Astronomy 351/392J   Astronomical Instrumentation

Professor: Daniel Jaffe   Spring 2011
TTh 9:30-11:00   RLM 16.304A   Unique No. 48300/48360

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Introduction

This course teaches the fundamentals of the design and construction of experimental apparatus using astronomical instruments as the model for the process. We will cover key aspects of some of the most important topics in the field: optics and optical design, mechanical design and machining, electronics design and fabrication, real-time computer control, project planning, and performance analysis. Since we cannot teach you everything you need to know in a single semester, we will try to equip you with enough background to be able to continue learning on your own.

Overall Objectives

By the end of the course, you should have a concrete knowledge of many of the essentials of instrumentation. You should be able to plan out, schedule, and organize an instrumentation project and have some idea of what goes into a project budget. You should understand the steps involved in the mechanical, optical, software, and electronics design. You should have a good working knowledge of where to obtain information you need for your project in each of these areas. You should have concrete knowledge of computer aided design (CAD) programs for mechanical design (**Inventor**), electronics design and simulation (**Multisim**), and optical design and simulation (**Zemax**). You will know how to do basic work with hand tools and with machine shop equipment. You will be able to assemble and understand some electronics circuits and be able to use laboratory equipment to test them. You will know the fundamentals of optical design and be able to design and build a grating spectrometer. You will be able to use **LabView** to interface an instrument to a computer.

How the Course Works

Philosophy

Astronomy 351/392J is a team-taught course where you are part of the team. There will be only occasional classes in a more conventional seminar/lecture format. Most of the time, the class will look more like an apprenticeship, an engineering project course, a physics lab course, or a bunch of curious people let loose in a room full of great toys. The learning in this course is centered around the activities of teams of 4-5 students. We have structured the activities to emphasize collaborative learning. As future teachers, researchers, and technical managers, you will need to know how to help colleagues, coworkers, employees, and students master complex material. You will start that process here. Your participation as a teacher/trainer in this course is as important as your role as student/trainee. You will be encouraged to work together on almost everything. Although there will be some background reading to do, most of the learning will take place in the form of activities. Compared to the typical course, this course will involve much more "class" time and somewhat less time outside of class. Expect to spend at least 6 hours per week in the lab or shop and 3 hours per week on reading and homework.

As professor and TA for this course, we serve four purposes: (1) As facilitators. We are here to make sure you have all resources necessary to do the activities and learn the material. This includes making sure the software works, the hardware is there, the materials are clear etc. (2) As part of the coaching staff. Along with the other members of the Department and the Observatory who are making themselves available, we are a knowledge resource. You can come to us for advice, for direction to additional people or material, or for help when you are flat-out stuck. (3) As referees. When there are conflicts between or within teams and groups over resources or (heaven forefend!) personalities that cannot be resolved satisfactorily without our help, we are there to deal with them. (4) As evaluators. This is after all a course. You will get a grade (see below). We also take seriously the part of this role that involves evaluating the course materials and organization, as well as the performance of the outside instructors and even ourselves. You need to contribute to this effort by taking your own evaluating role seriously.

<u>Texts</u>

Building Scientific Apparatus by Moore *et al.* (4th edition)
The Art of Electronics by Horowitz and Hill (2nd ed.)

Both of these are great references as well as textbooks. If you have any inkling at all that you may be around instrumentation in the future, **hang onto these books at the end of the semester!**

Suggested Labview References:

LabView for Everyone by Travis (2nd edition)
LabView Graphical Programming by Johnson & Jennings

<u>Segments and Segment Groups</u>

The curriculum for this class has been divided into four segments. Each segment covers an important aspect of instrument design and construction: mechanical design and fabrication, electronics and circuit design, optics and optical design, and computer interfacing and software design. The segments will consist of a reading assignment, a set of problems, some hands-on skill learning tasks and a laboratory exercise.

The class will be divided into **segment groups**. Each **group** will rotate through the segments in succession. **Groups** will have 3 weeks to complete each segment. You will do most of the activities as a group.

