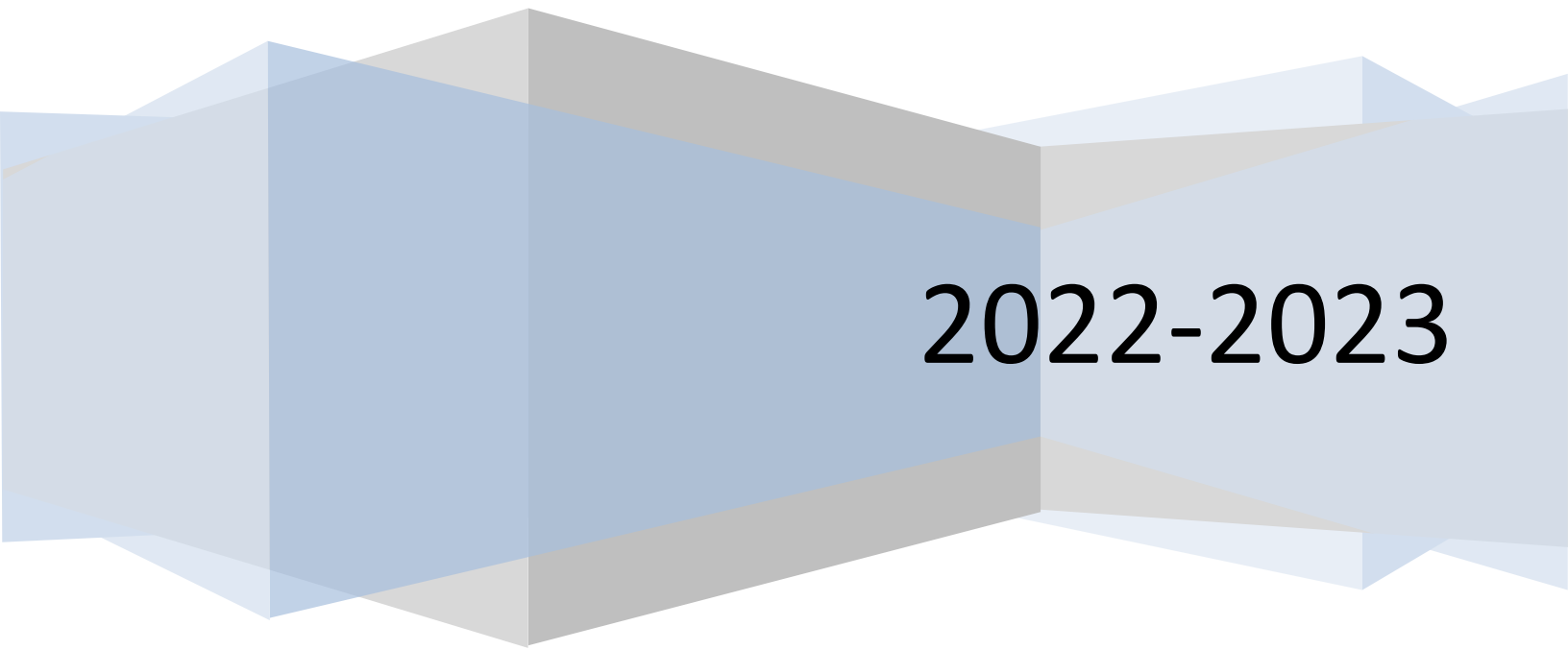


Electrical and Computer Engineering

Independent Work and Senior
Thesis Guide

A COMPENDIUM OF DATES, TIPS, GUIDELINES
AND PROCEDURES



2022-2023

INTRODUCTION

Electrical and computer engineers are well positioned to address a variety of the crucial engineering issues facing societies today. Think, for example, about:

Energy: efficient lighting, buildings, computing, and communications; solar cells; low power devices and circuits; energy harvesting from the environment; smart power grids;

Information: security; communications; networks; machine learning;

Health: informatics; medical imaging, sensing, and diagnosis; brain imaging;

Princeton's Department of Electrical and Computer Engineering is actively engaged in teaching and research on many topics related to these challenges.

