

# Junior Lab 8.13 Syllabus — Spring 2021

## Overview, Grading Policies, and Schedule

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### I. OVERVIEW OF 8.13

The purposes of Junior Lab are to give you hands-on experience with some of the experimental bases of modern physics, deepening your understanding of the relation between experiment and theory, and — in the process — to accelerate your professional development as a scientist in skills such as oral and written communication methods, the troubleshooting process, professional scientific attitude, data analysis, and reasoning about uncertainty. You will do experiments on phenomena whose discoveries led to major advances in physics. The data you obtain will have inevitable systematic and random errors that obscure the relations between the macroscopic observables of our sensory experience and the physical laws that govern the submicroscopic world of atoms and nuclei. You will be challenged to learn how each of the experimental setups works, to master its manipulation so as to obtain the best possible data, and then to interpret the data in light of theory with a quantitative assessment of the uncertainties. We believe you will find satisfaction in observing, measuring, and understanding phenomena many of which would have won you the Nobel Prize if you had discovered them.

Students enrolling in 8.13 are expected to have recently completed 8.04. If you have not passed 8.04, please see the head Junior Lab instructor.

#### I.1. Section Organization

The Registrar has preassigned you to one of the sections listed in Table I, with further adjustments reflected on the 8.13 Canvas website. If you cannot come to the assigned time, please email [spatrick@mit.edu](mailto:spatrick@mit.edu) ahead of time to see if your constraints can be accommodated. Attempts are made to keep each section's enrollment less than or equal to 8 students. If the course enrollment is especially large, you may not be able to have the section of your choice.

*It is essential that you show up to the first session of at least one 8.13 section in order to receive credit for mandatory radiation protection training.*

Each section of Junior Lab is run independently by one faculty member with the assistance of a graduate teaching assistant. *You are required to attend your assigned lab session for the full three hour period. Any exception must be approved by the section teaching staff.* Time reservations (3-hour block maximum, please) for Friday hours and overnight apparatus reservations can

be made through the Junior Lab online reservation tool at <http://jlvideo-2.mit.edu/jlab/>.

TABLE I. Junior Lab 8.13 Section Instructors — Spring 2021

Section	Instructor
Mon/Weds 2PM–5PM	Professor Philip Harris
Mon/Weds 9AM–12PM	Prof. Janet Conrad
Tues/Thurs 2PM–5PM	Prof. Christoph Paus
Tues/Thurs 9AM–12PM	Prof. Gunther Roland (8.13 Head)

*You are expected to work in pairs*, sharing as evenly as possible in the measurements, the analysis, and the interpretation of the data. The best choice for a lab partner may be someone who lives nearby and has a schedule that matches yours so that you can get together outside of class to analyze and interpret your results. You are *not* required to know who your lab partner will be before the semester starts. Most students find that they require the full 18 hours per week credited to 8.13 to do the work of the course.

#### I.2. Schedule Summary

The first several class sessions will familiarize you with the lab, giving everyone a common foundation in experimental techniques, data analysis, collaboration skills, oral and written communication, and computing tools including PYTHON and L<sup>A</sup>T<sub>E</sub>X. The first two sessions are dedicated to important organizational and administrative issues, plus important safety information and an introduction to the basics of work in 8.13. The following four lab sessions will include further instruction and in-class exercises on foundational skills, as well as your work on two preliminary experiments: ‘Pendulum Design’ and ‘Calorimetry’. Your work on the preliminary experiments will be graded for feedback, but will not count towards the final course grade.

Following this introductory period, you will plan, execute, analyze, and report on three longer experiments. These will be executed in 5 sessions each. The sequence of experiments performed by each student group is determined by the section leader early in the semester. At least one of the experiments will be a remotely operated experiment in the Junior Lab, with some amount of local support by the lab staff (‘Relativistic Dynamics’, ‘Rutherford Scattering’, ‘Hydrogenic Spectroscopy’, ‘NMR Spectroscopy’, or ‘Radio Astrophysics’). Another experiment may be an extended data analysis of a

large, modern physics open data set (LIGO, Higgs boson search, quark-gluon plasma, and more). A third experiment will be based on the CosmicWatch muon detector, using equipment that will be shipped to your remote location early in the semester.

