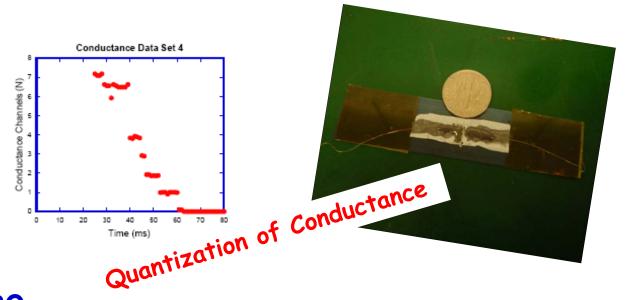
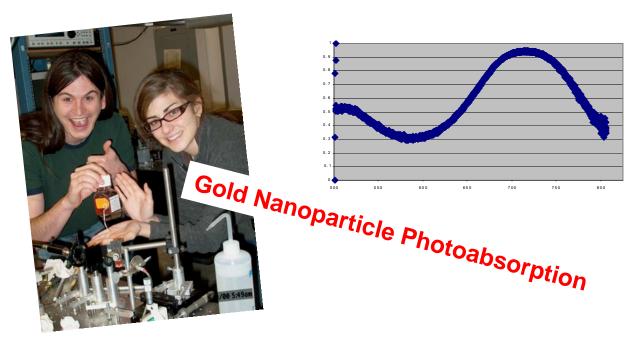
## BFY Conference



# W20: Frontiers in Contemporary Physics Education

Jan Yarrison-Rice & Khalid Eid Physics Dept. Miami University, OH



## **Frontiers in Contemporary Physics Education: Gold Nanoparticle Photoabsorption & Quantization of Conductance Experiments**

Jan Yarrison-Rice and Khalid Eid, Physics Department, Miami University

#### **Abstract:**

This BFY workshop highlights the new pedagogical format of our sophomore Experimental Contemporary Physics course. We strive to provide a strong underlying core of experimental skills in modern topics and, at the same time, encourage students to join faculty research groups. We follow a physics research model using experiments that explore contemporary physical concepts from ongoing faculty research projects. The experimental format shows students "how physics research is actually conducted!" The two experiments we will highlight, 1) Optical characterization of Au nanoparticles, and 2) Quantization of Conductance, were developed as a direct result of the nanoscience and technology research the co-leaders conduct in their own laboratories. Using this basic curricular plan, the course maintains a truly contemporary nature, while providing an introduction to the concepts and instrumentation skills necessary for our students to begin physics research.

- 1) We explore how surface area, volume and shape change material behavior via optical spectroscopy of Au nanospheres and nanorods (NPs). White light induces a plasmon resonance in the metallic NPs which is measured spectrally. The transmission and scattering spectra of the Au NPs provide a measure how the spectral plasmon resonances reflect the particle morphology. The basic optical setup requires a fiberoptic light source and a reasonably inexpensive spectrometer, as plasmon resonances are quite broad. The excitation of charge carriers in a semiconducting nanowire is introduced next. Finally, both concepts are brought together by describing their application in a plasmon-enhanced nanowire-based biosensor. Students enjoy the visual nature of this experiment and the opportunity to align an optical system.
- 2) We demonstrate an extremely simple and inexpensive experiment to introduce atomic-scale confinement effects and particle-wave duality. A manual break junction in a gold wire is utilized to explore the quantization of the electrical conductance when the wire width is stretched to the atomic limit. A simple circuit reads the voltage across the break junction via LabView. Just before the wire breaks, the lateral confinement of the conduction electrons causes a step- wise increase in resistance with steps that depend on two fundamental constants of nature divided by an integer. This is due to the wave nature of the electrons that traverse the junction. This experiment is exciting for students because they can measure a complex idea like wave- particle duality with objects that they can "see."

In addition, we discuss how small adjustments make the experiments appropriate for more advanced students.



#### COURSE LOGISTICS

#### Phy 293: Frontiers in Experimental Contemporary Physics

(An experimental Physics laboratory course for students completing the 180s courses)

#### Jan Yarrison-Rice & Khalid Eid

Two faculty members with experimental research foci co-teach Phy293 for  $2^{nd}$  Year Undergraduates. This course is the experimental equivalent of the Modern Physics Lecture Course which focuses on the early underpinnings of quantum mechanics and associated theory.

