SYLLABUS

MCEN 4228-010/MCEN 5228 -010
Flow Visualization: The Physics and Art of Fluid Flow
Spring 2009

Contact Information

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Office hours will be determined (with your help) during the second week of classes. In general, you can stop by for help anytime, but I can't guarantee I'll be free. If my door is shut, that is a definite 'not available'. I read my e-mail two or three times a day, and can give quick response to short questions that way.

Course Website: www.colorado.edu/MCEN/flowvis, or just Google 'flow visualization'. Our site is #1!

Course e-mail list: flowvis@ lists.colorado.edu. IMMEDIATE SUBSCRIPTION IS REQUIRED. To subscribe, send email from your favorite email account to listproc@lists.colorado.edu. In the body of the message include
Subscribe flowvis Firstname Lastname
(with appropriate substitution).

Prerequisites:

There are no formal prerequisites, but engineering students are encouraged to have completed a course in fluid mechanics, and fine arts students are expected to have completed a basic photography or film course

Textbooks:

Recommended

The Cloudspotter's Guide by Gavin Pretor-Pinney. Perigee/Penguin Publishers. 2006. ISBN 978-0-399-53345-7. $14. A non-mathematical but highly physical description of cloud physics and identification. Readable and useful for engineers and art students alike. An official publication of the Cloud Appreciation Society.

A Gallery of Fluid Motion by M. Saminy, K.S. Breuer, L.G. Leal, P.H. Steen. Cambridge University Press, 2003. ISBN 0 521 53500 X. $35. This is a collection of winners of the flow vis competition at the annual APS meeting. One of this course's images won in 2003, and another in 2006.

Multimedia Fluid Mechanics CD by C.F. Homsey et al. Cambridge University Press, 2000. ISBN 0-521-78748-3 CD-ROM. $16. This has introductory fluids concepts, using non-mathematical descriptions, illustrated by flow visualization stills and movies.

An Album of Fluid Motion by Milton Van Dyke. Parabolic Press, Stanford CA, 1982. ISBN 0-915760-02-9. This is $15, and worth every penny.

Flow Visualization Techniques and Examples, A.J. Smits and T.T. Lim. Imperial College Press, London, 2000. ISBN 1-86094-193-1. Available from World Scientific Publishing, http://www.wspc.com/books/engineering/p167.html. $98, but it's an excellent reference text.

Handbook of Flow Visualization, Wen-Jei Yang, 2nd edition. Taylor and Francis, NY,NY 2001. ISBN 1-56032-417-1.$246. Detailed information on a wide range of topics.

Schlieren and Shadowgraph Techniques by G.S. Settles. Springer Verlag, 2001. ISBN 3-540-66155-7. An excellent reference for these techniques, with practical suggestions for both small and very large systems.

Flow Visualization, Wolfgang Merzkirch, 2nd edition. Academic Press, Orlando, FL, 1987. ISBN0-12-491351-2 ($118). Classic flow vis reference. Quite technical, not a lot of examples.

Course Overview

Both science and art can be described as being fundamentally based in our perception of the world around us. In science, clear observations lead to understanding, particularly of physics, which is a prerequisite to successful engineering. In art, creating and influencing our own and others' perception of the work, whatever it may be, is the whole point. In this course we will focus on making the physics of fluid flow more avaliable to perception, specifically, in a word, visible. You may also find that your perception of fluid flow in everyday life has been sharpened. In the process we will be creating both art and science.

Flow visualization is particularly suited to the interface between art and science. Many fluid physicists are motivated not only by the important scientific and engineering goals of their work, but also by a visceral fascination with their subject. Few scientists or engineers admit as much, but the existence of several venues for display of fluid flow art belie purely dispassionate motivations. Foremost among these venues is the Gallery of Fluid Motion [1], a poster and video competition which held in conjunction with the American Physical Society Division of Fluid Dynamics (APS-DFD) annual fall meeting. Gallery entries are judged "based upon criteria of scientific merit, originality, and artistry/aesthetic appeal." Winners are published in a peer-reviewed journal, *Physics of Fluids,* and winners for the past 17 years have been recently collected into a volume [2]. A recent New York Times article [3] about the Gallery attests to the potential for general impact on students and the public. Additional examples include the seminal *Album of Fluid Motion* [4], which can be found on the bookshelf of nearly every fluid dynamics researcher, and the recent *Multi-Media Fluid Mechanics CD-ROM* [5]. In each of these examples, the sheer beauty of fluid flow is revealed and acknowledged to some extent. Thus we hope to encourage engineering students to gain a deeper perception of fluid flow by capitalizing on this previously unacknowledged motivation, that is, for aesthetic and creative purposes. In the case of the art students, the goal is to introduce students to the

simple beauty and fascination of fluid flow, as well as a bit of exposure to the discipline of experimentation.

