

**Today:**

- |                          |                       |
|--------------------------|-----------------------|
| Schedule                 | Bring to class:       |
| Team member behaviors    | Zeroblasters          |
| Facilities and Equipment | Small fog machine     |
|                          | Ultrasonic humidifier |
|                          | Desk toys             |

**Admin stuff:**

- Please sit with your team, so you can discuss possibilities as they come up today
- Team First project plan and selfies due this Friday, 9/14. Short statement of what you are planning to do. Each person, online in Canvas.
- Team First image due Monday Sept 24. Same upload and posting requirements as Get Wet.
- Example Reports: Read the guidelines. Good reports: 2012 team First Ryan Kelley, Nicholas Travers
- Chem Stores: on campus source for glassware, chemicals, lab supplies (cash OK):  
<https://www.colorado.edu/chembio/resources/research-facilities/chemstores-chemstores-east>
- Optics cleaning tips: <http://www.newport.com/How-to-Clean-Optics/141176/1033/content.aspx>
  - Cleaning fluids: OK to buy a commercial variety, or try distilled water first, then isopropyl (rubbing) alcohol, then ethyl alcohol (lab grade), then acetone as a last resort.

**Team Behaviors**

*Friday*

This American Life #370 Ruining It for the Rest of Us.  
Bad team behaviors: The Jerk, The Slacker, The Depressive  
The cure: solicit input from everyone.

<https://www.thisamericanlife.org/370/ruining-it-for-the-rest-of-us/prologue-0>

**Expectations For Teams  
Flow Visualization**

Reasons for putting you on teams:

1. So that you can attempt to image more complex flow phenomena. If the work of developing a setup is spread out among you, then you can try a challenging experiment.
2. So that you can attempt more challenging imaging techniques. The teams were chosen to spread out photographic and fluids expertise and equipment amongst the teams.
3. To have partners to bounce ideas off of. This makes ideas multiply.
4. To get informal feedback on your work.
5. To interact with students from different backgrounds.

Thus, working on a team is **STRONGLY EXPECTED**, but not strictly required for the team assignments. You are not required to work only with your team, but you are expected to make significant effort to be available to help them with their images and ideas. You do not all have to use the same equipment. Do plan to spend at least an hour or two to help **each** of your teammates, and recognize that you can plan on having 4 to 8 person-hours at your disposal for your project. Plan multiple meetings. If you find you are not available for specific sessions, figure out how to make it up to your team.

I hope you will take advantage of the benefits of working in teams and of the opportunity to broaden your network. Strong recommendation: don't work only with your friends. Bad for you professionally.

Following from this, here are the expectations for the deliverables on the team assignments:

Each student is expected to turn in a unique image or video that they had primary artistic and scientific responsibility for. You must give credit appropriately in your report, by explicitly naming the teammates that contributed, and what they did.

Each image/vid must be accompanied by a report. If several images come out of the same setup, you can copy descriptions of the apparatus, and the basic physics. If appropriate, give credit to report section authors. Be sure to describe the details relevant to your particular image.

Did you meet with your team?  
If not, why not. If so, how did it go?  
Have you ever been a team leader before?  
Do you have experience with delegating your responsibility to another, i.e. depending on another person to help you with your work?

**Equipment and Facilities**

**Flow Visualization Equipment and Facilities**  
09/11/18  
MCEN 4151-5151/ ATLS 4151/ Film 4200/Arts 5200  
Flow Visualization: The Physics and Art of Fluid Flow

Here is a list of flow facilities; equipment for checkout is listed below. Make a reservation with Daniel.Godrick@Colorado.edu to use the big facilities in the ITLL (flume, wind tunnel, sink space room, high speed camera). Some of our Flow Vis equipment will be first-come-first-served in the ITLL 1B level equipment bay (be sure to leave your contact info and a list of what you have). To check out the smaller equipment in the ITLL, see Kai Amey (ameyexc@Colorado.edu). His office is the checkout office on the 2B level of the ITLL. If he is not there, pick up the checkout phone on the south facing wall near the south stairs of either lab level; an equipment checkout person should be able to help you.

Shirley Chessman in the Idea Forge (east end of Fleming) has a huge assortment of free parts for DIY setups; glassware, plexi, pumps, plumbing, fans etc. Kai Amey in ITLL has a stash of miscellaneous free stuff in the Project Depot room.

Both ITLL and Idea Forge have space for temporary setups. For official access, everybody must take a short free orientation tour (once in your life) to learn what is available. Idea Forge tours are MTR @ 4pm, lower east entrance (Fleming building). ITLL tours M-F 5-15, lobby, bring Buifcard.

