Note: This syllabus serves as an outline and a guide for our course. Please note that I may modify it with reasonable notice to you. I may also modify the Course Schedule to accommodate the needs of our class. Any changes will be announced in class and posted on Canvas under Announcements.

Instructor: Wayne Springer 216 PHYS, (801)585-1390
wayne.springer@utah.edu (prefer Canvas Mail)
Office Hours: Thurs 1PM-5PM or by Appointment

Lab Technician: Zhiheng Liu 192 INSCC, (801)581-7001
zhliu@physics.utah.edu

Lecture: Tue 2:00 PM → 3:20 PM, Zoom Meeting Space

Lab: Thur 12:55PM→5:00PM, Your residence, Instructor on Zoom for consultation * First meeting (8/20) will be at East Entrance of South Physics Building

Canvas Page: https://utah.instructure.com/courses/633891

Required: Pick up materials from the east entrance of the South Physics Materials building on 8/20/2020 at 12:55PM. Reading materials will be made available on Canvas, the classroom and Library Course Reserves.

Prerequisites: PHYS 2235 AND PHYS 3740 AND MATH 2250

Designation: Quantitative Intensive BS. 4 Credit Hours

COURSE DESCRIPTION (from University Course Catalog).

A two-component course which includes: i) a lecture component covering data and error analysis and topics related to experimental procedures and scientific communication (papers and presentations) ii) a laboratory component in which these techniques are applied to actual experiments and provide a deeper understanding of theoretical material covered in lecture courses. Students will be introduced to the craft of experimental design with a focus on optimizing data-taking and analysis to understand the sources and significance of errors. Emphasis is on developing independent research skills and understanding the interplay between experimental data and the mathematical models in which the experiments are performed to test. Students will conduct experiments that have been crucial in the development of the modern era in physics, such as the photoelectric effect and measurements of some fundamental constants of the universe. Critical thinking and scientific communication skills will be honed through the qualitative and quantitative justification of results via in-class presentations and the writing of scientific papers. The learning experience will be enhanced by having small groups of 2-3 students per experiment.
**COURSE DETAILS**

- **Course Type:** *IVC Hybrid* (synchronous online + in-person).
- **Location & Meeting Times:**
- **Mandatory In-Person Attendance (when allowed):** Currently, the lab rooms have been deemed unsuitable for in-person class activities. Therefore, we will meet at the scheduled times on Zoom (with the exception of an in-person meeting on 8/20 to pick up materials outside of the east entrance of the South Physics building). If we are still not allowed to meet in-person at the time that Experiment 3 data-taking needs to occur, the instructor will perform the experiments under the direction of the students over a Zoom conference call. If the campus is closed to everyone, including the instructor, data will be provided to the students for their analysis. In the event that we are allowed at some future time to meet in-person, given the nature of this course, attendance is required and adjustments cannot be granted to allow non-attendance. However, if you need to seek an ADA accommodation to request an exception to this attendance policy due to a disability, please contact the Center for Disability and Access (CDA). CDA will work with us to determine what, if any, ADA accommodations are reasonable and appropriate. Please do not come to class if you are experiencing COVID-19 symptoms. Remember to maintain social distancing at all times.
- **Attendance & Punctuality:** The participation and collaboration of all students is a necessary component of this course. Therefore, attendance is required for all class meetings whether on Zoom or in-person. Student lab group meetings will be facilitated via the class Zoom room (or by other means). It is expected that you attend and be punctual to your lab group meetings as well. Participation accounts for 5% of your grade.
- **COVID-19 Considerations:** Students must self-report if they test positive for COVID-19 via coronavirus.utah.edu.
  - In the event that the class does meet in-person, Please do not come to class if you are experiencing COVID-19 symptoms. Remember to maintain social distancing at all times. Face coverings are required for students and faculty. Based on CDC guidelines, the university requires everyone to wear face coverings in shared public spaces on campus, including our classroom. As a reminder, when I wear a face covering, I am protecting you. When you wear a face covering, you are protecting me and all of your classmates. If you forget your face covering, I will ask you to leave class to retrieve it. If you repeatedly fail to wear a face covering in class, I will refer you to the Dean of Students for a possible violation of the Student Code. Note that some students may qualify for accommodations through the Americans with Disabilities Act (ADA). If you think you meet these criteria and desire an exception to the face covering policy, contact the Center for Disability and Access (CDA). Accommodations should be obtained prior to the first day of class so that I am notified by CDA of any students who are not required to wear a face covering.
  - The instructor reserves the right to perform no-contact temperature checks, as well as ask about whether you experiencing potential COVID-19 symptoms such as loss of the sense of smell.
Course Materials: Our class Canvas page will provide the means for you to access reading materials as well as PowerPoint slides and videos.