Projects and Project Teams

A major aspect of this course will be the use of what you are learning to design and construct a working instrument. The instrument project will consist of designing and building an optical spectrograph. This instrument will have a solid-state optical detector and operate under computer control. It should be able to take wavelength-calibrated spectra of bright emission-line sources (lamps).

You will carry out the project as a member of a **project team**. Each **team** will be responsible for planning, designing, and building its own instrument. The members of your **team** will all come from different **segment groups** so that your team quickly collects all of the skills needed to carry out the project.

Assignments and Deadlines

Each segment will have a reading assignment, a set of paper exercises, a piece of software to master, and a practical exercise. Because other **groups** will need access to the hardware, your **group** must complete each section within the allotted time. You should work out the paper exercises or problem sets on your own. You may then consult with your group about the answers. Once you are sure you know the answer, you must hand in your own writeup. Problem sets will be due at the end of each segment (note that, for the computer interfacing segment, you will need to demo your knowledge rather than do a problem set).

Each project team will have a conceptual design review, a preliminary design review, and a final review of the project. At the reviews, each member of the team will be expected to be able to stand up and make any part of the presentation. At the preliminary review, approximately six weeks before the end of classes, each team member will have to turn in a written description of the instrument, how it will work, and how it will be built. This document should be about two pages long, plus figures.

Class Meetings

The class will meet every TTh at 9:30-11:00. Every Tuesday each segment group will meet with the professor or TA to get started on a new segment, work on lab projects, or discuss any questions. For the labview segment you will demonstrate what you have learned on the last Thursday of that segment period. Occasionally, there will be a lecture for part of the class on Thursday. Otherwise, you will use it to work on your segment. Once you start work on your projects, each team will meet to discuss plans, progress, and problems each Thursday. You will also have to spend a substantial amount of time in the lab outside of class hours with your groups and teams. Find times when you can get together. On-time attendance at class, group, and team meetings is a course requirement.

Getting Help

(a) Your Segment group or project team: You are all working together, so split up the learning task in a way that makes sense to you and then teach each other what you know.

(b) Your classmates: Many of you come into this with a great deal of knowledge and talent. Make it your business to find out which of your classmates is already an expert in something and tap into that expertise.

(c) The Prof and TA: Each of us will spend time in the laboratory outside of class time, randomizing our hours to try to cover all the times used by groups and teams. If you need to meet with us, have a member of your group arrange a time for one of us to be here when your group or team is. Personal problems of individual students can be handled in my office, by arrangement.

(d) Other experts: One advantage in being in a place where a lot of building is going on is that somebody usually knows the answer to your question. We will be calling on some of the local experts to share their expertise in certain areas and to serve on the design reviews for your projects. Sometimes, these folks can be helpful before you get to that stage by getting you started on something, giving you a reference, or telling you your idea won't work. These folks can be found on the 15th to 17th floors of RLM. Here is a partial list.

Optics: John Lacy, Phillip MacQueen, Gary Hill
Electronics: Phillip MacQueen
Computer Interfacing: Chris Wilkinson
Mechanical Design: Gordon Wesley, Jimmy Welborn, Rupert Ruiz, John Booth

(f) A book. There are tons of books out there. Some of them are even helpful. Also, check out parts catalogs. They often have little tutorials in them. The parts themselves sometimes give you ideas. Individual segments will contain some specific references to relevant reading material.

Evaluation of Your Performance

We intend your grade in this course to reflect the amount of skill you acquire and the strength of your contribution to the efforts of your group to learn the material and your team to build the instrument. Items we will include in setting your grade are: (1) Attendance (including coming on time) (~15%) (2) Individual problem sets and group segment reports (~25%) (3) Your writeup of the instrument for the preliminary review (~10%) (4) Your performance and that of your team at the preliminary review (~10%) (5) The level of mastery you display when you (individually and as a team) exhibit and demonstrate your instrument at the end of the course (~40%). To carry out this last point, during the last week of class, your team will demonstrate your instrument. Each of you will have a private discussion with the professor and TA in which you explain the workings of the various elements of your system. Your evaluation on item (5) will depend equally on how well your team did on the project, and on how well you did yourself.