Junior and Senior independent work is an experimental, computational and/or theoretical study of an important problem that is investigated by an individual student or team of students outside of a structured lecture course. It is open ended, work is not circumscribed by syllabus, text, problem sets, etc. It can also have one or several different components (experiment, theory, computation, engineering design, to name but a few).

Independent work is often extremely challenging on both a personal and academic level, but is also very fulfilling. Because it is not circumscribed, more is expected from you. On the other hand, most students consider their independent work experience – working with one or more faculty members on a challenging problem – to be one of the high points of their Princeton education in providing a greater sense of accomplishment. The objectives of this guide are to:

1. give a brief overview of Electrical and Computer Engineering independent work.
2. explain the graded elements of independent work and certain rules and procedures governing the preparation of the final report or thesis.
3. help develop a schedule that will avoid the typical rush that occurs in completing independent work at the end of the semester.
4. provide some tips on how to organize your research and the write up your results in your final report.

SELECTING A PROJECT TOPIC AND FINDING AN ADVISER

Students seek out independent work topics based on their interest in research within the department. The student then proceeds to discuss possible project topics with the faculty member supervising the research. Students may also suggest their own topics. If a student is not able to obtain a firm commitment from a faculty adviser, the undergraduate representative, with the assistance of the faculty, will then make the final assignment of students to faculty, trying to satisfy student requests and yet maintain a reasonable distribution of students among all faculty members. The faculty adviser can be from outside the ECE department. The primary adviser can

also be from outside the University (e.g. a local company). In that case a secondary-adviser has to be selected from among the Electrical Engineering faculty.

ENROLLING IN INDEPENDENT WORK

To enroll in one semester of Independent work you must:

1. Register for ECE 297 or 397 (fall) or ECE 298 or 398 (spring)
2. Seniors must register for 497 (fall) and 498 (spring)
3. Prior to the start of the semester, reach an agreement with a faculty adviser on a project and have this information recorded in the Undergraduate Program office.

The independent work timetable will be distributed to students at the beginning of the semester.

SENIOR INDEPENDENT WORK FUNDS RESEARCH AND RESEARCH RELATED CONFERENCES

Limited funding is provided by both the Electrical and Computer Engineering Department and the School of Engineering for independent work requiring financial support for acquisition of data, or other special requirements. Awards are typically modest and not all proposals can be funded. Talk with your adviser if you feel you may qualify for this support. Remember, however, that the application deadline is relatively early, implying that you must already have a good idea of what you need and why it requires support. If you would like to apply, you must submit a one or two page proposal, including a budget, to your adviser who must then sign off on the funding application and forward it on to the Departmental Representative.

The Electrical and Computer Engineering Department also has limited senior thesis/independent work funding "Excellence in Engineering" which is available for both research and conference attendance. This funding encourages student attendance at electrical engineering conferences located in both the USA and Canada. *The selected conference must have components of professional development such as tutorials, plenary talks, poster presentation, etc.* The application and a waiver form for this funding can be picked up from the Undergraduate Coordinator's office.

SATISFYING REQUIREMENTS

DESIGN REQUIREMENT

A design-oriented project can satisfy the ECE design requirement. Your project adviser will determine whether or not your particular project satisfies this requirement. To have your project satisfy this requirement, you must first obtain approval from your adviser, based on a written project plan submitted with your sign-up form prior to beginning your work. Your plan must include appropriate specifications and a description of constraints. Final approval of satisfying the design requirement will be signified by your adviser checking the appropriate box on your final report grade form.

The thesis projects are also designed to prepare students for engineering practice. Therefore, it is required that the project incorporates appropriate engineering standards, which should be clearly identified in the thesis report.

P/D/F, BREADTH, CONCENTRATION AND DEPARTMENTAL COURSE

Independent work cannot be taken P/D/F. It cannot be used to fulfill the ECE breadth or concentration requirements, but it can be counted as a Department course.