At Miami University Physics Department, we generally have between 25-35 second year students, so the laboratory course has to be designed to handle these large numbers. This is done by providing a 70 minute class period on a Monday with ~15-20 minutes for post-lab questions and analysis discussions (from previous week's lab), and ~50 minutes for a pre-lab lecture for the experiment coming up that week. Then we break the group into 3 lab sections of ~10 students which meet for 2 hours on Wednesday and Thursday on the experiment being conducted each week. This allows students to work in groups of 2-3 depending on the lab. We use two faculty members to divide the teaching load.

Jan Y-R usually leads the post-lab discussions and gives the pre-lab lecture before the next lab, however both instructors come to the lecture to be involved in the students' discussions. Then the lecturer teaches 1 lab section and the co-instructor teaches the remaining 2 lab sections. Two graduate students are assigned as TAs to assist in experimental setups, to be part of a two-person instruction team for each lab section, and then to grade the pre-lab and subsequent lab reports. From the 2<sup>nd</sup> year onward, all undergraduate labs are taught by faculty members and depending on the class size, experimental complexity, etc. may have a graduate student assigned to assist in different ways. We make a strong commitment to having our students be guided by faculty members throughout their undergraduate careers at Miami.

Undergraduate students are an important part of each Miami Physics faculty research group. While some students begin doing research in their first year, it is more common for students to join a research lab in their second year. Thus, Phy293 has an additional goal besides teaching the fundamental experiments in Contemporary Physics – the goal of introducing students to some of the experimental instruments, techniques & analysis approaches, to research protocol, and to experiments that relate to the work being conducted by each faculty member.

#### COURSE SYLLABUS

#### Phy 293: Frontiers in Contemporary Experimental Physics

(An experimental Physics laboratory course for students completing the 180s courses)

#### Fall 2012

**Instructors:** Dr. Khalid Eid Dr. Jan Yarrison-Rice

Office: Rm. 35 Rm. 21

Email: <a href="mailto:eidkf@muohio.edu">eidkf@muohio.edu</a> <a href="mailto:yarrisjm@muohio.edu">yarrisjm@muohio.edu</a>

Phone: 9-1933 9-1862

#### Welcome to Physics 293!

This course is a 2 Credit Hour experimental contemporary physics course which includes 1 hour of lecture each week and a 2 hour laboratory section. Although it is related to the Physics 294 course you are taking, it is an independent course which focuses on learning contemporary physics like it is learned in experimental research laboratories. History tells us that many new physics ideas were first explored in the laboratory, and then modeled by theorists. At other times, theorists predict certain behaviors for physical systems which are then confirmed experimentally. It often depends on the "state-of-the-art" for each branch - meaning when do bright minds find the right tools to study particular physics questions. Are the latest theoretical constructs and methodologies ready to explore an idea? Is there sufficient computational speed, memory, etc approach the problem? Or Are experimental instruments developed to such a stage that they can be used to investigate the physics behind a new thought or observation? Is it possible to design, fabricate, and or put together new samples, devices, or full experimental set-ups at this time? Do they have they have the resolution, the signal strength, the analysis capabilities to understand new results?

Physics 293 uses the laboratory environment to explore modern physics. Physics 291 and 286 approach modern physics and computational physics from a theoretical viewpoiont. In this class, we provide an opportunity for you to conduct a series of experiments that contain a mix of fundamental twentieth-century ideas beginning with quantum mechanics, to recent twenty-first century physics. Questions being asked in research labs across the world right now!

#### **Introduction to Phy293:**

The course, Phy293: Contemporary Experimental Physics Lab, is an independent laboratory course which follows the first-year Introductory University Physics course. In that course you already have received an introduction to some of the fundamental ideas used in twentieth-century physics, including quantum mechanics, statistical physics, and relativity. Phy291: Contemporary Physics focuses on physics in the past 100 years, but from a theoretical viewpoint. Our objective for Phy293 in this term is to develop and apply these ideas in an experimental setting; to help you gain experimental skills that will be useful for advanced lab courses, but also skills that are particularly usesful in the different research labs at Miami. Therefore, the emphasis will be on learning modern physics topics while developing strong experimental capabilities such as knowledge of techniques, instrumentation, data analysis and drawing reasoned conclusions.

In order to appreciate the *significance* of the new results, we need some more physics "language," part of which will be supplied through Physics 291, and part in the laboratory. You will gain an experimental understanding for ideas in quantum mechanics, atomic and solid state physics, and nuclear physics. The ideas presented are chosen with the goal of understanding specific recent research being conducted in faculty research labs.