The term culminates in a series of public oral presentations given by you and your fellow students to peers, friends, and faculty in the style of a parallel session at an American Physical Society conference.

### I.3. Laboratory Access

For the Spring 2021 semester, 8.13 students are not allowed to access the lab and will instead conduct experiments remotely. Junior Lab staff will access the lab only for maintenance and for remote apparatus support purposes. At all other times the laboratories must be kept locked for safety and security, especially the security of radioactive sources. One should never work alone in a laboratory, especially if high voltages are involved. A partner or instructor must be within reach.

## II. ETHICS & PROFESSIONAL CONDUCT

*Nature is the ultimate enforcer of truth in science.* You will be tempted many times in Junior Lab to tamper with the integrity of your scientific results. Do not. This hurts yourself and others. You may also be tempted to plagiarize materials for your oral and written reports. Do not. All instances of academic misconduct in Junior Lab will be punished severely. Students are highly encouraged to review the materials on MIT’s Academic Integrity website, [integrity.mit.edu](https://integrity.mit.edu).

Please consult Junior Lab’s more extensive [Ethics in Science and Education](#) document [1] — which you are obligated to understand — for more specific discussion.

Furthermore, one must treat one’s peers and colleagues with at least as much respect as one treats one’s data. Well-being, respect, inclusion, collaboration, and mentorship are as essential to science as measurement and modeling. Please consult the [MIT Physics Community Values](#) statement. Again, you are obligated to understand these principles, so please raise a conversation with your peers or instructors whenever you find them in question.

## III. SAFETY IN JUNIOR LAB

Your safety in Junior Lab is the staff’s top priority. It should be your top priority, too. The most important safety rules, which the staff will enforce diligently, are as follows:

1. Never work alone.
2. No eating or drinking in the lab.

3. Treat radioactive sources according to the ALARA principle, as per your training.
4. Obey state regulations and Junior Lab practices on access and tracking of radioactive sources, as per your training.

On the first day of 8.13, Junior Lab students receive a general safety discussion, a lab tour, and a formal state-mandated training in the use of sealed sources of ionizing radiation from a member of MIT’s Radiation Protection Program. This training is required for work in both 8.13 and 8.14. Students who will be performing experiments using biological materials, Class 3b or Class 4 lasers, or requiring access to the MIT Nuclear Reactor facility will require further formal training from MIT’s Office of Environment, Health and Safety (EHS). The Junior Lab staff will provide information on the required training as needed.

Please consult the more extensive [Safety in Junior Lab](#) document [2] — which you are obligated to understand — for more specific discussion.

## IV. 8.13 GRADING POLICY

See Table II and discussion below.

TABLE II. 8.13 grading policy

Lab Performance & Attendance	10%
Laboratory Notebook	8%
Homework & Exercises	10%
Preparatory Questions (1)	2%
Oral Examinations (3)	30%
4-Page Written Summaries (3)	30%
Final Oral Presentation (Public)	10%

### IV.1. Lab Performance and Attendance — 10%

The regularity of your attendance will be a factor in determining your grade in the course, as will be your preparedness for performing measurements and alternating as the “lead” (with your partner) to carry them out.

It is essential that you efficiently use all of the laboratory time assigned to you. Extra time is available, but should not be essential. Several experienced experimental physicists will be present in every scheduled session, ready and eager to answer your questions and to help you make your apparatus function properly. Calling for help when you get stuck can only improve your lab performance grade.

Failure to have a “dry run” of the final presentation with a WRAP instructor (see Section IV.7 below) will result in a 2% reduction of the lab performance grade.

Failure to submit the preliminary oral exam or written summary (see Sections IV.5 and IV.6 below) will each result in a 1% reduction of the lab performance grade.

#### IV.2. Laboratory Notebook — 8%

Throughout the term, you will be required to maintain a detailed real-time record of your activities in a laboratory notebook. To help motivate the most effective use of this critical laboratory tool, notebooks will be comprehensively evaluated twice during the semester: once after the preliminary experiments (this preliminary grade does not count towards the course total), and once at the end of the semester for 5% of the final grade. In addition to these comprehensive evaluations, the notebook will also be briefly evaluated around the time of each oral examination, each for 1% of the total grade.