\* Means equipment is currently in Hertzberg's lab ECME 1B64

**FLOW FACILITIES: AIR**

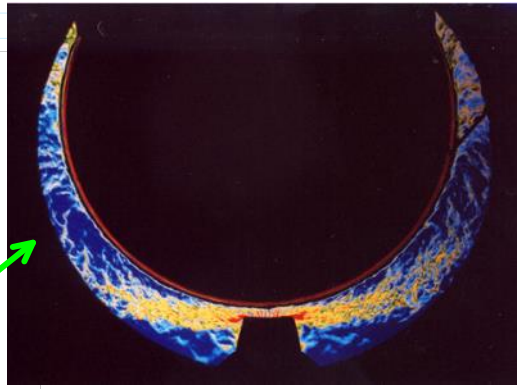
Facility	Lighting	Visualization	Phenomena	Access
Vortex ring generators, zeroblaster, or timed generator. Use in the ITLL sink space or Area 51 in Idea Forge (can be made dark), or checkout for home use.	Try projector for light sheet, or strobe	Stage fog	Vortex rings, symmetric and asymmetric	*Check out fog generators and timed vortex generator from ITLL; in 1B equipment bay. Check out zero blasters and projector from JH
Air sheet fog desk top	NOT in rooming units and green laser pointer	Hydro stage fog generator	Turbulent jet cross section and look for turbulence/mixing	*

Surprisingly difficult to capture.



Brynne Sutton, Emrys Hall,  
Thomas King, Bethany  
Rotherham FV2003

Misc air flows	Strobe for volume vis	Dry ice vapor <sup>1</sup> humidifiers, steaming pots, medical nebulizers (<S5) <sup>2</sup> Fog generators	Jet flows, positive buoyancy convective flow	JH has nebulizers, humidifier
Color Schlieren, Large system for ECME 1B64 (JH lab) only. 1 small system for home checkout.	EG&G strobe, provided. Maybe works. Bright single LED headlight works well too.	Schlieren: Light bent by $n$ gradients Could do stereo with 2 small systems	Convective flows from warm/hot objects: hands, candles, hair dryers (turbulent jet). You may need time to make your own color stops. Can be used in water too.	See Prof. Hertzberg, last two projects only.
Reuben's Tube	Flame	Flame length represents pressure.	Standing wave resonance in a pipe, excited by a loudspeaker on the end.	JH. You need to use a regulated pressure supply, and follow combustion guidelines.



Colleen Stroud FV 2004

<https://vimeo.com/74130357>  
by Susie Sie

**FLOW FACILITIES: LIQUIDS**

Facility	Lighting	Visualization	Phenomena	Access
ITLL Flume	Strobe or 500 Watt work lights or North Star lights, or new LED floodlights (JH checkout)	Free surface or food coloring. Be sure to bleach water clean. Try poster paint dots for surface flows.	Free surface: weirs, hydraulic jump, inclined flow. Wakes: submerged objects, one can inject dye. Jets: coflow, reverse.	Sign up for flume time in ITLL. See daniel.godrick@colorado.edu ITLL module engineer.



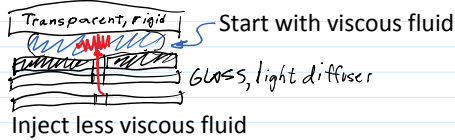
Tanner Ladtkow, Tim Read  
FV 2006

<sup>1</sup> Dry ice is solid carbon dioxide. Do not seal into a container, let it breathe. Handle with extreme care; it can freeze flesh and displace breathable air. Cover with hot water for best effect, otherwise a water ice shell will form.  
<sup>2</sup> Medical nebulizers require a small compressed air source. Do not nebulize oils (i.e. canola) without use of a proper respirator or aerosol filter mask; oil coated lungs defuse pneumonia and asphyxiation.



Melissa Talmage,  
Nigel Gorbald, Lok  
Kin lee, Christopher  
McCray, Taylor  
Simonson FV2006

Hele-Shaw cell  
Taylor-Saffman  
instability



<http://www.flowvis.org/category/flow-categories/saffman-taylor-instability/>

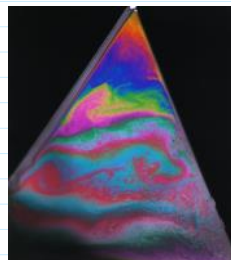
Needs glass top sheet

GI Taylor film includes reversible flow

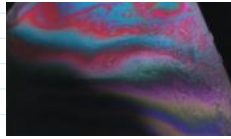
[http://www.youtube.com/watch?v=QcBpDVzBPMk&feature=youtube\\_gdata\\_plaver](http://www.youtube.com/watch?v=QcBpDVzBPMk&feature=youtube_gdata_plaver)

