Syllabus
Independent Study in Fluid Dynamics
Professor Hertzberg
Spring/Summer 1999

Instructor:
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My office hours will be determined after the start of the semester. In general, you can stop by for help anytime, but I can't guarantee I'll be free. I read my e-mail two or three times a day, and can give quick response to short questions that way.

Goals: In this course, you will carry out some form of research associated with my overall research program in combustion and fluid mechanics. Most of the work focuses on the three-dimensional interaction of flames and vortexes or vortex flows in the heart. Most of the projects involve laboratory experiments of some kind - real experiments, where nobody knows the answers yet.

Depending on your exact project, you will learn an assortment of practical engineering techniques such as how to shop for technical equipment, how to *buy* stuff in the context of an institution (CU purchasing procedures), how to design equipment and interact with a machinist and technician to get it built, how to perform library research on topics both old and at the leading edge of human knowledge, and how to acquire and present useful data. Along the way, you may build skills in personal and workstation computer use, image processing techniques, data visualization techniques, photography, video, plumbing, metal work, electronics, oral and written presentations, and maybe even combustion or fluid mechanics fundamentals.

Most of the focus of this experience is on hands-on laboratory and computer work. Still, you will have to demonstrate that you understand the basic physics underlying the work; both the overall research goals (control of shear layers) and the specific topics related to your project (stress analysis, acoustics, image processing, stereopsis, etc.). To start with, you will be assigned to read the appropriate original proposal, as well as some related journal articles. After that you'll find some material in textbooks, but for some of what you'll need, There Are No Textbooks. You will learn to find the information you need in the library. There are also no homework sets or exams for you to get feedback on your level of comprehension, or to inspire your studies. You will get guidance in your quest, but no hand-holding. This is a very independent study in that sense.

Prerequisites: MCEN 3027 or an equivalent Measurements Laboratory type course (taking it as a co-requisite is also acceptable). Since the work you do will be used by other people down the line, you must be able to organize and present technical information, and MCEN 3027 is where you start to learn that. In addition, courses in fluids and thermo will help you understand the basis of your work. If you have a background in any of the other above mentioned skills, let me know so we can make use of it.

You will be required to attend a Center For Combustion Research Safety Seminar, to be arranged early in the semester.

Course Format: During the first few weeks of the semester, there will be a one hour lecture each week covering research in general, my research program, and purchasing procedures. A few more lectures may be devoted to flow visualization techniques. Usually there are about 6 lectures all together.

A few weeks into the semester, your group will give a 15 minute oral presentation to the other students, describing your project and its background. This information will form the introduction for your final report, but you'll need to understand it early on. In addition, your group will write a 1 page summary setting out your exact goals for the semester.

Meanwhile, you will have started work on your project.

You will work in a team of 1-4 students, supervised by me and one of my graduate students. I expect around 150 hours total per per student for three credit hours. This is equivalent to 10 hours per week during the semester. This is just an estimate; you are not expected to keep track of your hours. However, this is a substantial time commitment, so be prepared. Think twice if you are taking one or more other project oriented classes at the same time. Projects get very intense at the end of the semester, and I don't want this course to take second place in your attention.

When you put in this time is up to you and your group. I suggest you make a schedule of when everyone in the group is free to meet, by having everyone x out their busy times on a single schedule sheet (I'll want a copy of it). You will also need to schedule a time to meet with your supervisor. In the past, the groups who had the most trouble with their projects were the ones that couldn't find sufficient time to meet all together. So, if your group can't find at least 8 hours a week to come together, consider switching between groups or maybe consider doing this in a different semester.

Each week, your team will submit a half-to-one page summary of the week's accomplishments, and your plans for the next week. This 'PAL' (Planning Agenda List) will form the agenda for your weekly meeting with your supervisors. Meeting lengths can range from 15 minutes to an hour, so put it in your schedule. Your attendance at these meetings is important.

Two weeks before the end of the semester, your group must submit your final report (including all figures). I will edit this version, and indicate changes to be made. The final report (one per group) will be in lieu of a final exam. The requirements for the final report are described in a separate document, which you must read before you start your project.

There are may be other deadlines you must meet. This is sponsored research, and every six months or so the sponsors (NASA, the Navy) require substantial progress reports, or there may be a scientific conference where our latest results are to be presented. You may be required to produce specific results for these reports.