- **Textbook:** There is no textbook required for purchase. However, there will be reading assignments from the recommended textbooks that will be available in the Marriott Library Reserves or online chapters on Canvas.

- **Additional course materials:** Equipment and supplies to perform experiments will be provided to you on Thursday August 20 outside of the east entrance of the South Physics Building at 12:55PM.

Technical requirements:

- Students are expected to be computer literate and Canvas and Zoom navigation skills are expected. Knowledge and navigation of canvas and Zoom is critical to access all features and resources of this course. It is recommended that students log into Zoom for class with audio and video enabled. Zoom meetings may be recorded for future reference.

- Course Canvas Page: Students are expected to log in and check canvas **everyday** for posted announcements and assignments. Students are also strongly advised to set up notifications for canvas.

- Please ensure that you connect to the Zoom meetings over a network connection of adequate bandwidth.

- You will be supplied with an Arduino processor. Arduino software will need to be installed on your computer (MAC/Windows/Linux and ChromeOS). The Arduino software is available from [https://www.arduino.cc/en/Guide](https://www.arduino.cc/en/Guide). The Arduino comes with a USB type B to type A cable. You may need an adapter or different cable to connect to your computer. Additional software to access SERIAL communication will be made available.

- Students are expected to use Python and/or Matlab (as well as Origin if necessary) for data analysis of their experiments as well as additional exercises that may be assigned. Ideally the student has access to this software on their computer. Access to Departmental computer servers with Python and MATLAB will also be available for students of this class.

- You may need additional hardware to mount some of the experimental equipment (such as the pendulum) at your residence. Contact the instructor for help if necessary.

COURSE PLAN AND GOALS

- Three initial activities and experiments (Introduction to Instrumentation, Surface Gravity and Geiger) serve as a warm-up on data collection and error analysis. Students will then choose one experiment from the set of possible advanced experiments listed below.

- Generally, students will not be provided with the experimental design. The overall objective of the course is to foster the ability of students to design an experiment, conduct the experiment, and communicate the results.

- To accommodate the independent skill development in the design of experiments, students will submit the introduction and procedure portion of their lab report after the first week of each lab exercise. The students will receive individual feedback to ensure that proper experimental design has been achieved. Good experimental design optimizes precision and accuracy with available resources.

- Students will conduct and analyze experiments in student groups to foster the ability to collaborate with scientific colleagues.

- Students will be required to communicate the results of experiments and their analyses in both written (scientific paper) and oral (brief presentation) form.
• Students will be introduced to modern computational tools for recording, processing and presenting experimental data. Students will be expected to construct instrumentation as well as implement programs to acquire data using Arduino processors and circuits.
• Emphasis will be on student understanding of the interplay between experimental data and the mathematical models that the experiments are performed to test.
• The student should achieve proficiency in conducting experiments, performing data and error analysis and presenting scientific results in written reports and oral presentations

