Today:
Admin
Choices in imaging: Categories of Flow Vis

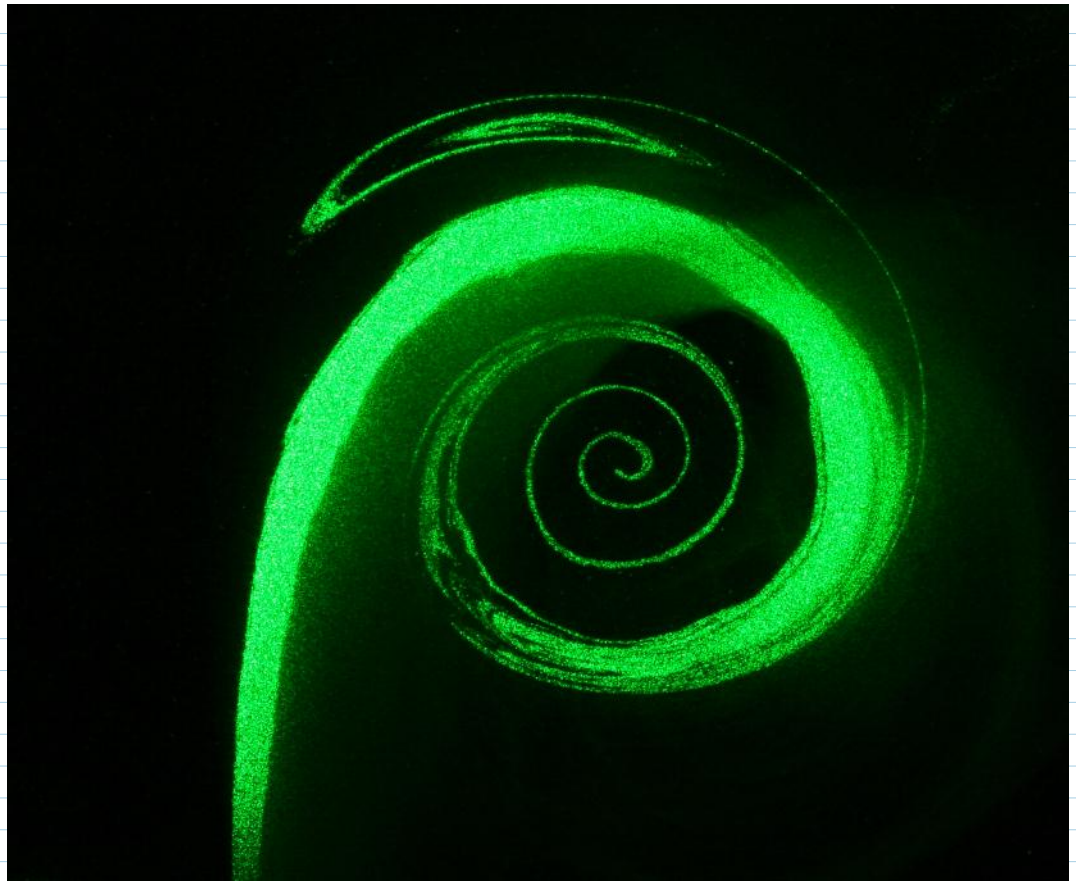
Admin:
Put signed Use Agreement, Syllabus Agreement, on piles up front.
1) Perception Survey due(online) 2) Background survey due (online)
Best of Web due THURSDAY.
bailey.leppek@colorado.edu
Use paper pads for 'minute papers' Please put your name on it first.
Seating chart; please put your name on sticky in typical location.

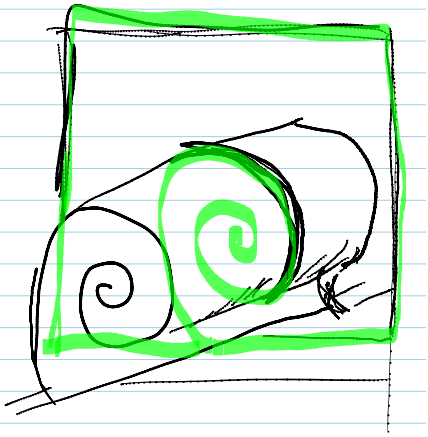
Last time:
Make CHOICES:
1. Flow phenomenon: Water boiling? Faucet dripping?
   - Why does it look like that: Consider FORCES:
     - Body forces: gravity, magnetism
     - Surface forces: Pressure (normal, perpendicular), and shear (parallel to surface)
2. Visualization technique: Add dye? See light distorted by air/water surface?
3. Lighting (source of worst image problems)
4. Image acqusition: Still? Video? Stereo? Time lapse? High speed?
5. Post processing, final output. Edit, at least crop the image, consider contrast.

2. Visualization Techniques

a. Seeded Boundary techniques
b. Index of refraction (light bending)
c. Particle tracking

a. Seeded Boundary techniques:
One fluid is seeded with dye or particles which scatter or absorb light. The other fluid is transparent, not scattering or absorbing light. The boundary can be seen.

