the resultant vector measures the two vectors added together (Q1)

Both graphical and experimental methods produced magnitudes and directions that were similar to the analytical values. I expected the graphical results to be more accurate because there are more chances for error in the experimental process. Graphical analysis contains parallax as a possible source of error while experimental measurements can include weight error, angle parallax, and other errors within the force table used. My results reflect that the graphical analysis was more accurate in all areas except for the absolute error in Resultant $\mathbf{F}_{12}$ and Resultant $\mathbf{F}_{56}$. These are the only two instances where the graphical error is slightly larger than the experimental error (Q2)

Finding the magnitude and the direction of a force can be determined through a known x-component and a known y-component. For example, if the x-component of a force is 65 N and the y-component is -35 N, the resulting magnitude can be found by the following equation:

$$V = \sqrt{(V_x)^2 + (V_y)^2}$$

$$V = \sqrt{(65N)^2 + (-35N)^2} = 74N \quad \text{Q3}$$

The direction of this vector can then be found using trigonometric equations. The angle can be found, for instance, by using the following information:

$$\cos\theta = \frac{adjacent}{hypotenuse} \qquad \theta = \cos^{-1}\left(\frac{adjacent}{hypotenuse}\right)$$

DSS OK

$$\theta = \cancel{\cos}^{-1}\left(\frac{-35N}{74N}\right) = 118° \quad \text{~~Tan~~}$$

DERIVED CORRECTLY

However, we know that the vector is in quadrant four so we must add 180° to θ giving us a vector direction of 298°. Q3

Graphically, subtracting vectors would require taking the same magnitude of one of the vectors but drawing it 180° opposite of the original. Then you would continue with the parallelogram method to find the resulting vector which would be equivalent to the difference of the given vectors. Experimentally, you would move one of the two given vector hangers 180° and continue with the procedure. The difference of the vectors would be the resultant angle (Equilibrant-180°). Q4

The analytical, graphical, and experimental values for the resultant angles were used to find the absolute error instead of the percent error. Here I will compute what the percent error would have been if it was part of the laboratory procedure.

	Analytical Values (True)	Graphical Values	Experimental Values	Graphical Percent Error	Experimental Percent Error
Resultant $\mathbf{F}_{12}$	64.7°	66.0°	65.0°	-2.0%	-0.46%
Resultant $\mathbf{F}_{34}$	133°	133°	130°	0.0%	2.3%
Resultant $\mathbf{F}_{56}$	-0.57°	2.0°	0.5°	450%	188%