Another goal of this course is to give you a chance to work with students from different disciplines. Art and engineering students have been trained with different approaches and values. In this course you will work with a range of colleagues, and discover your differences and similarities. Hopefully, you'll see value in the range of perspectives.

It seems that imaging (including both still and motion photography/video etc) provides us with a crucial model of an art and a science that provides a bridge between the quite different worlds and roles of the artist and scientist. What is the role of photography in the cultural assimilation of technology and the popularization of experimental science? What is the future of an aesthetic of scientific imagery? Is an aesthetic of beauty appropriate or even desirable for the consideration of scientific imagery? If so, in what cases and why? Are there aesthetic approaches other than considerations of beauty that come into play in the processes of aesthetization ("museumization")? If so, how can these processes be characterized? And, finally, what are the relationships between art and science that we can learn from this course?

Course Content

This course will reveal the techniques of making laboratory and everyday fluid flows visible for both scientific and aesthetic purposes. Students will create images using photographic techniques. In addition, the evolution of photography from a scientific pursuit to an established art form will be studied. Questions such as "what makes an image scientific? What makes an image art?" will be explored.

Students will also gain technical expertise in a range of flow visualization techniques drawn from the following list. Quantitative applications and analysis will be considered where appropriate. A prerequisite in Fluid Dynamics is recommended for engineering students, and some background in photographic technique is expected of the art students..

Possible fluid media:

- Paint (comb/paper techniques)
- liquid dye in water
- smoke or fog in air
- water in air; sprays, clouds
- many combinations of everyday fluids such as milk, vegetable oil, alcohol, shampoo, etc.

Fluid phenomena:

Wakes
Jets
Shear layers
Vortex rings
Buoyancy induced flows
Surface tension driven flows
Two phase flows (fountains, bubbles, sprays)
Laminar or turbulent flow
Immiscible effects
Combusting flows
Ultrasonic driven flows (fountain/fog generators)

Visualization techniques:

Laser sheet visualization
Particle image velocimetry
Stroboscopic volume visualization
Schlieren/ shadowgraph techniques

Oil flow techniques (wind tunnel applications)
Thermal and pressure sensitive paints

Imaging techniques:
Photography (digital or film, stereo or mono)
Video/movies (analog, digital or film)
Post processing of above.

Course Format

The course will consist of lectures on visualization techniques and/or art history with occasional lab/studio sessions. Student teams will have access to a range of fluid flow and photographic equipment in the ITLL, and selected research laboratories, as well as the photography and image processing facilities in the College of Arts and Science. Emphasis will be placed on the production of student images. A final showing will be produced (possibly in the Engineering Center Gallery or the Boulder Museum of Contemporary Art) and students will be encouraged to submit work to the American Physical Society's Gallery of Fluid Motion annual competition, as well as other art/science competitions.

Fees

Currently there are no course fees. Students are expected to provide their own imaging device in lieu of a textbook. A digital camera of 5 Mpx or more is recommended. The camera should provide the option of **manual focusing** and some type of exposure (shutter speed, aperture or both) control. Large format digital printing is available in the ITLL for $10/linear ft (x 42 inches wide).

Assessment and Grading

Assignments will consist of images paired with written technical reports. Typically there are one or two individual assignments, two more individual cloud photography assignments and three team project assignments. All students are expected to provide written reports and self-aassessments with their images, but expectations for the level of science discussed vary with the student's standing. Final grades will be assigned by Hertzberg for engineering students, and Sweetman for non-engineers.

Detailed graded feedback is not likely to be provided. Instead, feedback will be provided during class critique sessions.

Publications

This course has attracted a great deal of interest from the fluid dynamics and engineering education and art/science communities. Student images from previous course offerings have been presented at conferences (garnering several awards), published in professional journals and on the web, with the instructors as co-authors and selected for traveling and permanent public display. Thus, students will be asked to submit high resolution digital files of their work (scanning services will be provided for those working with film), and

release a non-exclusive copyright to the instructors. Students who supply contact information will be kept informed of all future publications of their work. All images and reports produced for the course will be published on the course website.

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[1]. http://www.aps.org/units/dfd/.

[2]. Saminy M, Breuer K, Leal G, Steen P. *A Gallery of Fluid Motion*, Cambridge University Press, 2003.

[3]. Schechter B. "From flowing fluids, beautiful images and unlocked secrets," *New York Times*, June 24, 2003.

[4]. Van Dyke ed. *An Album of Fluid Motion*. Parabolic Press, 1982.

[5]. Homsy GM, Aref H, Breuer KS, Hochgreb S, Koseff JR, Munson BR. *Multi-Media Fluid Mechanics CD-ROM*, Cambridge University Press, 2000.