COURSE OBJECTIVES

At the end of the course the student will have
• Demonstrated an ability to carry out appropriate experimentation and analysis of acquired data to support or disprove a model.
• Demonstrated an understanding of the concept of a model and how it represents a physical system.
• Demonstrated an understanding of how a model is tested.
• Demonstrated an understanding of how to estimate uncertainties and apply statistical and systematic error analysis.
• Demonstrated mastery of equation editors and similar technology required to generate a technical scientific report.
• Demonstrated mastery of data analysis software such as Matlab or Python.
• Demonstrated an understanding of the statistics of counting experiments.
• Submitted a total of three lab reports, which describe a model of a physical system, summarize a theoretical description of the system being modeled, detail measurements of physical parameters of the system, estimate the errors in those measurements, propagate those errors to the quantity being measured and establish whether the data support the model or not, including a quantitative assessment of the degree to which the model is supported.
• Written the advanced experiment report in the style and format of a scientific journal paper,
• Presented a talk to the class on one of the lab’s experiments, in the format of a 10-minute contributed talk to a meeting of the American Physical Society.

CONTENT OVERVIEW

• Lecture/Discussions. The purpose of lectures is to present the principles of statistical analysis, error analysis, and the tools needed to work as experimental physicists. Lectures/Discussions will be held on Tuesdays during the first few weeks of classes. Powerpoint Slides/Recorded Videos will be made available on Monday morning (or earlier) prior to the day of the lecture. Therefore, the Zoom meeting should be more of a class discussion than a standard lecture. Relevant assigned readings will also be discussed during these meetings. The lecture times will be used for other purposes, such as consultations and oral presentations during the latter portion of the course. All of the lecture meetings will take place in our class Zoom Room available via Canvas on Tuesdays from 2PM-3:20PM.

• Laboratory Sessions. There is a University-scheduled four hour lab period each week from Thursday 12:55PM-5:00PM. The instructor will be available on Zoom for consultation during this time period. Materials for Experiments 1 and 2 will be provided to students during the first Thursday meeting, which will take place outside of the South Physics Building. These experiments/activities can be performed by the student at their place of residence. At this time, the lab rooms have been deemed unsuitable for in-person class activities. If this remains the
case at the time that Experiment 3 data-taking needs to occur, the instructor will perform the experiments under the direction of the students over a Zoom conference call. If the campus is closed to everyone, including the instructor, data will be provided to the students for their analysis. The objective of this class is for students to master concepts and techniques to understand what they are doing in each experiment.

- **Lab reports / Scientific Papers.** These are opportunities for the students to demonstrate to the instructor that the objectives of the lab have been met because a model has been tested, errors in the measurements have been estimated, and carried through calculations and a quantitative estimate of the validity of the model established. The advanced experiment report must be written in the style and format of a scientific journal paper,

- **Oral presentation.** Each student will give one oral presentation at the end of the semester. The presentation will be a public recount of the important activities, results and conclusions on one of the lab experiments in the format of an oral conference presentation.

- **Quizzes/Problem Sets.** Canvas-based online Quizzes and Problem sets will be assigned on the lecture and reading materials.

### Grading

<table>
<thead>
<tr>
<th>Grading</th>
<th>Tentative Grading scheme :</th>
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<tbody>
<tr>
<td>Experiment 1</td>
<td>15%</td>
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<tr>
<td>Experiment 2</td>
<td>15%</td>
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<tr>
<td>Experiment 3</td>
<td>15%</td>
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<tr>
<td>Problem Sets/Quizzes</td>
<td>15%</td>
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<tr>
<td>Scientific Paper</td>
<td>15%</td>
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<tr>
<td>Oral Presentation</td>
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<tr>
<td>Final Assignment</td>
<td>10%</td>
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<tr>
<td>Class Participation</td>
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- **Grading Scale**

<table>
<thead>
<tr>
<th>Score</th>
<th>GPA</th>
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<tbody>
<tr>
<td>A</td>
<td>93-100</td>
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<tr>
<td>A-</td>
<td>90-92</td>
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<tr>
<td>B+</td>
<td>87-89</td>
</tr>
<tr>
<td>B</td>
<td>83-86</td>
</tr>
<tr>
<td>B-</td>
<td>80-82</td>
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<tr>
<td>C+</td>
<td>77-79</td>
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<tr>
<td>C</td>
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<td>C-</td>
<td>70-72</td>
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<tr>
<td>D+</td>
<td>67-69</td>
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<tr>
<td>D</td>
<td>63-66</td>
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<td>D-</td>
<td>60-62</td>
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<td>E</td>
<td>0-59</td>
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- **Late Assignment** Documented medical reasons are excusable.