Please talk with your section instructors before your notebook evaluations if you have any questions. Spot checks of your notebook may also occur during lab sessions as an indicator of lab performance. Spot checks during the oral exams also provide an indicator of data quality.

A detailed discussion of how to set up and use a physical scientific notebook is given in a one page [Notebook Guidelines](#) quick-reference document [3] available on the Junior Lab website, a copy of which is recommended to be taped to the inside cover of your notebook for routine consultation. An example of a shared electronic notebook using Dropbox Paper on MIT Enterprise Dropbox Paper will be made available.

#### IV.3. Homework & Exercises —10%

A number of in-class exercises will be performed during the introductory period to help you learn core scientific skills, especially data analysis. Preparation before class and follow-up practice are both necessary to maximize the utility of these exercises. Therefore, the in-class work will be surrounded by a small number of graded homework assignments, some of which will take place on the [lms.mitx.mit.edu](http://lms.mitx.mit.edu) 8.13r website with video instruction.

#### IV.4. Preparatory Questions (1) — 2%

Each experiment's chapter on the [lms.mitx.mit.edu](http://lms.mitx.mit.edu) 8.13r website contains a set of preparatory questions which point you to the essentials of the experiment, including safety information. You are expected to work out the solutions and/or predictions to the preparatory problems in your notebook and submit the answers on [lms.mitx.mit.edu](http://lms.mitx.mit.edu) before starting the experiment. *Late solutions will not be accepted because you will need to know this material before starting the experiment: late solutions do not make sense.*

The preparatory questions for preliminary experiments will be graded for feedback, but will not count towards your final course grade.

#### IV.5. Oral Examinations (3) — 30%

For each main experiment, a one-hour total length (2 students  $\times$  30 minutes each) oral examination and discussion will be scheduled with one or more of your instructors, your lab partner, and yourself within 10 days of the last scheduled session for that experiment. You and your lab partner must both bring your lab notebooks to the exam session. All oral exams are video-recorded so that you may review your presentation technique.

*Each student should prepare a 15-minute oral report on the theoretical and experimental aspects of a single portion of the experiment.* This is a short time, so it is essential that you rehearse your presentation as you would if you were giving a 15-minute presentation at a meeting of the American Physical Society. Please review the Society guidelines at <http://www.aps.org/meetings/policies/speaker.cfm>.

You must prepare your visual aids electronically (*e.g.* slides in the L<sup>A</sup>T<sub>E</sub>X BEAMER class or MS POWERPOINT) for use with a digital projector in a professional-style presentation. We suggest a maximum of ten slides. The Junior Lab website has detailed instructions and templates for generating your own presentations: <http://web.mit.edu/8.13/www/writtensum.shtml>

The theoretical section should briefly demonstrate a mastery of some portion of theory relevant to understanding the significance of the experimental results. The experimental section should dominate the discussion and demonstrate an understanding of how the equipment works, what was measured, how the data were reduced, and how the random and systematic errors were estimated. *Each student must discuss different aspects of the motivating theory and experiment. Furthermore, it is not acceptable to discuss theory only or experiment only; every presentation should contain a balance! Full cooperation with lab partners and others in preparing for the oral reports is encouraged and required.* This latter aspect is particularly important to ensure that both partners report the same results!

Orals exams will be graded using the following criteria:

- Theoretical and/or experimental motivation: 15%
- Description of experiment: 35%
- Analysis of data and results: 35%
- Style and English: 15%

To familiarize you with the examination procedure, a one-hour oral exam will be held on one of the twopreliminary experiments of your choice. This oral will proceed identically as the others. It will be scored but will not count towards your final course grade. (However,

as discussed above, failure to execute the preliminary oral exam will result in a 1% deduction from the overall lab performance grade for the semester.) It is designed to give you feedback on content, style and presentation without the pressure of a graded performance. Partners should choose different preliminary experiments for this initial oral exam. Video recordings of these practice orals will be used to facilitate guidance from the Lecturers in MIT's Program in Writing, Rhetoric, and Professional Practice (WRAP) who are part of the Junior Lab staff. You must schedule a one-hour appointment for feedback with one of these instructors within a week following their practice oral.