THE GRADED ELEMENTS OF INDEPENDENT WORK

During the semester you need to complete the following three elements of Independent Work.

1. **Project Proposal Form (ungraded but required)** The aim of the project proposal is to ensure that you are headed in the right direction. The majority of problems that arise in independent work are due to a late start. We want to see that you have an advisor selected, a project with a well-defined objective, and some idea of the steps it will take to achieve your objectives. Obviously, projects evolve as the semester progresses; you are not bound by our original proposal, but it will help guide your research. **Due back to UG office by 9/16/22.**

If you are having trouble finding an advisor, look at

<https://ece.princeton.edu/academics/undergraduate/student-projects/independent-project-ideas>

For a list of ideas. You are welcome to work on a project outside of a faculty research area, but will need to find a faculty mentor for these projects. If you are having difficulty, contact either the independent work supervisor (Lori Bailey), faculty adviser (Paul Prucnal) or departmental representatives (Prateek Mittal or David Wentzlaff).

2. **Poster Presentation (10% of grade) – December 14, 2022 at 12pm**
All independent work students, a majority of the faculty, and many interested students throughout the department will be in attendance. A group of faculty, including your advisor, will provide a grade for your poster presentation. You should prepare a poster that can clearly express your work this semester, including project goals, background and context, accomplishments and results, methodology, conclusions and future directions. Remember, posters need to be printed, so plan ahead!
3. **Final Written Report (90% of grade)** Students doing two semester independent work/thesis are required to provide via email a copy of the Independent Work/Thesis mid-year report to the Departmental Undergraduate Office by 3pm on Friday, December 16, 2022. **In addition**, by the same deadline, they should email a pdf file of the report to **each of their advisors**.

Final report for fall IW is due by 3 pm on December 16, 2022 to your advisor, second reader and UG office (lbailey@princeton.edu)

Final report for spring IW is due by 3 pm on May 9, 2023 (Dean's date) to your advisor, second reader and UG office (lbailey@princeton.edu)

SENIOR THESIS

A senior thesis is mandatory for all ECE majors.

An interim report (90% of grade) is due on **December 16, 2022 by 3 pm** to your advisor, second reader and the UG office (lbailey@princeton.edu). A poster session (10% of grade) will be held on **Wednesday, December 14, 2022**, to showcase your work to date. The interim report and poster session will represent your grade for ECE497.

The written thesis (90% of grade) is the document submitted as the ELE 498 project report. The thesis is formatted specifically to the stated University regulation that will be provided to the student. Thesis students are required to email a pdf of the thesis to the department office (lbailey@princeton.edu) by 3pm on the senior thesis due date of **Monday, April 17, 2023**, as well as advisor and second reader.

Poster Presentation (10% of grade) – at a poster session on **May 3, 2023** during Reading Period. A group of faculty will provide a grade for your poster presentation. You should prepare a poster that can clearly express your work this semester, including project goals, background and context, accomplishments and results, methodology, conclusions and future directions.

SENIOR THESIS GUIDELINES

The written thesis is the document submitted as the ECE 498 project final report. The thesis is to be submitted by spring semester deadline per University regulations as previously stated. The thesis is to be formatted specifically to the same format as a two semester final report.

The advisor and a second reader, agreed upon by the advisor and student, will examine the thesis. Each member of the committee will provide both a quantitative and a written evaluation of the thesis, which must include a written statement recommending the project for recognition as a senior thesis.

GENERAL ADVICE REGARDING FORMAT OF FINAL REPORT

The most frequently asked questions concern what is actually in the final report (how much detail, how long should it be, etc.). This section of the guide is a strictly informal set of guidelines describing the basic components of a final report. Since projects differ widely, it is impossible to develop a general set of guidelines that applies equally to all students. Regardless of how well you think your own research fits the following guidelines, you should talk to your adviser to determine the most appropriate style of presentation for your own work.

The essence of any scholarly work is to establish the following:

- Definition of the problem and review of the literature
- Presentation of your particular contribution
- Identification of fruitful areas of further research that others in the field may use to guide their own work

Toward these three goals, the following list of questions may prove useful for organizing both your research effort and the final writing of the final report.