The Experimental Physics Fundamentals in Physics 293 include 1) quantization of atoms and molecules, 2) behavoirs of atoms, molecules and solids, 3) how quantum effects are used in characterizing materials and devices, 4) when to use VIS-NIR light, xrays or gamma rays, or electrons to study materials and how they are applied in various research situations from spectrocsopy to ceramic strengths and medical applications to nanophysics, 4) electric & magnetic materials, as well as insights into nuclear structure.

The research techniques on which we will focus are

- Spectroscopic Techniques for Gaseous and Solid Samples
- Characterization Techniques for Various Samples
- Other Quantized Systems in Electronic, Magnetic & Nuclear Physics

The samples you investigate will come from a variety of sources reflecting faculty research areas: gases, molecules, biosamples, nanosamples, semiconductors and magnetic samples.

Because Y	OU a	isked f	or i	it!	•••••	•
-----------	------	---------	------	-----	-------	---

As a result of student input from the past few years, we have created a general approach to Physics 293 that mimics how experimental research is conducted by physicists across the world. Our goals include providing you with specific research and analysis skills, as well as reporting skills; what some might call critical thinking skills. You will do background reading via journal articles related to the research topic. We will provide more time for you to work with, think about, analyze and reach conclusions about the experiments you run, and we have you conduct fewer experiments throughout the course to enable this process. We will focus on the physics questions being investigated, equipment/detection systems, and their use in several different types of experiments. You will have time each week during lecture to discuss questions which arise after you have left the lab, so that you gain a fuller understanding of the work you are doing.

#### The Importance of Communication:

Finally, you will present your research results to your lab section at the conclusion of each group of experiments in the form of a group PPT presentation like at a conference, and the next week with a lab write-up which is similar to a research journal article (but with more of the "gritty" details that a real manuscript would not contain, so we can check your understanding of the fundamental physics behind your experiments.) After all, the ability to effectively communicate about your work is an essential skill in any career you may ultimately choose.

In Physics 293, you must be comfortable describing your experimental procedure, analysis, results and conclusions, both verbally and in writing. Being a scientist, does not mean hiding in a laboratory or behind a computer all the time!! Communication skills are important for all physicists - Otherwise, how would you become well-known in your area of expertise? You will be speaking or writing to clients, other scientists, or the public. You will need to seek funding for your new projects, even in the private and government sector. You will use these skills if you are a lobbyist, a lawyer, a doctor, a physicist, an engineer, a teacher, or a technical writer. So, communication of ideas and results is an integral part of the scientific process, just as having a new question to probe or knowing the background literature (research already done in the area), or actually conducting the experiment and analyzing your results. Physics encompasses all these skill areas.

This course is structured to provide you with the opportunity to experience experimental physics research through the way we group experiments and have you prepare for, run, and then report on the different experiments. We will have the experiments set-up for you, as the time required for this additional step is too long for the scope of this 2 credit hour class. Your job is to understand how the instruments work and the best way to run your experiment for the cleanest, reliable data.

## Research Opportunities at Miami will be Highlighted througout Physics 293

Remember, Physics 293 is an experimenal laboratory course, used to introduce contemporary physics topics, as well as to teach some of the skills necessary for conducting research in those fields. The Miami Physics website has links to each faculty member's basic research information, although these are not always completely current. (<a href="http://www.muphysics.org/">http://www.muphysics.org/</a>) Physics 293 will provide a "starter" set of skills for being able to do research in faculty research labs. Some of you may already have started working for a faculty member, but those of you who have not, should consider approaching different faculty and joining a research group.

#### General Format of Course:

- Each week, you will read literature or other background information on the upcoming experimental area
- The first week of the experimental area will introduce the basic physics and allow you time to learn about the equipment/detection system to be used
- Three related experiments will then be conducted in next three weeks
- You are to focus on data analysis and utilization of your understanding of equipment, experimental techniques and/or detection for best analysis and realiable conclusions
- The final week, groups from each lab section attend a "conference" to present PPT based talks on one of the experiments from the collection in the three main areas. you will provide some background/reasoning behind taking such measurements, the experimental technique (its calibration/resolution/limitations/inherent errors), your data, description of the analysis, graphs/tables/images which result from the analysis and lastly your conclusions. The rest of the lab group will ask questions for you to answer. We will discuss each experiment and the results as a group.
- Following the PPT presentation, you will edit your full lab report utilizing the
  discussions from your talk to complete a journal style report to hand in the next
  week.
- This will complete the "representative" research process

For each of the three different techniques or foci listed above, we will complete this full process.

