Junior Lab 8.14 Syllabus — Spring 2022
Overview, Grading Policies, and Schedule

Helena Foundation Junior Laboratory Staff, *MIT Department of Physics*
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I. OVERVIEW OF 8.14

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 8.14 are expected to have recently completed 8.05 and 8.13 so as to be prepared to immediately begin conducting investigations. If you have not taken 8.13, please see the head Junior Lab instructor.

I.1. Section Organization

If you cannot come to the assigned time, please email `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 16 students.

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.* The lab is also open on Fridays from 10AM to 4PM for additional lab time outside of your regularly scheduled section. Time reservations (3-hour block maximum, please) for Friday hours and overnight apparatus reservations can be made by communicating with your peers and staff using the experiment's discussion channel on Junior Lab's Slack workspace at http://mitjlab.slack.com.

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 8.14 to do the work of the course.

TABLE I. Junior Lab 8.14 Section Instructors — Spring 2022

Section	Instructor
TR 2PM–5PM	Prof. Nikta Fakhri

I.2. Schedule Summary

The first class period will be dedicated to selecting partners, choosing the first experiment, and brief introductory remarks by the section instructors. The remainder of the term will be divided into three experimental sessions of 7 days each. The first two experiments will be selected from the standard Junior Lab menu. The third will be an open ended project of your own design.

Before the second experiment begins, each student group will propose a topic for the open ended project, the scientific goals of which should be defined in the proposal. A brief draft proposal will be due near the middle of the first experiment, while a more formal two-page written proposal will be due near the end. Proposals should outline the required resources and scheduling constraints for the open ended project. Projects beyond the scope of Junior Lab will be identified and scaled back at the draft proposal stage.

Examples of projects include:

- deeper exploration of a previously performed 8.13 or 8.14 experiment
- performing an experiment still under development by the Junior Lab staff
- assembling and performing a simple Junior Lab style experiment from the American Journal of Physics
- other projects subject to approval

The open ended project will be evaluated based on a scientific poster prepared by the group and presented in

an open poster session at the end of the semester. The student group judged by the 8.14 teaching staff to have proposed and performed the best original project of the year will be awarded the annual Pickering Prize.

Note that the additional days per experiment (beyond what you had in 8.13) raises the level of expectations regarding the completion of "challenging" aspects of the lab manuals and an expectation to exceed the standard material.

I.3. Laboratory Access

Beyond your required assigned lab time, the laboratory will be open every class day from 9AM–5PM (except for Junior Lab staff meetings) and Friday from 10AM–4PM with staff help available to discuss physics and maintain equipment. At all other times the laboratories must be kept locked for safety and security, especially the security of radioactive sources. Junior Lab students may occasionally be permitted access to the lab outside of the normal hours, but only after consulting with their TA or section leader. It is each student's responsibility to maintain security by making sure the doors are kept locked at all times outside of the regularly scheduled sessions. 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`.

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 understanding these principles, so please raise a conversation with your peers and 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.

In particular, the 'Doppler-Free Saturated Absorption Spectroscopy' experiment utilizes a Class 3b near-IR laser operating at 40 mW of output power; the 'Raman Spectroscopy' experiment utilizes a Class 4 (532 nm, 2 W) laser. As such all users of these experiments must undergo MIT Laser Safety Training (EHS Course 371, about 1.5 hours in length, offered by online by EHS) prior to performing the experiment. All students should download the MIT Laser Safety manual and read, at a minimum, Section Two.XVI.D dealing with Class 3b laser controls.

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

IV. 8.14 GRADING POLICY

See Table II and discussion below.

IV.1. Lab Performance and Attendance — 12%

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

TABLE II. 8.14 grading policy

Lab Performance & Attendance	12%
Laboratory Notebook (2 checks)	10%
Preparatory Questions (2)	6%
Oral Examinations (2)	24%
5-Page Written Summaries (1)	12%
Project Proposal (2 parts)	12%
Project Poster (2 parts)	14%
Project Peer Review	10%

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.

IV.2. Laboratory Notebook — 10%

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 evaluated twice during the semester. The first check will be around midterm for 4% of the final grade, and the final check will be at the end of the semester for 6% of the final grade. Having already taken 8.13, you should be well versed in how to maintain a good laboratory notebook. Spot checks of your notebook may also occur during lab sessions as an indicator of lab performance, and as part of the oral exams as an indicator of data quality.

A detailed discussion of how to set up and use a physicsl 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. Preparatory Questions (2) — 6%

Each experiment's chapter on the lms.mitx.mit.edu 8.14r 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 *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.*

IV.4. Oral Examinations (2) — 24%

For each main experiment, a one-hour total length (2 students × 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 LaTeX BEAMER class or MS POWERPOINT) for use with an 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%

IV.5. 5-Page Written Summaries (1) — 12%

A written summary must be prepared for two of the three standard experiments. The purpose, theory, and results of the experiment must be summarized in no more than 5 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 LaTeX 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.6. Open ended project — 36%

The open ended project will occur during the third experiment period. The project should fall within Junior Lab's resources and scope of modern physics, but the design and goals of the project are to be determined by the student group.

Each group will submit a single project proposal as a formal 2-page written document. The proposal will be due on the Friday following Day 5 of Experiment 1, and will count as 10% of the total grade. As this may not allow enough time to correct malformed projects before they could begin in Experiment 2, a rough form of the proposal — which nevertheless provides enough detail for the Junior Lab staff to judge its merits — will be due one weeks earlier. This rough proposal will count for 2% of the total grade, and will be graded as either a 2 (for an adequate proposal), 1 (for a proposal which shows little thought), or 0 (for no proposal). It is expected that all groups should receive full credit on the rough proposal. After all proposals are received, the Junior Lab staff will serve as a review committee which will: determine if any proposals are making competing requests for resources, and attempt to adjudicate such conflicts; determine if any proposals have components which are beyond the scope of the program, and scale back these components; and approve a coordinated schedule for the projects to go forward.

Projects will be evaluated based on a scientific poster of comparable detail to the reports due for the other experiments, prepared and presented by the group at a poster session at the end of the semester, making up 12% of the total grade. There is no oral report or written summary for the project. Criteria for grading are themselves open ended, but will largely reflect how well the project goals were pursued — or adapted, in the case of unforeseen circumstances.

The poster will be preceded by a draft for 2% of the total grade, graded similarly to the rough proposal. Each poster will be peer-reviewed by other students. The written peer-review report of other students' projects will count for 10% of the total grade.

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 8.14. 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 guides supplement and are partially redundant with additional material at the 8.14r website on `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 8.14.

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

***Experiments in Modern Physics*:** by A. Melissinos (Academic Press: 1966 1st Edition & 2003 2nd 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*:** 2nd 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® 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 by 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

[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