WHAT ARE YOU LOOKING AT?

You must begin by defining your problem. In the introduction of the final report, you want to do this in a general way that gives the reader a sense of the scope of the project and a basic understanding of your problem. For example, you may be solving a problem of interest to a particular company, or developing a new approach to a problem that is of interest to the research community as well.

Why are you looking at it?

Motivate your work. Explain to the reader why the problem is interesting and important. Establish who will benefit from your work and why. Note that you do not have to get the whole world interested in your work. Most independent work involves the application of existing techniques to particular problems, and hence the people who will be most directly interested may be those working for a particular company, engineers working on a specific project, and so on.

Who else looked at it?

Now that we (the readers) have a rough idea of what your problem is, you must firmly establish what the state of the art is in the area. This is particularly critical if you wish to claim that you have a better way of solving/approaching a problem than has appeared previously in the literature. List others who have worked on the same or similar problems and briefly describe their work. If you are duplicating the approach used by others in the field, but using a different data set that is of particular interest to you, say so and describe why you have chosen this approach over others that may have been used.

How are you looking at it?

At this point, you may need to review your problem again but at a much higher level of detail, introducing any mathematical notation required and describing any subtle aspects of your problems that may in fact be the central component of your research but which were too detailed to put in the introduction. Empirical research, which involves gathering data to prove some relationship, can often be introduced by citing one or more hypotheses which you feel your research will prove (or disprove).

Not all work is conducive to initial statements of hypotheses, particularly methodological topics which are aimed at better solutions to existing problems (the implicit hypothesis is that your method is better than others, but this need not be stated as such). In any event, unless your work is purely theoretical, you should describe in detail your experimental design: how you structured your data collection, problems you encountered, and how you conducted your experiments. The description should be sufficiently detailed to allow another researcher to duplicate your efforts. A key part of your description should be a clear list of major assumptions you are making and why you are making them. It is useful at the same time to indicate which assumptions are perfectly reasonable (e.g. other researchers have used the same assumption and have obtained good results) and which are likely to affect your results but are required for time/budget reasons.

What are the limitations of your work?

One of the most difficult aspects of research is understanding exactly what you did and what you did not do. If you were limited by your data, explain how you think this might affect the generality of your conclusions. Discuss openly any shortcuts required due to time/budget/data availability constraints. Do not try to claim credit by stating that you feel that your method will work in more general situations if you have done only limited testing. At the same time, do not feel you are getting off the hook by over-qualifying your work (e.g. "Because of such and such restrictions, no valid conclusions can be drawn until more extensive experiments are carried out using so and so's data or equipment."). Clearly drawing the line between what you did and did not do is a central step in the scientific method since it helps define the state of the art.

What are your conclusions?

In view of the limitations above, what conclusions can you draw from your research? Because your conclusions are often inextricably intertwined with the limitations of your research, both questions are often answered simultaneously. It may be useful to discuss limitations of specific aspects of your work while you are describing the work itself, but defer a discussion of how such limitations actually impact your results until later. Your section on conclusions is usually brief, and should specifically and clearly describe your contributions to the field. Frequently, researchers familiar with the field will start by reading your conclusions and, depending on your claims and then decide whether to read the report itself. Again, do not underrate your work, but do not claim to have solved problems that are not firmly substantiated in the body of the final report.

What next?

Areas for future research. Now that you are an expert in your particular area, you should have both a narrow understanding of a well-defined problem as well as a broader understanding of the field as a whole. As such an authority, it is now your responsibility to guide others in the fields that do not have the benefit of your particular experience in directions that you feel will provide the greatest good. Such recommendations are usually based on an evaluation of the major weaknesses in your

own work, in which case you might recommend how others (preferably with more time and money than you enjoyed) could overcome these weaknesses. Be sure, however, to specify those weaknesses that you feel would have the greatest impact on your conclusions. Some assumptions that you may have made may be perfectly reasonable, in which case a more accurate model would not improve the final results.