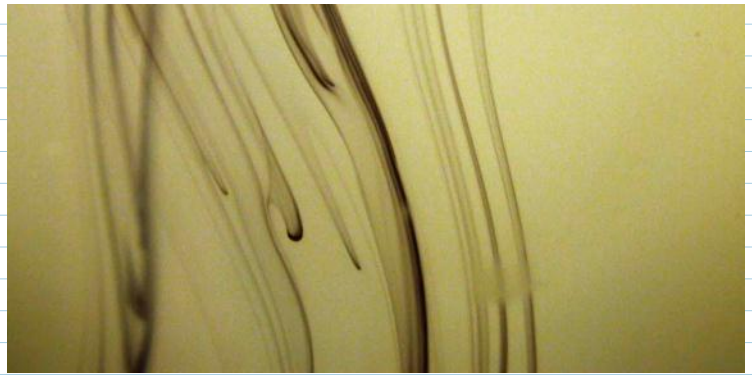




Stage fog illuminated by a sheet of laser light forms a suddenly started laminar planar jet at Re = 330. Tanner Ladtkow, Geneva Wilkesanders, Tim Read, Andrea Fabri. Team Project 3, 2006

India ink falling through water shows the Rayleigh-Taylor instability. Gordon Browning. Get Wet Fall 07.

Back-lit. Dark ink absorbs light.



http://www.colorado.edu/MCEN/flowvis/galleries/2009/Team-1/FV_popup1-21.htm

Lucy Dean, Joseph Duggan, Tim Jarrell, Melissa Lucht

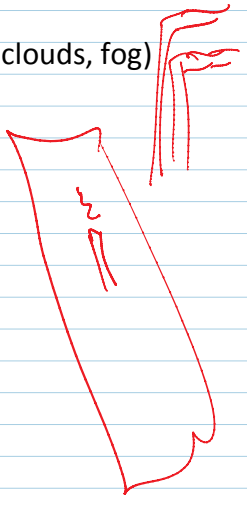
White gas (naptha) pool flame.
Team 1 Spring 2009

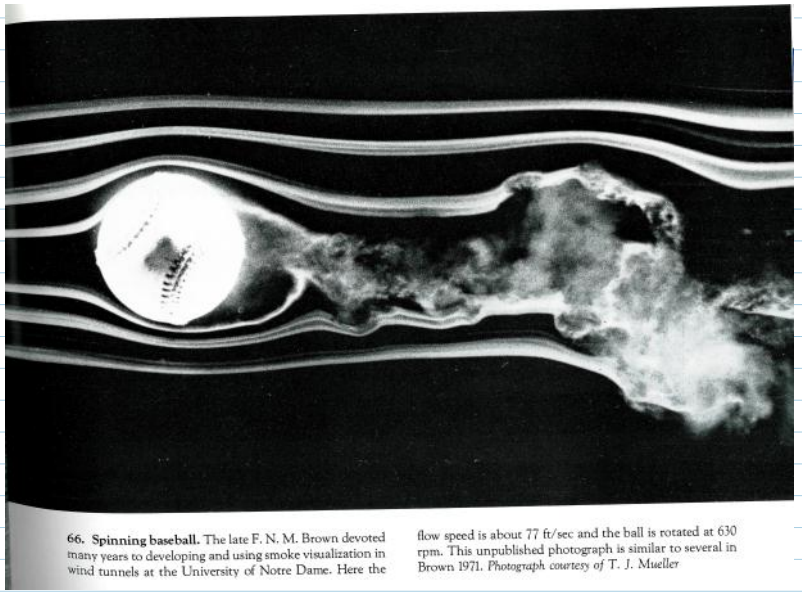
Light emission shows hot soot region
Red to yellow to white

Blue = specific emission from C_2 or CH radicals

Seeded boundary technique is characterized by dense seeding, can't see individual particles:

- Dye = food coloring
- Hydrogen bubbles (in water)
- Smoke
- Water droplets (clouds, fog)





66. **Spinning baseball.** The late F. N. M. Brown devoted many years to developing and using smoke visualization in wind tunnels at the University of Notre Dame. Here the flow speed is about 77 ft/sec and the ball is rotated at 630 rpm. This unpublished photograph is similar to several in Brown 1971. *Photograph courtesy of T. J. Mueller*

Van Dyke book: An Album of Fluid Motion

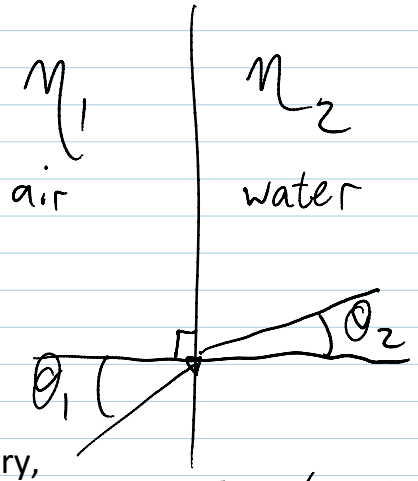
This is a relatively easy technique.
Remember, choose environmentally benign fluids: foods, personal care products. No chemicals down the drain here.

b. Index of refraction techniques

Minute paper, in groups: What is the index of refraction?