#### Thus,

#### Grading:

- Each week pre-lab assignment: 10 pts each
- Lab manual to keep data in → checked for content before leaving lab
- Spreadsheet analysis with initial analysis each week 25 pts each
- ullet 3 PPT presentations of your experiment the week before the full report is due

50 pts each

• 3 groups of three experiments → 3 Full Reports 100 pts each

#### <u>Pre-Lab Assignment - Handed in at Lecture</u>

- Articles and/or individual pre-lab assignments will be posted on Niihka under the Resources section of the website menu.
- Read the article, analyze, hand in at lab lecture each week.

For Article Analysis include the following:

- Full citation of article: "Article Title," Authors names (First Initial. Last name), Journal Title, Vol. # (59) in bold, Inclusive pagination (133-135 or article # 12245[1-3]) (Year).
- Bullet points of Main Points of Article (phrases are good)
- Copy of Figure you find most interesting
- Description of figure (again bullet points), information found there, and conclusions it leads you to
- Conclusions from article

Other assignments will have directions independently provided, but will still be worth 10 pts each.

#### Before Upcoming Experiment's Lecture:

Everyone will have time to ask questions and discuss the experiment that they will have to hand in as a Weekly Lab Report  $\sim$ 15-20 min.

#### Weekly Experiment Lecture:

After discussions on past week's experiment, then the new experiments are introduced - some basic theory, description of experimental technique and analysis, and identification of possible trouble spots.

# Come to Lab having READ the Experiment for the Week in ADVANCE in order to Conduct your Experiment in a TIMELY Manner!!

#### Weekly Lab Reports: In bullet or outline form

- Data Graphs, Spectra, Images, etc.
- Spreadsheet with calculations, graphs of data (if needed)
- Sample hand calculations and other analysis
- Discussion of resolution, error, and how results are affected
- Conclusions you have drawn

#### PPT Presentations: Done by groups in Conference Style Format

- Should include information from your weekly lab report including answers to questions given to you in the lab manual.
- Each person in the group should provide input to the presentation
- Each person in the group will present part of the PPT
- Each person will entertain questions from the rest of the class and instructors.
- Presentations should be ~15 min. long and include references.
- Any figures from articles or the lab manual must be referenced.

#### Full Lab Reports

Your written report is to summarize your work in the lab and present the results in clear form emphasizing their significance. Your report is expected to adopt the following standard format, and to be written in a clear and concise manner. In each group of experiments, a single lab report will be written based on the first lab your group works upon.

#### Report Contents based on Physical Review Journal:

#### 1. Title Page

Title of experiment, your name and the name(s) of your lab partner(s), and an abstract giving a brief (less than 100 words) summary of the experiment and the results.

#### 2. Introduction

This part contains a general introduction to the topic and background information from articles, your book, or other readings/websites. You should explain the significance of the experimental problem and put it in context.

#### 3. Experimental Set-Up & Procedure

A brief description or outline of the experimental system with experimental steps and techniques used. The system's calibration, resolution, or other information which will be important to know when analyzing data should be provided in this section.

4. Data Presentation of your experimental data and results in a way that helps the reader understand. Most of the time you will present data in form of a graph or a table. When the result is in form of a spectrum, a copy or computer printout should be included. You are expected to provide and justify an estimate of experimental uncertainty ("error bars") in your results.

#### 5. Analysis and Discussion of Data

Explanation of your interpretation and a discussion of the significance of the results. You should consider your system's limitations, any errors that you noted while taking data, and any important information which assists in interpreting the data in your report.

#### 6. Conclusion

A conclusion should be written for each report in which you restate the important findings of your experiment and discuss how the results inform you on the general topic of your study section. You might also suggest other directions one might take if there were more time, or things you would have done differently to positively affect the results.

Now let's go explore the experimental contemporary physics world!

#### **Phy293 Experiments**

**Experiment 1: Critical Thinking, Plagiarism, Graphing and Error Analysis**Jennifer Blue's Research in Physics Education

First Experimental Focus: Spectroscopic Techniques for Gaseous and Solid Samples

**Experiment 2: Introduction to Spectrometers -- the Hydrogen Balmer Series** 

Experiments 3-5: D-Lines of Alkalai Atoms, Magnetic Fields & Stellar Spectra, Laser Induced Flourescence (LIF) & Saturated Absorption in Iodine, & Absorption and Scattering of Au Nanoparticles

Theorists: Steven Alexander, James Clemens, & Perry Rice; Experimentalists: Burcin Bayram, Samir Bali, Jan Yarrison-Rice