Data Table 4 – Percent Error in Angles

$$\%error = \frac{|true - observed|}{true} \times 100\%$$

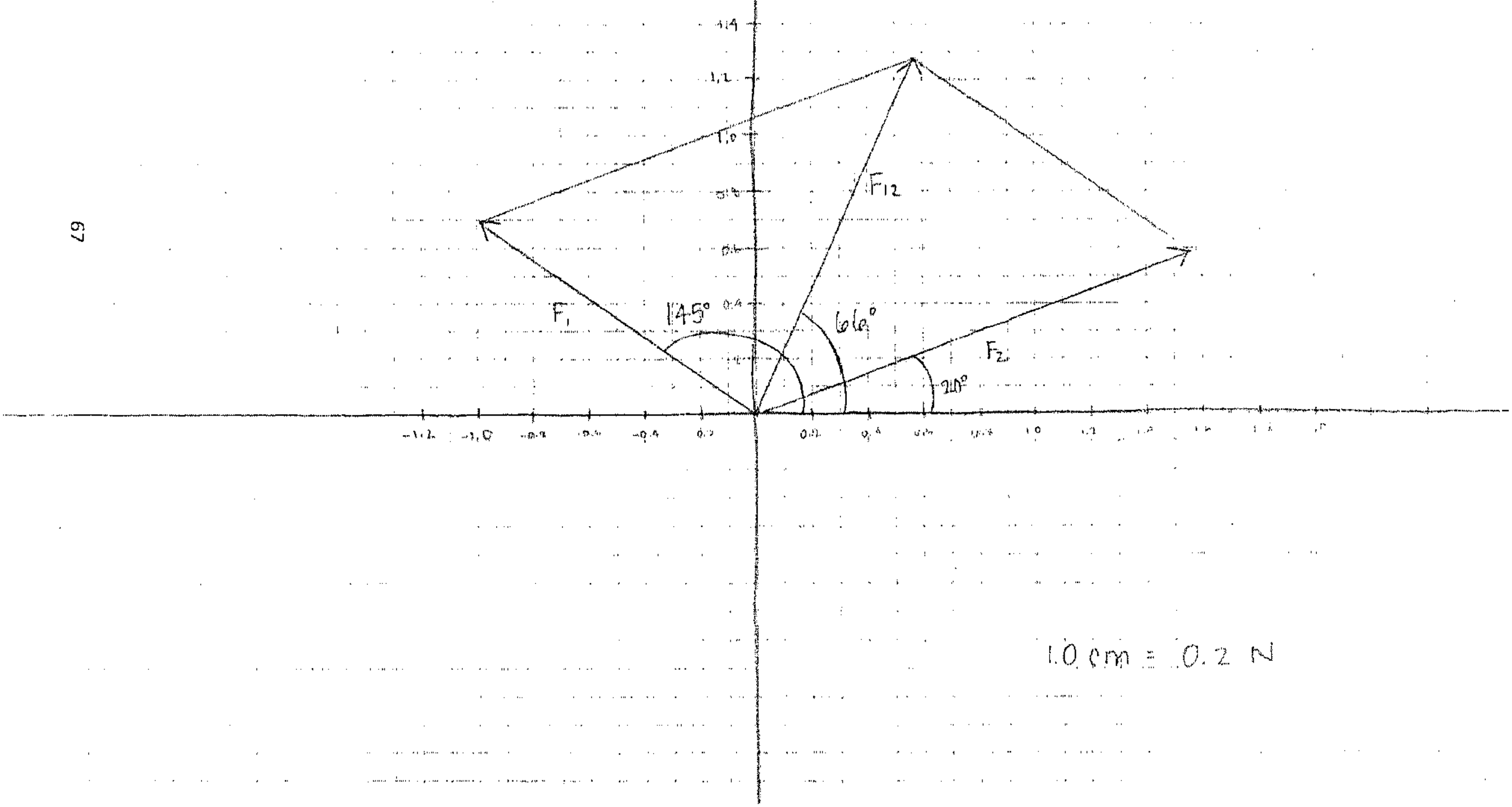
$$\frac{|64.7° - 66.0°|}{64.7°} \times 100\% = -2.0\%$$

I presume that we weren't asked to perform this set of calculations because the percent errors vary immensely. From -2.0% to 450%, it is difficult to draw conclusions from values that are so vastly different. Q5

