Electrical Engineering

Independent Work and Senior

Thesis Guide

A COMPENDIUM OF DATES, TIPS, GUIDELINES
AND PROCEDURES

2013-2014
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Electrical 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 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 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 EE department. The primary adviser can also be from outside the University (e.g. a local company). In that case a secondary-adviser should also be selected from among the Princeton Faculty.

ENROLLING IN INDEPENDENT WORK

To enroll in one semester of Independent work you must:

1. Register for ELE 397 or 497 (fall) or ELE 398 or 498 (spring)

2. 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 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 write a letter of support and forward it on to the Departmental Representative.

The Electrical 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 EE 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.

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

Independent work cannot be taken P/D/F. It cannot be used to fulfill the EE 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 graded elements of Independent Work (for detailed grading rubrics, see Appendix A):

1. **Preliminary Report (10% of grade)**. The aim of the preliminary report is to ensure that project formulation and thinking through the project’s objectives, scope and required background material starts in earnest from the beginning of the semester. It is hoped that the preliminary report will help frame the project and serve as a template for the introductory parts of the final report. The preliminary report should explain the project to be undertaken, provide motivation, outline the project goals, and give the first steps of any relevant literature or background material search. We realize this is only four weeks into the semester, so we are not expecting a lengthy write-up. This is intended as a means to ensure that students have their projects underway.

   The student should email the preliminary report to both the adviser and to the EE undergraduate office ("Cynthia L. Menkes" cmenkes@princeton.edu) by the deadline stated in the independent work timetable. Each adviser will give their advisee’s report a numerical grade on a 5-point scale, using the following guidelines:

   5  A+ = exceptional.
   4  A   = very good, well above nominal expectations.
   3  B   = good, outlines everything that is expected.
   2  C   = adequate but would have liked to have seen more.
   1  D   = marginal at best.
   0  F    = unacceptable or not submitted.

   **Seniors who are doing a two-semester independent work project are only required to submit a preliminary report in the fall semester.**

2. **Oral Presentation (25% of grade)** at a specified time during Reading Period. Both students and faculty will be in attendance, and food and drinks will be provided. Students will have their own allotted time to present their research.

   Students will be asked to give a 10-minute oral presentation on their Independent Work project. Nominally, the presentation should give: the big picture description and motivation for the project, a summary of the work done, and a description or demonstration of the main accomplishments/results/outcomes, ending with any relevant conclusions. Two or more faculty
members (a committee) will be present among the audience. Independent Work advisers have been asked to be present at the oral presentation of their advisees as one of the members of the committee. The committee, and others, may ask questions on the project for about 5 minutes. A copy of the presentation (as a PPT file) must be submitted by the student to the EE undergraduate office by the date stated in the independent work timetable. The copy will then be forwarded to the orals committee in advance of the oral presentations.

3. **Final Written Report (65% of grade for two-semester Senior Independent Work and 65% of grade for all other Independent Work)**. Thesis and two-semester reports will be due before 3pm on the University’s specific due date for thesis. For all other Independent Work (one and two semester), the deadline will be Dean’s Date.

Final reports should be submitted to the EE undergraduate office (cmenkes@Princeton.EDU) as a Word or pdf document. The final report will be promptly emailed to the adviser as well as to a second reader for grading. There will be two readers for each project: the adviser and the course instructor. The course instructor will, of course, have freedom to consult with the adviser.

**SENIOR THESIS**

**Starting with the Class of 2016** a senior thesis will be required. Until that time, we encourage seniors to pursue a Senior Thesis option. Work on a single project extending over the entire academic year under the supervision of the same faculty member for both semesters can be afforded additional department recognition through the Senior Thesis option.

**SENIOR THESIS GUIDELINES**

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

The student and adviser need to coordinate in order to arrive at a committee of two faculty members (including the adviser) who will hear an oral presentation of the project. Normally the two faculty members will be Princeton faculty, with an EE faculty member participating when the adviser is not from EE. The committee will provide a written statement recommending the project for recognition as a senior thesis. There is no requirement that the second committee member submit a written evaluation of the thesis; the adviser will submit a written report along with the recommendation for the project grade for ELE 498.

Students are required to email a pdf of their independent work or thesis to the ELE Departmental Undergraduate Office on dates provided at the start of the semester. In addition, by the same deadline, they should email a pdf file of the final report/thesis to each of their advisers. Please check with your adviser(s) if they would like a printed copy as well - the undergraduate office is NOT responsible for providing the final report of Independent Work to advisers (pdf or printed). For those
students doing a senior thesis, the EE Department requires one bound copy to be left with the UG office. Please check with your adviser to see if they will require a bound copy as well.

GENERAL ADVICE REGARDING FORMAT OF FINAL REPORT

ONE SEMESTER AND TWO SEMESTER/SENIOR THESIS

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.