Grading: Grades for independent study courses tend to be both generous and arbitrary. I will assign a grade for the course based on your performance over the course of the semester, including the completion of a significant amount of work, the quality of the work, the quality of the final report, and individual displays of common sense, talent, responsibility, creativity, critical thinking, and initiative. Similarly, displays of carelessness, sloppy work, or lack of adequate time commitment can lose you brownie points. At the moment, a full A is reserved for absolutely outstanding achievement, and please realize that this grade is not awarded for effort only. Still, most people find this a stimulating experience, do a tremendous job and put in a lot of work. They are rewarded with grades of B+'s and up, and often a host of new skills and experiences. Here is a breakdown of how the grade is determined:

25% final report
25% work accomplished: nominal versus maximum
25% Effort and time put in
10% oral report
10% meetings
5% other documents (PO's, PAL's)

Projects: Here is a list of the projects for this semester:

Bifurcating Diffusion Flame. This is a study of an acoustically forced diffusion flame. A flame new phenomenon has been discovered which is being investigated. An explanation for the phenomenon in terms of shear layer instabilities and chaos theory is being developed, and measurements to test the theories must be made. This encompasses a variety of sub-topics which are suitable for individuals and teams (supervised by J.H., and John Carlton):

1. stereo visualization (3-d photographs!)
2. phase-locked flow visualization.
3. nozzle geometry effects (vary the size and shape of the nozzle)
4. gas chromatography: the combustion products from the flame need to be analyzed to see how the flow affects the combustion. The chromatograph will need a new column, and to be calibrated.

Cardiac Vortex Ring Formation: In the human heart, a vortex ring is formed each time the mitral valve opens. However, the relationship between the diameter of the valve and the amount of fluid that goes into the ring is unknown. This relationship could be used to improve diagnoses and artificial heart valve design. This study will examine this relationship in a laboratory vortex generator using photography and video. The apparatus has been constructed, so the project will focus on data acquisition and image analysis.

Microsensors for Cardiovascular Applications: The techniques used for making microelectronics are being used to make miniature sensors for implantation in the human body, specifically in the arteries of the heart. Several projects are available in this area, and will be supervised by one of several faculty in the MEDICA (MicroElectronic Devices In Cardiovascular Applications) research group. One possibility is that these sensors will need a power source, and this project focuses on using natural processes like breathing or blood flow to provide power to these sensors. Dynamics and Thermodynamics are prerequisites for this project.

Stereo Data Visualization: Much of the work described above focuses on three-dimensional fluid dynamics, and the results must be imaged in a three-dimensional way. In addition to experimental work, numerical studies are in progress. The best method for visualizing this type of three-dimensional data is to use stereo imaging techniques to create separate right- and left- eye views (remember ViewMaster?) and then deliver these views to the correct eye exclusively. There are several ways to present these views:

1. Separate photographs of the computer screen showing the two views can placed side by side and viewed using an old-fashioned stereoscope. The proper views of existing data need to be computed, photographed, and mounted. A stereoscope will need to be acquired or fabricated. Some research into established stereo techniques will be required.
2. A new technique which has become popular recently is known as RDS, Random Dot Stereograms, or Magic Eye pictures. You have probably seen these patterns which become 3-d images when viewed properly. I have one in my office. This technique can be applied to visualize 3-d surfaces. The patterns and colors may be used to provide additional information on the flow field. Computer programs to create these images are available and will need to be adapted to display our data.
3. Our high-speed graphics computers are capable of displaying animations, cartoons, of time dependent data. Simultaneous display of right and left eyed animations will produce 3-d cartoons. There are some new low cost systems available that need to be investigated and applied to our purposes.
4. For the library oriented, I would like an investigation of the history of the use of 3-d imaging in fluid mechanics.

Stereo Flow Visualization: Some of the 3-d fluid mechanics studied in the lab are best recorded directly with stereo photography. There are a couple of cameras available on the used market to perform this, including the Stereo Realist and the Nimslo. Another possibility is fabrication of a 3-d video system. There are some very small cameras that can be placed close together, allowing close up 3-d images to be made.

Suggested Reading List

Grinstein, F.F. and Kailasanath, K. 1993, Dynamics of spatially developing reactive square jets. *Ninth Symposium on Turbulent Shear Flows*, Paper 25-4, Kyoto, Japan, August 16-18.

Gutmark,E. and Ho, C.M. 1986, Visualization of a forced elliptic jet.
AIAA Journal, Vol. 24, No. 4, April 1986, pp. 684--685.

Hertzberg, J.R. and Ho, C.M., 1992, Time-averaged three-dimensional flow in a rectangular sudden expansion. *AIAA Journal*, **30**(10), pp. 2420, errata **30**(11), pp. 2803.

Hertzberg, J.R. and Ho, C.M., 1995, Three-dimensional vortex dynamics in a rectangular sudden expansion. *J. Fluid Mechanics*, **289**, pp. 1-27.

Hertzberg, J.R. Conditions for a Split Diffusion Flame. Submitted to *Combustion and Flame* CCR Report 96-01. 1996.

Ho, C.M., and Huang, L.S. 1982, Subharmonics and vortex merging in mixing layers. *Journal of Fluid Mechanics*, **119,** pp. 443--473.

Kambe, T., and Takao, T., Motion of distorted vortex rings. *Journal of the Physical Society of Japan*, Vol. 31, No. 2, 1971, pp. 591--599.