PPT Presentation by Lab Groups & Individual Journal-style Full Lab Reports

Second Focus: Characterization Techniques for Various Samples

Experiment 6: Activities on how AFM, STM, TEM & Xray Diffraction work

Experiments 7-9: AFM of Target and Microcircuit Sample, STM of Graphite and DNA Molecule, and X-ray Spectra of Cubic solids & Study of Medical Xrays

Experimentalists: Herbert Jaeger, Paul Urayama, Khalid Eid, Michael Pechan, & Jan Yarrison-Rice

PPT Presentation by Lab Groups & Individual Journal-style Full Lab Reports

Third Focus: Other Quantized Systems in Electronic, Magnetic & Nuclear Physics

Experiments 10-12: Magnetic Thin Films, Quantization of Nuclear Energy States, & Quantization of Electronic Current

Experimentalists: Herbert Jaeger, Michael Pechan, & Khalid Eid

PPT Presentation by Lab Groups & Individual Journal-style Full Lab Reports

# Assessing Student Learning in Phy 293 Frontiers in Experimental Contemporary Physics [or] The Research Model = Critical Thinking

Developed by
Herbert Jaeger & Jan Yarrison-Rice
Physics Department
Miami University, OH

# Project Began in Fall 2006 Assessing Student Learning In Phy293: Frontiers in Experimental Contemporary Physics

#### Herbert Jaeger & Jan Yarrison-Rice

#### **Pedagogical Approach:**

We began our project with the goal of assisting students to develop critical thinking skills. What began with adjusting 3 labs in the semester (out of 12 total) to have more depth and questions with a higher complexity level, i.e. which required critical thinking to be successful, soon changed into a serious revision of the course as a whole. As described in the Course Syllabus, we view the steps one takes in fundamental research as being, in fact, critical thinking skills.

By 2010 we began teaching Phy293 using a research model throughout the semester. We looked at the different research that faculty were conducting and chose experiments which were directly related or were first steps in understanding the ongoing research in the Department. We found common instrumentation, data analysis approaches, or research topics and developed experiments that took advantage of faculty expertise. Different faculty were consulted and assisted in the individual write-ups for particular experiments. We then edited them to fit our perceived ability of second year students to develop the skill sets necessary to conduct and understand the experiments. Lastly, we grouped like experiments together as described in detail in the course syllabus.

In a given semester, we can assess student learning by applying a general grading rubric to the journal-style full reports and the PPT presentations. We also survey student perceptions both with written anonymous surveys and with class discussion at the end of the course. The written questions keyed into the students' learning and study habits as well as the effectiveness of the learning environment, while the full class discussions provided detailed feedback for course improvements of a different type.

Students were surprisingly open to comment on their likes and dislikes. - What they feel worked well in the course and what suggestions they had to improve things. A single student comment often lead to a full class discussion with ideas bouncing back and forth. This provided us with a better, more fluid and more in-depth commentary to base improvements upon for the next semester the course was offered.

#### **Analysis of our project:**

1. Assessment of student lab write-ups was accomplished by using the **Scientific Inquiry** Rubric for Assessing Students' Critical Thinking Skills which was written by B.A.P. Taylor, Faculty Associate for Assessment, Miami University, Spring 2005. See Table 1A. This rubric was based on a more general critical thinking rubric from U. Washington. It used categories that were more specific to the scientific enterprise, in particular science research, to study student learning.

For Phy293 we modified two entries in the Scientific Inquiry Rubric. The original rubric was written for advanced labs and for students working in research labs to complete a research capstone experience (Table 1A). Because Phy293 is a 2nd year undergraduate course in which students have only 2 hours to complete a particular experiment in the lab (after a 1 hour lecture earlier in the week), some entries in the rubric were not appropriate for the Phy293 setting and were changed as noted in the Table 1B.

The rubric is scored using a student's written or presented work on a scale of 4. Half steps are allowed in the assessment, so scores can vary from 0 - completely lacking to 1.5 to 3 for instance.

- a. Completely lacking was assigned a 0.
- b. Inadequate development 1
- c. Minimal development 2
- d. Moderate development -3
- e. Substantial development 4
- 2. We used a Student Survey about the class as seen in Table 2.

Students were asked a total of 15 questions about the course. We have questions about our extra discussion times before lab lecture each week and their impressions of how helpful the discussions were in promoting critical thinking. Obviously the survey can be modified in a number of ways to study whatever areas of inquiry or your course you might have for your own lab class.

