Flow Visualization – Syllabus

Course information: Ph 348, 3 credits, Spring 2019, Meetings TBA in room 301 NAB

Instructor: Philip Yecko, Office: 511 NAB, tel: 4316, yecko@cooper.edu

Media: Course website on *Moodle* will be required; course *Slack** may be used.

Pre-requisites: ESC 340 or permission of instructor.

Course description:

Study of a broad range of fluid flow phenomena emphasizing the features and patterns characteristic of each. Introduction to visualization techniques used to reveal and capture details of these flows, leading to the application of these techniques to actual flows in the lab or in the field. Essential photographic methodology for still images and movies, including lighting, exposure, depth of field and digital image post-processing. Use of tracers, including dyes, pigments, vapor, bubbles, particles and particles as well as optical tools, such as schlieren and/or shadowgraph.

Both natural and human-made flows will be examined, both aesthetically and by connecting to mathematical and physical properties (including buoyancy, interfaces, vorticity, streamlines, etc.).

Student work and assessment is project-based; project topics are broadly defined by the instructor and the student work will be any visual form, but usually an image or movie. Frequent critiques will be used for students to evolve their work based on instructor and peer feedback. There will be a public exhibition of student projects at the end of the course.

Course topics (core content in bold, other topics as time permits):

- **Fluids fundamentals**: mathematical descriptions, Lagrange vs. Euler; physical properties: viscosity, buoyancy, surface tension
- **Photography fundamentals**: aperture, exposure, lighting, depth of field; stroboscopic images, high speed video
- **Forces and Scaling**: Non-dimensional numbers (Reynolds, Rayleigh and Rossby); example flows visualized
- **Producing high quality scientific images**: software post-processing (Gimp, ImageJ, Matlab, Photoshop); Gallery of Fluid Motion
- **Mathematical models**: potential flow, streamfunction, geostrophy, Stokes flow, shallow water and lubrication solutions
- **Tracers**: dyes, pigments; particles: bubbles, clouds, dust, smoke, vapor, rheoscopic fluids

* *Slack* is a secure messaging app for small collaborative teams

- **Multiphase flows**: bubbles and bubbly flows, droplets and sprays, jets, splashes, suspensions
- **Optics**: refraction, scattering, bi-refringence, caustics, surfaces, schlieren and shadowgraph
- **Instabilities**: Kelvin-Helmholtz, Rayleigh-Taylor, Rayleigh-Benard, Rayleigh-Plesset-Savart, Taylor-Couette, Faraday
- **Art and aesthetics: fluid flows as art and in art, fluid dynamics of artistic techniques, distinctions between artistic and scientific images**
- Astrophysical and geophysical fluid images (*special topic*)
- Quantitative visualization: particle imaging velocimetry (PIV) and particle tracking velocimetry (PTV) *special topic*

Objectives:

Students will gain the knowledge and skills needed to:

(i) describe and analyze a wide variety of natural and industrial flow features and patterns;

(ii) plan visualization experiments and observations;

(iii) capture effective images and/or movies by applying appropriate techniques and tools of flow visualization.

Students will learn to critique visualizations based on scientific merit and aesthetic value and to apply knowledge of fluid flows and visualization methods to improve and/or evolve their results. Students will gain new skills of perception, a deeper appreciation of fluid flows and the value and utility of visualization in natural and industrial flows.

Course format:

The course will consist of classroom lecture and discussion of: (a) fluid dynamics, including illustrations, analysis strategies and examples; (b) visualization methods including demonstrations. Other class meetings will consist of critiques and/or student presentations. At least one guest lecture will take place during the semester. Field / laboratory work will take place in class during most weeks of the semester. It is expected that additional field and/or laboratory work will be required outside of class in order to complete required assignments and projects.

Assessment:

Projects will be graded based on visual effectiveness, using a rubric tailored to each type of project; generally both aesthetic and scientific content will be included in all projects. A final project will be started mid-term and due before the end of the course.

Policies:

Class attendance is important, especially during critiques. Academic dishonesty, including plagiarism of visual content, will not be tolerated and will receive zero credit and appropriate disciplinary action. Safe laboratory practices are expected of all students, including safe field work, when applicable. Engineering students are expected to be aware of and follow the fundamental principles of professionalism in the ABET/NSPE Code of Ethics.

Equipment:

A camera is required. Smartphone cameras are acceptable, but a digital camera with higher resolution and direct control of aperture, shutter and focus is preferred. An updated list of low cost options will be maintained on the course website. Specialized pieces of photographic equipment, including some cameras, will be available for short term loan.

Textbooks and other resources:

No textbook is required. Course notes and required readings, including articles and excerpts from books, will be provided both electronically (when possible) and as hard copy. A list of useful textbooks (some of which are freely available online), journals and online resources is provided below:

Books and Journals:

An Album of Fluid Motion 14th ed. by M. Van Dyke, Parabolic Press, 1982, ISBN 0915760029

The Shape of Content by Ben Shahn, Harvard Univ. Press, 1957, ISBN 0674805704

Flow Visualization Techniques and Examples 2nd ed. by A.J. Smits and T.T. Lim, Imperial College Press, 2000, ISBN 1848167911

Handbook of Flow Visualization 2nd ed. by W.J. Yang, Taylor & Francis, 2001, ISBN 1560324171

Flow Visualization 2nd ed. by W. Merzkirch, Academic Press, 1987. ISBN 0124913504

Schlieren and Shadowgraph Techniques by G.S. Settles, Springer-Verlag, 2001, ISBN 3540661557

A Gallery of Fluid Motion by M. Saminy, K.S. Breuer, L.G. Leal and P.H. Steen, Cambridge University Press, 2003, ISBN 052153500X

Journal of Visualization, published by Springer-Verlag since 1998 for the Visualization Society of Japan, since 1981.

Online resources:

Gallery of Fluid Motion: gfm.aps.org. American Physical Society annual competition of the Division of Fluid Dynamics.

Making Science and Engineering Pictures: ocw.mit.edu online course RES10-001 by Felice Frenkel, MIT Open Courseware

FlowVisual: software for teaching 2D flow visualization; see ASEE Proceedings 2013 Paper # 6268 by M. Wang, J. Tao, C. Wang, C.K. Shene and S.H. Kim.

Fuck Yeah Fluid Dynamics: fuckyeahfluiddynamics.tumblr.com. A popular online forum.