[http://www.youtube.com/watch?v=iGySs9bJbwU&feature=youtube\\_gdata\\_plaver](http://www.youtube.com/watch?v=iGySs9bJbwU&feature=youtube_gdata_plaver)

			transverse. Boundary layers and surface flows.	North Star lights in Idea Forge
Small water tunnel for checkout; 3' long, 2" deep	Includes water pump for circulation	Bubbles Dye, rheoscopic fluid, paint, anything safe for drains	Designed for object wakes	JH
Large Fish Tank in ITLL (50 gal)	Strobe or work lights	Food coloring. Be sure to bleach water clean afterwards	Short jets, vortex rings, boundary layers	*Check with JH first. ITLL sign-up/checkout
Hele-Shaw cell	Work light or bounced strobe	Food coloring of detergent, corn syrup, water, etc	Saffman-Taylor instability	*ITLL checkout in 1B Equipment Bay.
Small (10 gal) Fish Tanks, larger fish tank, pumps available too.	Strobe	Food coloring, alumina powder, cornstarch particles; anything you are willing to put down your own drain.	Short jets, vortex rings, boundary layers Steady vertical vortex (from stirring machine) Small ring generators available.	*ITLL or JH checkout (take home 2 days)
Soap Film Tunnel; high humidity needed.	Diffuse sunlight is best.	Thin film effect	Jets, wakes, shear layers	JH lab. Could use a redesign.
Glitter Tanks 6 foot X 3 inch black PVC half tubes	LED or other worklights	Glitter (Pearl-Ex), Pearl Swirl or pearlescent shampoo	Wake and wave phenomena	*In ITLL 1B Equipment Bay. Would benefit from small recirc pump.
Fish Tank	Strobe, LED or	<b>Hydrogen</b>	Any motion in	JH. Extra



Glitter Tanks 6 foot X 3 inch black PVC half tubes	LED or other worklights	Glitter (Pearl- Ex), Pearl Swirl or pearlescent shampoo	Wake and wave phenomena	*In ITLL 1B Equipment Bay. Would benefit from small resirc pump.
Fish Tank JH lab only (voltage source limitation)	Strobe, LED or work lights	<b>Hydrogen Bubble apparatus</b>	Any motion in salted water	JH. Extra training and work required
Liquid Desk Toys: lava lamp, vortex		Built in	Various, including low- order	JH. An assortment of dynamic desk



Katina Butler, Kerstin Lieff, Adrien  
Robert, Chris Wilke, FV 2004 team1

### Ferrofluid Climbs

<http://vimeo.com/55136676>

David Oakley, Peter Davis, Kerylyn Lay,  
Jakob Anderegg, Brayden Hass.

2012

Pasted from <<https://vimeo.com/home/myvideos/page-2/sort:date/format:video>>

### Ferrofluid Flies Up

<http://vimeo.com/55075720>

Brayden Hass, Jakob Anderegg, Peter  
Davis, Kerylyn Lay, David Oakley

2012

Pasted from <<https://vimeo.com/home/myvideos/page-2/sort:date/format:video>>

Add watercolors:

<http://fabianoefner.com/?portfolio=millefiori>



<https://www.youtube.com/watch?v=mb4b2hNMEfo>  
Kline's Flow  
Visualization  
NCFMF vid

lamp, drip timers, sparkly fluid in balls, etc.			turbulence, wakes, droplet motion	toys that have fluid motion.
Blackstock Rheoscopic Fluid cell	Has polarized light setup	Streaming birefringence	Cylinder wake	Prof. Hertzberg. Also have extra fluid available, but apparatus must be very clean: no salts.
Ferrofluid	Normal studio lighting	Move it with magnets	Magnetic field lines	*ITLL or Idea Forge? Impossible to clean up spills. Will stain anything. Nontoxic, though.
Glycerin				JH lab. Mix with soap solutions to extend soap film life
Droplet Splash System	<del>dedicated</del> Nikon camera and strobes	Reflection and refraction of fluids	Worthington jets, crown splashes	Check out from JH only

#### Small Equipment Checkout


Please note that this equipment may be either expensive, rare, or both. Students checking out equipment are expected to take responsibility for the equipment. If equipment is lost, stolen, or broken, there are no funds available for replacement or repair (no, CU has no insurance for this stuff).