Pre lab #3

PHY 223 lab3
Vectors 1 & 2

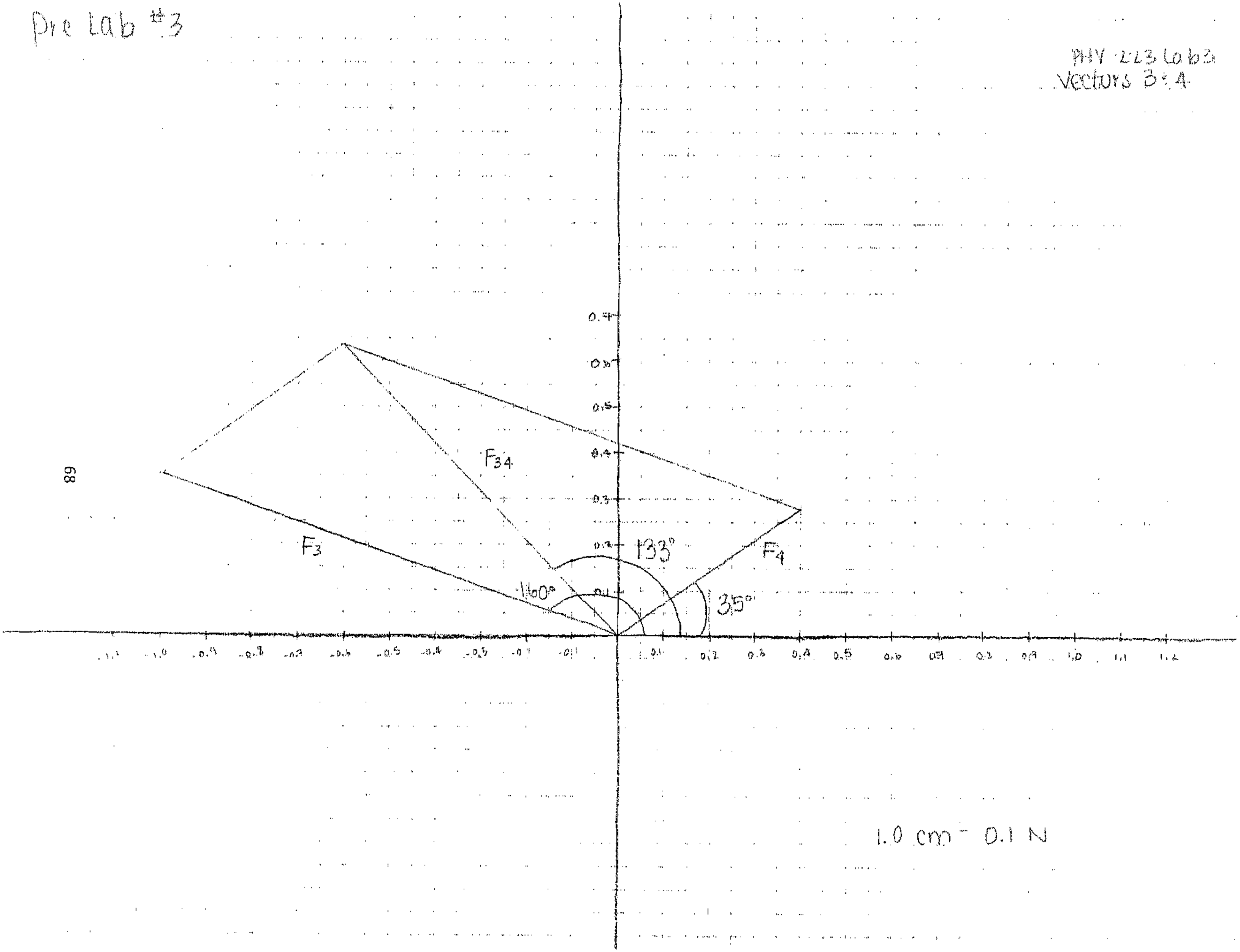
DJB



1.0 cm = 0.2 N

Pre lab #3

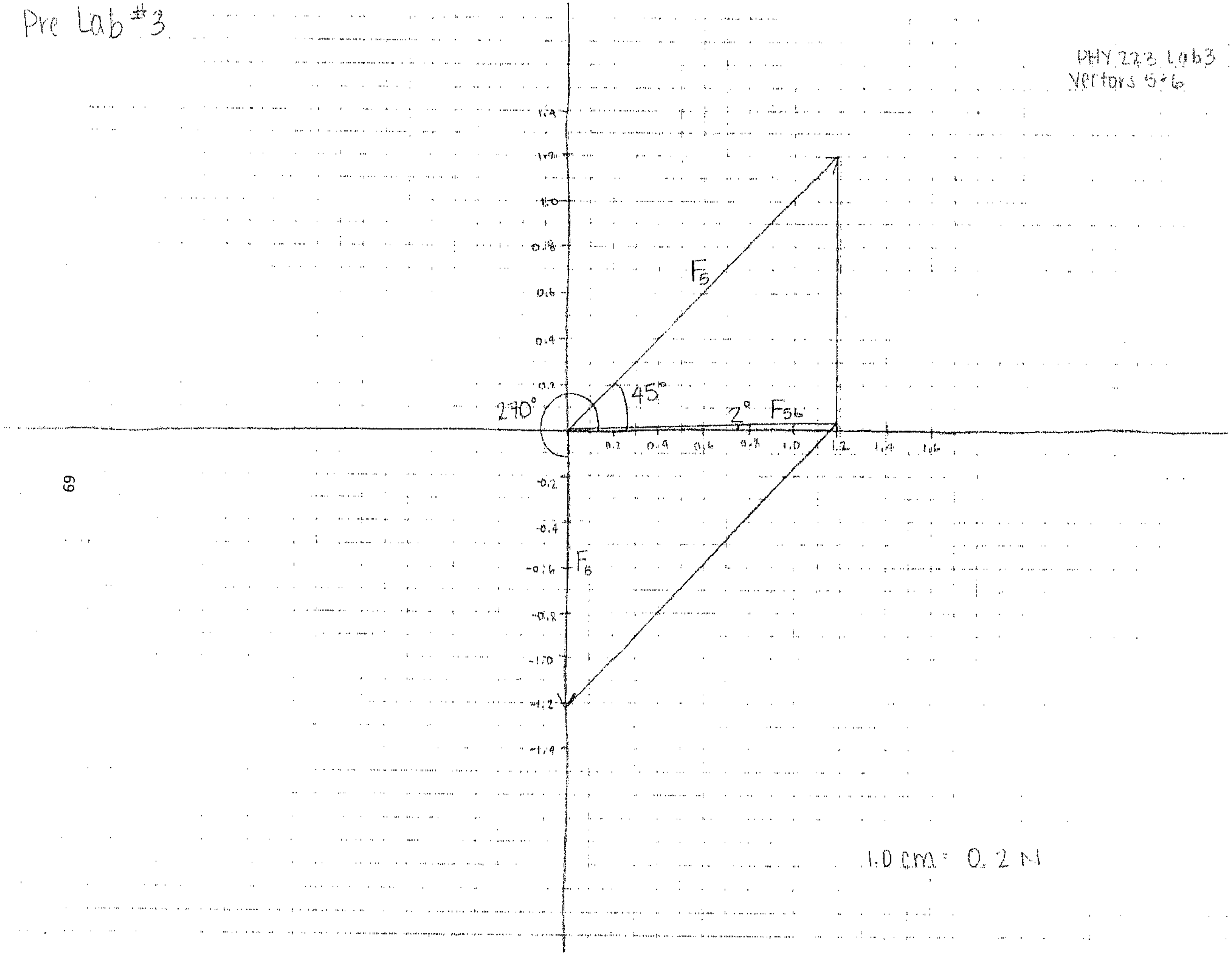
PHY 223 Lab3
Vectors 3 & 4



1.0 cm = 0.1 N

Pre Lab #3

PHY 223 Lab3
Vectors 5+6



Pre Lab #3

Vector	Mass (kg)	Force (N)	Direction
F_1	0.125	1.225	145°
F_2	0.175	1.715	20.0°
Resultant F_{12}	—	1.42	66°
F_3	0.110	1.078	160°
F_4	0.050	0.49	35.0°
Resultant F_{34}	—	0.885	133°
F_5	0.175	1.715	45.0°
F_6	0.125	1.225	270°
Resultant F_{56}	—	1.20	2°

Figure 1. Results of Parallelogram Method

Vector	Mass (kg)	Force (N)	Direction	x component	y component
F_1	0.125	1.225	145°	-1.003	0.703
F_2	0.175	1.715	20.0°	1.612	0.587
Resultant F_{12}	—	1.43	64.7°	0.609	1.29
F_3	0.110	1.078	160°	-1.013	0.369
F_4	0.050	0.49	35.0°	0.401	0.281
Resultant F_{34}	—	0.89	133°	-0.612	0.650
F_5	0.175	1.715	45.0°	1.213	1.213
F_6	0.125	1.225	270°	0	-1.225
Resultant F_{56}	—	1.213	-0.57°	1.213	-0.012

Figure 2. Results of Component Method

Due w/ lab 3
5/17

PHY 221/223 Laboratory Homework Assignment #2

Scientific reports rely heavily on presenting information visually. Tables, charts, graphs, sketches, photographs, and illustrations are the staples of scientific communication. There are three primary reasons for choosing to present information visually:

- To make deciphering information or analysis of information easier.
- To describe relationships among data that are not apparent through other means.
- To communicate visual aspects of a phenomenon or apparatus.