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 Engineering
Princeton University
```

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 in Whitman College, 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. You may sign up for an appointment at http://www.princeton.edu/writing/appt. Enter through Baker Hall.

GRADING

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

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

Name of Student:

Title of Independent Work:

Please write your descriptive evaluation and grade based on the following criteria:

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

Technical Quality – Consistency, control, reliability/reproducibility.
Completeness – Background, motivation, completion and accomplishments of project, and future work. Indicate if publishable; how much follow-up work is needed?

Level of Scholarship -- literature search and reference.

Writing Quality – Crisp, well written, needs little editing or revision.

Relative Standing – How does the student compare with students under your supervision in the past 5 years in this course?

DESCRIPTIVE EVALUATION

Overall Numerical Grade:

Signature (Name) ________________________________

Guide:

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

EXAMPLE OF THE PRELIMINARY REPORT GRADE SHEET

The preliminary report, due after one month of starting the Independent Work project, should explain the project to be undertaken, provide motivation and outline the project goals and give the first steps of any relevant literature or background material search. It carries 10% of the final grade for the course.

Name of Student: ________________________________

Title of Independent Work Project: ________________________________

Project expected to satisfy the Engineering Design Requirement (circle as appropriate).

Yes   No

Preliminary Report Grade (On a 5-point Scale; please circle the appropriate grade and remarks):

5 (A+) = exceptional.
4 (A) = very good; well above nominal expectations.
3 (B) = good; outlines everything that is expected.
2 (C) = adequate, but would have liked to have seen more.
1 (D) = marginal at best.
0 (F) = unacceptable or not submitted.
Additional Remarks by adviser, including suggestions for improvement in reporting and/or execution of project for the rest of the semester.

**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 (0 – 5).

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:**

Signature (Name) ____________________________

Guide:
5 (A+) – Truly exceptional
4 (A) – Very good to excellent; well above nominal expectations
3 (B) – Good to very good; covers everything that is expected
2 (C) – Adequate to fair; would have liked to see more
1 (D) – Marginal
0 (F) – Unacceptable
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.

<table>
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<tr>
<th>Course Learning Objectives</th>
<th>ABET Criterion 3</th>
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<tr>
<td>an ability to design and conduct experiments, as well as to analyze and interpret data</td>
<td>b</td>
</tr>
<tr>
<td>an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability</td>
<td>c</td>
</tr>
<tr>
<td>an ability to identify, formulate, and solve engineering problems</td>
<td>e</td>
</tr>
<tr>
<td>an understanding of professional and ethical responsibility</td>
<td>f</td>
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<tr>
<td>an ability to communicate effectively</td>
<td>g</td>
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<tr>
<td>the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context</td>
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<td>a recognition of the need for, and an ability to engage in life-long learning</td>
<td>i, j</td>
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<td>a knowledge of contemporary issues</td>
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Grading of Electrical Engineering independent work projects should follow the published grading guidelines. In addition to the information solicited on the project grading report, additional information as described below should be reported for use in Program Assessment of the electrical engineering undergraduate program. There are a variety of student outcomes to which individual independent projects may contribute. It is expected that the various contributions will depend on the nature of the project. Program Assessment will involve an analysis of the data supplied for all individual projects.
The following outcomes will be assessed for individual independent projects using the ratings provided by advisers. The rating is to indicate the level at which the project demonstrates the outcomes. Faculty are asked to use a rating scale of 1 to 5 (low to high) for their responses. A rating of 1 should be used when an outcome is not applicable to the project. An ability to design and conduct experiments, as well as to analyze and interpret data.

Rate the experimental work _____ Rate the analysis and interpretation of data _____

An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability

Rate the overall design work _____
List specific design accomplishments:
List constraints that were addressed:

An ability to identify, formulate, and solve engineering problems:
Rate the project for demonstrating these abilities _____

An understanding of professional and ethical responsibility:
Rate the documentation, with appropriate use of citations, of prior work _____
Rate the performance regarding deadlines and interim requirements _____
List any additional relevant project elements (e.g. lab safety issues, lab protocols):

An ability to communicate effectively:
Rate the communication skills demonstrated in the final written report _____
Rate the communication skills demonstrated in the poster presentation _____

The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context:
Rate the extent to which the project deals with such impact _____
A recognition of the need for, and an ability to engage in life-long learning
Rate the extent to which the project addresses future opportunities _____
Rate the extent to which student sought out sources of information _____

A knowledge of contemporary issues:
Rate the extent to which the project is “cutting-edge” _____
Rate the extent to which the report reflects current status of technology _____

An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice:
Rate the use of engineering tools, equipment, etc. _____
Provide specific examples of software, equipment, skills, etc.

Please provide your comments regarding the information solicited above, including suggestions for other factors that might be rated in the future.