- **Recommended Reading**
  - An Introduction to Error Analysis, John R. Taylor, University Science Books, Sausalito CA (1997). Available in the U Bookstore for $66.65, $50.00 for used if they have any; from Amazon: $65.00 new, from $57.93 used.
  - Experimentation, D. C. Baird, Prentice-Hall, Englewood Cliffs NJ (1995). Out of print, but we have permission from the publisher to reproduce; a PDF copy is available to instructors and is on reserve in Marriott Library.
  - Recommended reading: Experiments in Modern Physics, A. C. Melissinos and J. Napolitano, Elsevier Science, San Diego CA (2004). Several sections are relevant to the experiments in this lab. Also on reserve in the Marriott Library; there is a copy in the lab.
  - These and additional material will be made available in Marriott Library Course Reserves, online in our Canvas pages and in the lab reading area.
• Lecture Topics
  o Introduction and course organization.
  o Measurements - Instruments and Data Acquisition
  o The Arduino hardware and software platform.
  o Graphing, linearization of data.
  o Least-squares fitting, random and systematic error.
  o Probability distributions – binomial, Poisson and Gaussian
  o p-values, counting experiments
  o Using Python/Matlab for Data Analysis.
  o Propagation of uncertainties
  o Correlated measurements and uncertainties
  o Evaluating experiments
  o Designing experiments.
  o Writing scientific papers.
  o Oral presentations and power point slides.

• List of Experiments/Activities
  o Introduction to Instrumentation
  o Basic Experiments (choose 2)
    ▪ Experiment 1 – Surface gravity of Earth
    ▪ Experiment 2 - Geiger counter
  o Advanced Experiments (choose 1)
    ▪ Franck-Hertz
    ▪ Photoelectric effect
    ▪ Electron charge to mass ratio
    ▪ Optical spectroscopy
    ▪ Speed of light
    ▪ Universal Gravitation Constant
    ▪ Muon Lifetime
    ▪ Compton-Scattering
<table>
<thead>
<tr>
<th>Week</th>
<th>Dates</th>
<th>Topic</th>
</tr>
</thead>
</table>
| 1    | Aug 25/27 | Lecture: Course overview and introduction  
                   Lab: Activity 1 (Instrumentation/Arduino) |
| 2    | Sep 1/3   | Lecture: Measurements, Arduino  
                   Lab: Activity 1 (Instrumentation/Arduino) |
| 3    | Sep 8/10  | Lecture: Measuring Surface Gravity  
                   Lab: Experiment 1 (Surface Gravity) |
| 4    | Sep 15/17 | Lecture: Precision & Uncertainty  
                   Lab: Experiment 1 (Surface Gravity) |
| 5    | Sep 22/24 | Lecture: Reporting Experimental Results  
                   Lab: Experiment 1 (Surface Gravity) |
| 6    | Sep 29/Oct 1 | Lecture: Geiger Tube & Counting Statistics  
                   Lab: Experiment 1 (Geiger-Mueller) |
| 7    | Oct 6/8   | Lecture: Probability Distributions  
                   Lab: Experiment 2 (Geiger-Mueller) |
| 8    | Oct 13/15 | Lecture: Analysis Software (Python/Matlab)  
                   Lab: Experiment 2 (Geiger-Mueller) |
| 9    | Oct 20/22 | Lecture: Experimental Design  
                   Lab: Experiment 2 (Advanced Experiment) |
| 10   | Oct 27/29 | Lecture:  
                   Lab: Experiment 3 (Advanced Experiment) |
| 11   | Nov 3/5   | Lecture: Scientific Papers & Conference Presentations  
                   Lab: Experiment 3 (Advanced Experiment) |
| 12   | Nov 10/12 | Lecture: Student Consultations  
                   Lab: Experiment 3 (Advanced Experiment) |
| 13   | Nov 17/19 | Lecture: Student Consultations  
                   Lab: Experiment 3 (Advanced Experiment) |
| 14   | Nov 24    | Lecture: Student Consultations  
                   Lab: Experiment 3 (thanksgiving holiday) |
| 15   | Dec 1/3   | Student Oral Presentations  
                   Final Assignment |
| 16   | Dec 7     | Final Assignment |