FORMAT OF THE FINAL REPORT

The Independent Work report should look like a professional document – 12-point font (Times New Roman preferred), appropriate margins, double or 1½ - spaced.

The report should be divided into chapters, numbered sequentially, and a table of contents provided immediately after the first 4 pages (i.e., starting page 5).

Supplemental material (e.g., lengthy computer code used in the Independent Work, or long tables of supporting data) should be provided in appendices after the concluding chapter, and numbered sequentially.

The report should contain a proper bibliography. References should be numbered in order they appear in the report (preferred); alternatively, they should be referenced as [author, year]. The complete reference list should be provided at the end, either sequentially by number, or alphabetically by author, depending on which of the above referencing schemes is used. The engineering standards used in the thesis and their role should be clearly identified in the written thesis. This may be done in through footnotes or references in or in a focused section of the thesis report.

All non-original text should be properly attributed. Failure to cite sources for ideas, tables, text or diagrams is a violation of Princeton University's code of ethics. If you are unsure about how to cite sources properly, ask your adviser.

Charts, tables, diagrams, etc., should be accompanied by proper captions, and should be appropriately referenced in the text. Footnotes, if necessary, should be used sparingly. If the numbered referencing scheme is followed, references could be used in lieu of footnotes.

The final report should be printed on one side of standard-size paper (8 ½ X 11 inches). The typing should be "double-spaced" or 1.5 spaced. The latter is recommended, with the exception of footnotes and bibliography, which should be single-spaced. All margins should be 1 inch or larger. All pages must be numbered. The format of the first four pages should be as given below.

INSTRUCTIONS FOR FIRST FOUR PAGES

Page 1:

The first page should include the title of the project, name of author, date, name of adviser(s), and the statement:

Submitted in partial fulfillment of the requirements for the degree of Bachelor of Science in Engineering Department of Electrical and Computer Engineering Princeton University
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Page 2 – The second page should contain the following statement:

I hereby declare that this Independent Work report represents my own work in accordance with University regulations. Your Signature Your Name

Page 3 – The third page should contain the title of the Independent Work project, your name, and an abstract all of which fit within ONE page:

Title
Author
Abstract - text

Page 4

The fourth page, entitled "ACKNOWLEDGMENTS", should contain relevant acknowledgments, citing your debt to individuals who contributed to your thesis, as well as any sources of financial support (departmental/SEAS funds, federal grants – check with your adviser for specific details). Any dedications should be part of this page.

TIPS ON ORGANIZING YOUR TIME

One of the most common mistakes made by students doing independent work is underestimating how much time it takes to complete certain tasks, in particular the actual writing of the final report. Avoid undertaking overly ambitious projects, because they often take much longer than you expect. Order any parts you need as early as possible.

It may be helpful to divide the effort into three primary tasks:

1. Defining the problem and reviewing the literature through survey reading and digesting the background material. Plan the project, week by week, so that you have a finished project well before the deadline.
2. Doing the work (including experimental work, if applicable). Don't hesitate to redirect, redefine or even change your project if you are stuck. One objective of independent work is to recognize when it is appropriate to quit and try something else.
3. Writing the final report. Make an outline for the final write up well in advance of the writing so no time is wasted reorganizing or rewriting major sections in the last minutes before deadline.

If your research is fairly well defined (usually with the help of your adviser), then the first stage may be somewhat reduced. Naturally, the three tasks will overlap, since you may have to do additional

literature review when you finally settle on a specific problem, and it is often useful to begin writing certain sections of the final report while the actual research is in progress.

Please do not underestimate how long it takes to write a good final report/thesis. **START EARLY!**

EXTENSIONS

Extensions are not normally given. If, for any reason you must be away from campus when one of these reports is due, plan to turn the report in early. Extensions for turning in the final report /thesis will be granted only in the case of illness (or family emergencies) and only when such illness or emergency makes it impossible to complete the final report on time. All final report extensions must be requested in writing and turned in to the Departmental Representative prior to the deadline for the final report. Each request must be approved first by the student's adviser and then by the Departmental Representative and finally by the Office of the Dean of the College. Extensions will not be granted for unexpected delays due to problems in your experiment, analysis, or simulations.