Equipment	Location	Notes
Stage fog generator (cooled)	*JH	Fog is nontoxic water-based glycol solution. \$40/gal., don't waste. Can leave residue.
Stage fog generator, (small)	*ITLL 1B Equipment Bay or JH	
Zero Blaster ring generator and fog fluid	JH	
Ultrasonic humidifier	*ITLL 1B Equipment Bay	
4.5" schlieren system (2) Big schlieren (20" diameter,	JH	

<http://www.flowvis.org/2016/09/11/worthington-jet-of-first-drop-collides-with-second-drop/>



8' focal length, need 24' dark space)		
<b>CAMERAS and LENSES</b>		
Vision Research VR Micro C110 High speed video.	After 2/14 in class demo	Check out from ITLL. Mo.Woods@colorado.edu.
Olympus I-Speed high speed video system	ME: Idea Forge. See Shirley Chessman	Training required. Up to 30,000 fps, but is low resolution, and low sensitivity, needs lots of light.
Canon EOS Rebel XT 8 Mpx, no movie mode	See Prof. Hertzberg	
Canon extension tubes (for cheap lenses, no electronic pass thru)	JH	
Canon zoom lens: EF 75-300 mm	See Prof. Hertzberg	Autofocus, but no image stabilization.
Nikon extension tubes	See Prof. Hertzberg	
Nikon 24 mm wide angle lens	See Prof. Hertzberg	
Nikon 50 mm lens	See Prof. Hertzberg	
Nikon macro lens 102 mm	See Prof. Hertzberg	Manual only
Closeup Lenses: +1, 2.4 in 58 mm dia, +2, +3 in 72 mm dia.	JH	
Stereo cameras (film)	See Prof. Hertzberg	
<b>LIGHTING</b>		
Sunpak Auto 383 Flash (strobe) unit & 25' pc cable	See Prof. Hertzberg	
Nd-YAG pulsed laser, green light	See Prof. Hertzberg	Serious safety training required
<del>CW Nd:YAG laser</del> I/O Green LED Lasers	See Prof. Hertzberg	Serious training and power logistics required
Party strobe	JH	
500 W work lights, several sets	ITLL, JH	
Fluorescent shop lights: 3 foot X 2 tubes	JH	
LED worklight pair, on tripod	JH	
North Star video lights (2), cooled	Idea Forge	

<b>MISC</b>		
Gretag-Macbeth/X-Rite Eye-1 Spectrophotometer	See Prof. Hertzberg; on loan to Prof. Bruns	For color calibration of monitors, cameras, printers and projectors.
Large black backdrop (8 foot square).	Idea Forge	
Small white table-top tent, 2 ft <sup>2</sup>	Idea Forge	Provides diffuse white light and control of reflections
black velvet	JH	
Assorted tripods	JH	
Velbon Macro Slider	JH	Attaches between tripod and camera. Donated by FV alum Nick Travers.
		
I.P. Turntable	JH	For study of rotating flows

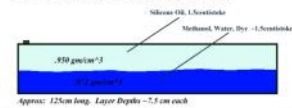
#### ATOC Equipment

Scott Kittelman <alan.kittelman@colorado.edu>  
Department of Atmospheric and Oceanic Sciences  
CB-311  
303-492-4248 (lab phone number)

Scott has a wide range of equipment available, but he is only able to help two Flow Vis groups this semester, so contact me if you want to use this equipment.

1) Karman vortices – Kalliroscope visualization in a large circular tank

2) Two layer tank with two immiscible fluids



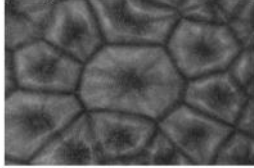
Example of a gravity current with two layer tank.  
Kelvin-Helmholz instability in a 6' clear acrylic tank –two or three layer - dye visualization

3) Double diffusive convection "Salt fingers"

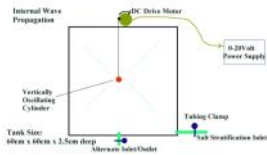


Salinity and temperature diffusion rate differences result in vertical mixing within a statically stable fluid.

4) Marangoni convection - aluminum flake visualization, timelapse video best



5) Internal gravity waves in a continuously stratified fluid- shadowgraph or Schlieren visualization



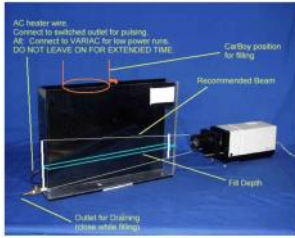
6) Capillary waves - visualization using a view graph projector.



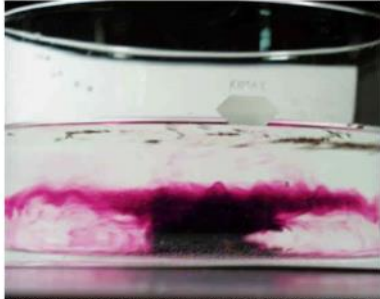
7) Surface gravity waves with a shallow water ripple shadowgraph imagery.

Can visualize wave:  
interference  
reflection  
refraction  
dispersion group and phase velocity plane  
and circular waves  
Doppler effect

8) Thermal convection - aluminum flake visualization of convection over a heating pad in a 6" layer of silicone oil



9) Secondary circulations in rotating flows, Ekman boundary layers.



Side view image of dye erupting vertically up out of the bottom Ekman boundary layer.