All classes will be online the weeks of October 5-10 and November 30-December 3

**IMPORTANT DATES:** ([https://registrar.utah.edu/academic-calendars/fall2020.php](https://registrar.utah.edu/academic-calendars/fall2020.php))

- Classes begin: Monday, August 24
- Our first meeting on Zoom: Tuesday, August 25
- Last Day to Drop (Delete) Classes: Friday, September 4
- Last Day to Withdraw: Friday, October 16
- Last day to reverse CR/NC option: Thursday, November 7
- Classes End: Thursday, December 3
- Grades Posted: Monday, December 21 (hopefully much earlier!)
University Policies

1. **The Americans with Disabilities Act.** The University of Utah seeks to provide equal access to its programs, services and activities for people with disabilities. If you will need accommodations in the class, reasonable prior notice needs to be given to the Center for Disability & Access, 162 Olpin Union Building, 801-581-5020. CDA will work with you and the instructor to make arrangements for accommodations. All written information in this course can be made available in alternative format with prior notification to the Center for Disability & Access.

2. **Addressing Sexual Misconduct.** Title IX makes it clear that violence and harassment based on sex and gender (which includes sexual orientation and gender identity/expression) is a Civil Rights offense subject to the same kinds of accountability and the same kinds of support applied to offenses against other protected categories such as race, national origin, color, religion, age, status as a person with a disability, veteran's status or genetic information. If you or someone you know has been harassed or assaulted on the basis of your sex, including sexual orientation or gender identity/expression, you are encouraged to report it to the University's Title IX Coordinator; Director, Office of Equal Opportunity and Affirmative Action, 135 Park Building, 801-581-8365, or to the Office of the Dean of Students, 270 Union Building, 801-581-7066. For support and confidential consultation, contact the Center for Student Wellness, 426 SSB, 801-581-7776. To report to police, contact the Department of Public Safety, 801-585-2677(COPS).

3. **Campus Safety.** The University of Utah values the safety of all campus community members. To report suspicious activity or to request a courtesy escort, call campus police at 801-585-COPS (801-585-2677). You will receive important emergency alerts and safety messages regarding campus safety via text message. For more information regarding safety and to view available training resources, including helpful videos, visit safeu.utah.edu.

4. **Academic honesty** You must do your own original work in this course; failure to make clear the sources of any outside material you incorporate in your work constitutes plagiarism, a violation of University standards. Wherever the ideas or words of others appear in your own work, they must be properly cited. Basically there will be three kinds of sentences in your reports: (1) “common knowledge”, statements of fact familiar to those working in the field; (2) statements copied from the literature, references for which you cite and (3) your original work. Anything not in the first two categories will be assumed to be in the last. The text and lecture notes posted online should be referenced when appropriate. The one exception is your data: we understand that you and your partner will turn in identical sets of data.

It is required that you be aware of the University of Utah policies as you will be held accountable to University of Utah standards. Please read the University of Utah Code of Student Rights and Responsibilities, which states in part, "In order to ensure that the highest standards of academic conduct are promoted and supported at the University, students must adhere to generally accepted standards of academic honesty, including but not limited to refraining from cheating, plagiarizing, research misconduct, misrepresenting one's work, and/or inappropriately collaborating."