Once again imagine that you have collected the data shown in Table 1 below. The data come from the measurement of the forces on an object in circular motion. This data will be similar to some you collect in Experiment #7. Just as in the first assignment, do not worry if you do not know the physics, use the equations below the table; this is an Excel exercise, not one in physics.

Your TA will show you, in lab, how to put a constant in an Excel spreadsheet, how to calculate values using the constant, how to graph data and how to create a trendline from a graph.

Type the following set of data into an Excel spreadsheet and do the calculations. Staple this page, a printout of your completed table, a printout of your formulas and a printout of your graph (with a trendline) to the end of your report for Experiment #3. This assignment is worth two points of the twelve you can earn for Experiment #3.

Hanging Mass = 0.521 kg

Radius (m)	Period (s)	Force (N)
0.1100	0.7721	
0.1220	0.7741	
0.1339	0.7762	
0.1459	0.7783	
0.1577	0.7806	
0.1696	0.7830	
0.1821	0.7856	
0.1943	0.7891	
0.2056	0.7921	
0.2179	0.7956	

Delete label = key

Title goes <u>below</u> graph

Table 1. Data and calculations from rotational motion of a mass.

axes y Force (N)
x Radius (m)
major & minor gridlines
(vert & horiz)

trend line polynomial (2nd order)
linear fn automatic
☑ display eqn on chart
change y = _x to F = _r

Hanging mass = 0.521 kg

Radius (m)	Period (s)	Force (N)
0.1100	0.7721	3.80
0.1220	0.7741	4.19
0.1339	0.7762	4.57
0.1459	0.7783	4.95
0.1577	0.7806	5.32
0.1696	0.7830	5.69
0.1821	0.7856	6.07
0.1943	0.7891	6.42
0.2056	0.7921	6.74
0.2179	0.7956	7.08

Average period:
0.7827 sec

Table 1. Data and calculations from rotational motion of a mass

Hanging mass = 0.521 kg

Radius (m)	Period (s)	Force (N)
0.11	0.7721	=(39.48*D2*C5)/(D5^2)
0.122	0.7741	=(39.48*D2*C6)/(D6^2)
0.1339	0.7762	=(39.48*D2*C7)/(D7^2)
0.1459	0.7783	=(39.48*D2*C8)/(D8^2)
0.1577	0.7806	=(39.48*D2*C9)/(D9^2)
0.1696	0.783	=(39.48*D2*C10)/(D10^2)
0.1821	0.7856	=(39.48*D2*C11)/(D11^2)
0.1943	0.7891	=(39.48*D2*C12)/(D12^2)
0.2056	0.7921	=(39.48*D2*C13)/(D13^2)
0.2179	0.7956	=(39.48*D2*C14)/(D14^2)

Average period:
=AVERAGE(D5:D14)

Table 1. Data and calculations from rotational motion of a mass (with formulas)