On the survey we found the following trends to be interesting:

- Students reported that they seldom prepared rough drafts of their reports before the discussion in class.
- Students did not want to have rough drafts required.
- The course received high scores on questions about how useful the discussion had been to increasing their understanding of the experiments and underlying physics, and to better interpretation of experimental results.

#### Table 1A: Original Scientific Inquiry Rubric for Upper Level Undergraduates

- 1) Identifies and summarizes the problem/question to be investigated.
- 2) Identifies existing, relevant knowledge and views.
- 3) Uses appropriate equipment and experiments to collect data.
- 4) Analyzes data in an appropriate manner.
- 5) Draws sound inferences and conclusions from data.
- 6) Reflects on own work to assure that conclusions are justified.
- 7) Suggests steps for further inquiry.

#### Table 1B: Assessment Rubric as Revised for Phy293 - a 2nd Year Lab Course

- 1) Identifies and summarizes the problem/question to be investigated
- 2) Identifies existing, relevant knowledge and views
- 3) Understands how equipment works to collect data for instance, system calibration, resolution, sources of error, ways to reduce systematic error

This rubric entry was changed due to the manner Phy293 is setup -- e.g. experiments are already setup prior to students coming to lab since 2 hours is not enough to setup and run experiment and begin data analysis. Also we are just starting to show students research methodology, so they are really novices in this advanced lab situation.

- 4) Analyzes data in an appropriate manner
- 5) Draws sound inferences and conclusions from data
- 6) Reflects on own work to assure that conclusions are justified

We found that students were not generally ready to make this intellectual step in the 2nd year

7) Ways to improve the Experiment -- these needed to be a substantive thought about the instruments, error, calibration or resolution. Also thoughts about analysis methods would satisfy this step.

Here the student's suggestions for improvements to the experiment was considered sufficient for 2nd year students and the lab style. Students were not always thinking in the direction of the original rubric which was more in tune with the advanced students laboratory experience level.

Scoring Scale: 0 - completely lacking

1 - inadequate

2 - minimally developed3 - moderately developed4 - substantially developed

### Example of How to Judge Scoring for Some Elements in Scientific Inquiry Rubric\* \*We describe scores 1-4, as a 0 is self-explanatory

For instance, in Category 1: Identifies and summarizes problem/question to be investigated

**Inadequate:** Question identified is too broad or vague to relate to the experimental design.

**Minimal:** Has identified an appropriate question, but lacks a clearly stated hypothesis. Experimental plan is present in a broad outline, but lacks specifics.

**Moderate:** Uses prior knowledge to identify a question to be studied. Has a clearly stated hypothesis. Breaks the question down into smaller steps but may not identify which parts of the experiment or analysis will address these steps.

**Substantial:** Uses prior knowledge to identify a question to be studied. Has a clearly stated hypothesis. Breaks the question down into smaller steps, and is able to identify which parts of the experiment or analysis will address these steps. Can see some of the subtleties or complexities that will come up in the experiment.

This should provide the flavor we used to describe each of the 7 critical thinking skills as evidenced in the Phy293 Frontiers in Experimental Contemporary Physics laboratory course.

#### Table 2: Phy 293 Critical Thinking Development: Student Survey

- 1) At the time the discussion took place (the Wednesday after the lab exercise) did you have a draft of your report prepared?
- 2) Was this draft a near-final version or more like a (very) rough draft?
- 3) Did you do substantial or minor editing as a result of the discussion?
- 4) Did the discussion help to clear up some points that you were unsure of?
- 5) Would you be in favor of "enforcing" that students have a draft report at the time of the after-lab discussion? (i.e. we would collect the draft report after the discussion)
- 6) The prelab exercises helped me think about the kinds of results I expected for the experiments.
- 7) In order to answer the prelab questions, I always had to read the lab manual.
- 8) In order to answer the prelab questions, I always had to read the lab manual **and** another source (PHY291 textbook, PHY291 notes, websites, etc.).
- 9) Preparing powerpoint-slides for the after-lab discussion was helpful for my data analysis.
- 10) The after-lab discussion added to the understanding of the experiment.
- 11) The after-lab discussion was helpful for the data analysis.
- 12) The after-lab discussion was helpful for conclusions of the lab exercise.
- 13) The after-lab discussion helped me decide if my conclusions are justified.
- 14) The after-lab discussion made me look back at the experiment as a whole and consider how my conclusions fit into the science we were doing.
- 15) Do you think it would be beneficial to the course as a whole, and for the students enrolled in it, were this model (i.e. discussion after lab) expanded to the entire course?