#### IV.6. 4-Page Written Summaries (3) — 30%

A written summary must be prepared for each of the three standard experiments, plus the preliminary experiment that was presented orally. (As usual, the preliminary written summary does not count in the final grade, but failure to submit it will result in a 1% reduction from the overall lab performance grade for the semester, as discussed above.) The purpose, theory, and results of the experiment must be summarized in no more than 4 pages, including all figures, with a neat appearance and concise, correct English.

You must prepare your summary *individually*, not as a group. *All of your work on the experiment should be summarized, not just the part you chose for your oral presentation.*

You must submit a .pdf copy of your written summary to your section instructor on Canvas by the appointed deadline: specifically, written reports for each experiment will be due by midnight on the day after your oral exam. It is expected, however, that the paper will be essentially complete by the time of your oral exam. The delay between oral exam and paper submission allows you to correct any egregious mistakes that were uncovered during the exam so as not to repeat them in your written work and receive a double penalty!

Your summary's organization and style should resemble that of an article in the Physical Review Letters (<http://journals.aps.org/prl/authors>). *In particular, the abstract is essential. It should briefly mention the motivation (purpose), the method (how measured) and most importantly, the quantitative result with uncertainties.*

The report must be typeset in a form that would be suitable for submission as a manuscript. To aid you in this process, we have produced a sample paper template written in L<sup>A</sup>T<sub>E</sub>X that we encourage you to study and use for your own submissions. The sample paper is downloadable from the Junior Lab site along with its associated .tex file: <http://web.mit.edu/8.13/www/writtensum.shtml>

Papers will be graded using the following criteria:

- Theoretical and/or experimental motivation: 15%

- Description of experiment: 35%
- Analysis of data and results: 35%
- Style and English: 15%
- Papers not submitted by the deadline will be deducted 10% for each day they are late.

MIT has excellent resources for technical writing and oral presentations (including on-line writing consultations) at the [CMSW Writing and Communication Center website](#) [4]. Use them!

#### IV.7. Final Oral Presentation (Public) — 10%

At the end of the term in May, you will give a 15-minute public oral presentation which will be attended by all students in your section and any other interested parties. The last class sessions are reserved for this purpose. The public oral presentations should be given in the style of a paper presented at a conference, with careful attention paid to the preparation of visual aids — in the form of an electronic presentation — and to the clarity of the oral discussion. Questions from classmates and the audience are encouraged, allowing for a general discussion of the experiment.

This public presentation, in addition to the four jointly prepared oral examinations given earlier in the term, is a major component of the [CI-M requirement](#) [5] which 8.13 fulfills. Revision of past work is essential to this requirement, as it is to all formal communication. You are required to make a 1-hour appointment with a WRAP Program instructor to do a “dry run” and receive feedback at least four days prior to your public presentation. The dry run will not be graded, but, as mentioned above, failure to do it will result in a 2% reduction of the lab performance grade. Obviously, to present on an experiment in the public presentation, it must have previously been presented as an oral exam with the section instructor.

## V. TEXTS & REFERENCE MATERIAL

Junior Lab has several required and recommended texts with which you should become familiar.

### V.1. Required Texts

The following items are required for 8.13. They should be studied and understood, thoroughly.

**Experimental Lab Manuals:** by the Junior Lab staff, available for download from the [Junior Lab web site](#) [6]. Lab instructors will be delighted to accommodate your improvements and corrections to the lab manuals! These lab manuals supplement and are

partially redundant with additional material at the 8.13r website on [lms.mitx.mit.edu](http://lms.mitx.mit.edu).

***Ethics in Science and Education:*** by the Junior Lab Staff, available for download from the [Junior Lab web site](#) [6].

***Safety in Junior Lab:*** by the Junior Lab Staff, available for download from the [Junior Lab web site](#) [6].

## V.2. Essential References

The following items should be consulted on a regular basis in 8.13.