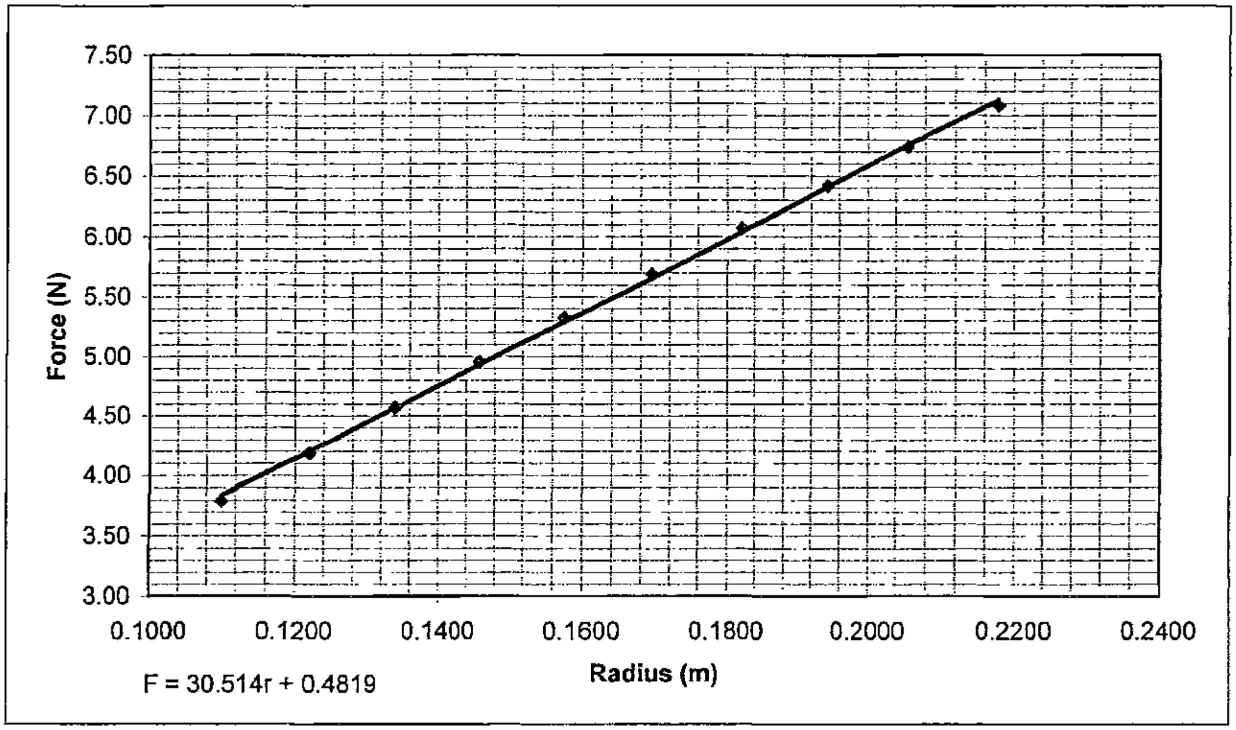


Figure 1. Graph of Force (N) vs. Radius (m) with trendline

Lab Report Grading Rubric for PHY 221/223 Experiment #3

Poor — Excellent

Section Pts	Section							Section Score
0	**Cover Page**	-0.5	-0.4	-0.3	-0.2	-0.1	0	0
	Includes the five required elements						✓	
2	**Abstract (≤ 75 words)**	0	0.2	0.4	0.6	0.8	1	2
	Abstract conveys a sense of the full report -a person should be able to read the abstract (perhaps in a library of lab reports) and understand the objectives and outcomes of the experiment.						✓	
	The abstract should be no more than 75 words long. Please provide a word count.						✓	
4	**Introduction**	0	.20	.40	.60	.80	1	4
	Effectively presents the objective and purpose of the lab						✓	
	Successfully discusses the general principles and laws						✓	
	Successfully describes equations and their uses						✓	
	Discusses the role of the equipment						✓	
2	**Results**	0	0.1	0.2	0.3	0.4	0.5	2
	Effectively describes, in a couple of sentences before each table or drawing, how the data was obtained or the table was drawn.						✓	
	Presents visuals (tables & graphs) **typed** clearly and accurately -all tables and graphs should have appropriate titles -briefly describes trends seen in tables and/or on graphs						✓	
	A sample of each required calculation is shown (read the lab manual carefully to identify all the necessary calculations) **-all equations should be typed and appear as they would in a physics textbook** **-used correct units** & significant digits -calculated answers are correct						✓	
	Correctly identifies at least two specific sources of error. Successfully discusses how each error would affect the measured and calculated outcomes.						✓	
1	**Questions**	0	0.2	0.4	0.6	0.8	1.0	1
	Questions presented in the lab manual are answered correctly and thoroughly. (This week number your answers.)							
1	**Calculations Using Component & Parallelogram Method**	0	0.2	0.4	0.6	0.8	1.0	1
	Student has correctly completed the calculations **BEFORE** coming to lab.						✓	
2	**Excel Calculation & Graphing Homework**	0	0.4	0.8	1.2	1.6	2.0	2
	Completes calculations; submits spreadsheet with formulas & graph						✓	
0	**Grading Rubric**	-0.5					0	0
	Student has downloaded and attached the correct rubric						✓	
	Penalty for late submission							

Points Earned	12