ADDITIONAL RESOURCES

Writing Support

Located at 2 New South, the Writing Center offers free one-on-one conferences with experienced fellow writers trained to consult on assignments in any discipline. Special 80-minute conferences are available for JP and Senior Thesis writers, who may sign up to work with a graduate student fellow from the department of their choice. The Writing Center also holds 50 minute regular conferences seven days a week, and drop-in hours Sunday through Thursday evenings. View their website to make appointments at <https://writing.princeton.edu>

GRADING

The following are examples of the grading sheets that will be used to evaluate the graded elements of independent work.

EXAMPLE OF AN ADVISER GRADING SHEET FOR THE FINAL REPORT/THESIS

Name of Student:

Title of Independent Work:

Please provide scores, write your descriptive evaluation, and overall grade based on the following criteria:

1. **Originality and Creativity** – e.g., clear independence and novel thinking; going beyond literature and advisor.

1 (low)	2	3	4	5 (high)

2. **Technical Quality** – Consistency, control, reliability/reproducibility.

- Quality of the experiment/device/system/process design

1 (low)	2	3	4	5 (high)

- Quality of data and data analysis

1 (low)	2	3	4	5 (high)

3. **Communication Quality**

- a. **Completeness** – Background, motivation, completion and accomplishments of project, and future work. Indicate if publishable; how much follow-up work is needed?
- b. **Level of Scholarship** -- literature search and reference.
- c. **Writing Quality** – Crisp, well written, needs little editing or revision.

1 (low)	2	3	4	5 (high)

4. **Relative Standing** – How does the report compare with Independent Work reports you have seen in the past five years?

Below Average	Average	Top 30%	Top 5%

DESCRIPTIVE EVALUATION

Guide:

- (A+) - Truly exceptional
- (A) - Very Good to Excellent; well above nominal expectations
- (B) - Good to very good – covers everything that is expected
- (C) - Adequate to fair; would have liked to see more
- (D) - Marginal
- (F) - Unacceptable

EXAMPLE OF ORAL PRESENTATION GRADING SHEET FOR ADVISERS AND FACULTY COMMITTEE:

Name of Student:

Title of Presentation:

Please provide a short description of your evaluation, along with a grade (A-F).

In making your descriptive evaluation, you may wish to consider the following, given the time allotted for the presentation (10 minutes):

1. Did the student provide adequate background for the technical presentation?
2. Was the motivation for the project well presented?
3. Did the presentation give a clear idea of the methodology and technical merit of the work?
4. Did the student present the accomplishments clearly?
5. Were the conclusions justified and well articulated?
6. Did the student suggest follow-up investigations or directions as a result of the work done?
7. How did the work compare with that of your other students in this course in the past 5 years – best, one of the better ones, average, below average, one of the lower achievers?

Descriptive Evaluation

Overall Grade:

Guide:

- (A+) – Truly exceptional
- (A) – Very good to excellent; well above nominal expectations
- (B) – Good to very good; covers everything that is expected
- (C) – Adequate to fair; would have liked to see more
- (D) – Marginal
- (F) – Unacceptable

COURSE LEARNING OBJECTIVES

The following learning objectives (student outcomes) constitute the minimum skills that every student must acquire through the senior thesis/independent work experience. These objectives will be used, in part, to evaluate the student's work and in the assignment of a grade.

Course Learning Objectives	ABET Criterion 3
An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science and mathematics	1
An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental and economic factors	2
An ability to communicate effectively with a range of audiences	3
An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental and societal contexts	4
An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives	5
An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions	6
An ability to acquire and apply new knowledge as needed, using appropriate learning strategies	7

The Senior Thesis in the Department of Electrical Engineering is also designed to provide students with a major design experience based on the knowledge and skills acquired in earlier course work and incorporating appropriate engineering standards and multiple realistic constraints.