***Data Reduction and Error Analysis:*** 3<sup>rd</sup> Edition, by P.R. Bevington and D.K. Robinson (McGraw-Hill: 2003).

***Experiments in Modern Physics:*** by A. Melissinos (Academic Press: 1966 1<sup>st</sup> Edition & 2003 2<sup>nd</sup> Edition). Consult both before and during your investigations. This text is only “Recommended” because the Junior Lab staff feel it is too expensive to “Require”. *Material which is essential to the understanding of an experiment and which can be found in the Melissinos text is generally omitted from the lab manuals.* Note that the Physics Reading Room has both editions which offer different material: you should consult them both!

The Bevington and Robinson text contains a comprehensive treatment on error analysis and will be useful throughout your career.

## V.3. Other Useful Texts

There are several other recommended textbooks on reserve in the Junior Lab library.

***The Art of Experimental Physics:*** by Daryl Preston and Eric Dietz (John Wiley: 1991).

***An Introduction to Error Analysis:*** 2<sup>nd</sup> Edition, by John Taylor (University Science Books: 1997). This book covers much of the same material as Bevington & Robinson, but in a style that some find more accessible.

***Bayesian Logical Data Analysis for the . . . :*** . . . for the Physical Sciences: A Comparative Approach with Mathematica<sup>®</sup> Support. by Phil Gregory (Cambridge University Press: 2005)

***Concepts in Applied Physics:*** a portion of the [Junior Lab Student Wiki](#) [7].

## V.4. Reference Articles and Equipment Manuals

At this stage of your training as an experimentalist, you should realize that there is no “comprehensive” or perfect textbook. Much of the material you will need to dig into are the early journal papers which originally detailed many of these important discoveries. The Junior Lab website has an [electronic library](#) [8] containing many of these articles in PDF format and which is accessible using MIT certificates. Junior Lab also has numerous books on reserve in the Hayden Library Reserve Book Room (14N-132) and the Physics Reading Room (4-332). References and lending book resources are available through Barker and Hayden Libraries and students should become familiar with both of these Institute resources. Finally, there is a small Junior Lab library in 4-361. These books may not be taken from the laboratory, but copies of a few pages may be made on the lab photocopier.

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- [1] Junior Lab staff. *Ethics in Science and Education*. MIT Physics: 2014 August 12. Available from: <http://web.mit.edu/8.13/www/JLIntroFiles/JLEthics.pdf>
  - [2] Junior Lab staff. *Laboratory Safety and Regulations in Junior Lab*. MIT Physics: 2014 August 18. Available from: <http://web.mit.edu/8.13/www/JLIntroFiles/JLSafety.pdf>
  - [3] Junior Lab staff. *Requirements for Experimental Notebooks*. MIT Physics: 2014 August 12. Available from: <http://web.mit.edu/8.13/www/JLIntroFiles/JLNotebooks.pdf>
  - [4] WCC staff. [Website] *Writing and Communication Center*. MIT CMS/W: retrieved 2016 August 31. Available from: <http://cmsw.mit.edu/writing-and-communication-center/>
  - [5] SOCR staff. [Website] *Undergraduate Communication Requirement*. MIT Office of the Communication Requirement: retrieved 2016 August 31. Available from: <http://web.mit.edu/commreq/background.html>
  - [6] Junior Lab staff. [Website] *M.I.T. Junior Lab 8.13/8.14*. MIT Physics: retrieved 2016 August 31. Available from: <http://web.mit.edu/8.13/www/>
  - [7] Junior Lab staff. [Website] *Concepts in Applied Physics*. Junior Lab Student Wiki. MIT Physics: retrieved 2016 August 31. Available from: [https://jlab.mit.edu/wiki/Concepts\\_in\\_Applied\\_Physics](https://jlab.mit.edu/wiki/Concepts_in_Applied_Physics)
  - [8] Junior Lab staff. [Website] *Junior Lab Electronic Library*. MIT Physics: retrieved 2016 August 31. Available from: <https://web.mit.edu/8.13/8.13a/library-index.html>