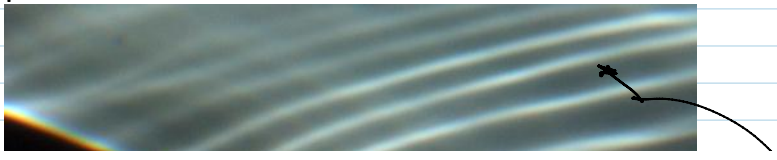
$$\eta = \frac{c}{v} = \frac{\text{Speed of light in vacuum}}{\text{Speed of light in medium}}$$

eetah



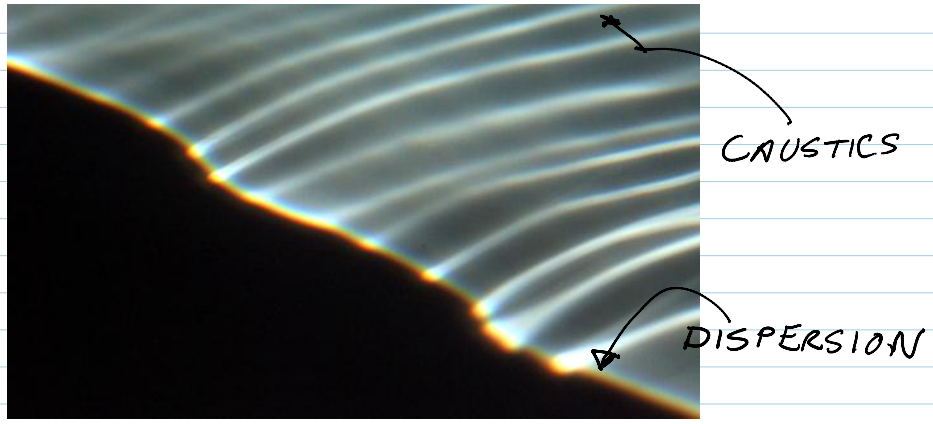
= 1.5 for glass
= 1.3 for water, plexiglas, approximately
=1.00029 in air

Specific techniques: schlieren, shadowgraphy, interferometry, holography,
Free liquid/gas surfaces, thin film effects (soap bubbles), oil on puddles



SNELL'S LAW

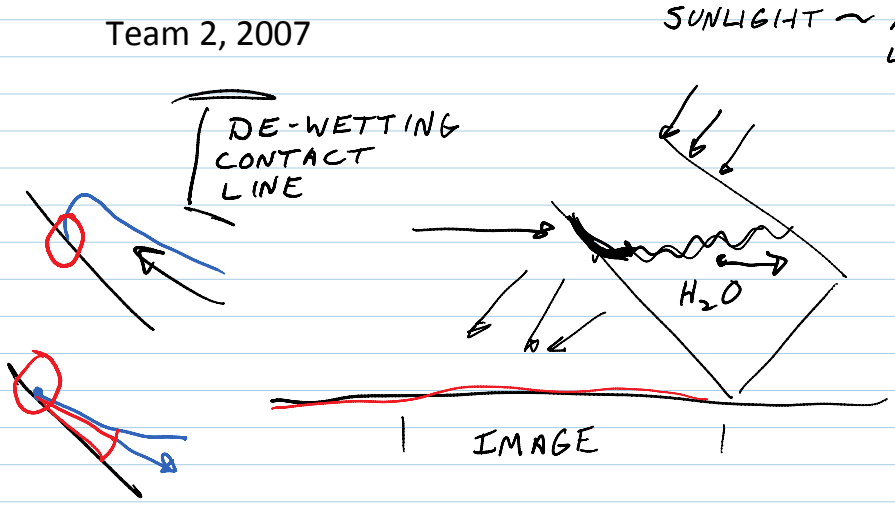
$$\frac{\eta_1}{\eta_2} = \frac{\sin\theta_2}{\sin\theta_1}$$



Pasted from <http://www.colorado.edu/MCEN/flowvis/galleries/2007/assignment4/Hnath.jpg>

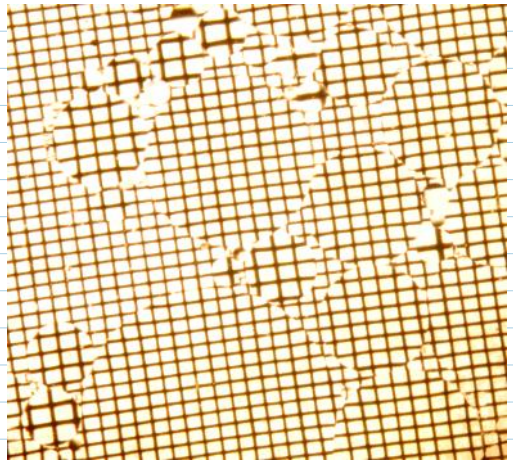
A rectangular tank, partially filled with water, was tipped on edge. Sunlight projected through the waters' edge to the ground, resulting in Moire interference patterns : CAUSTICS.

Owen Hnath, Gordon Browning, Tracy Eliasson, Travis Gaskill, Trisha Harrison
Team 2, 2007



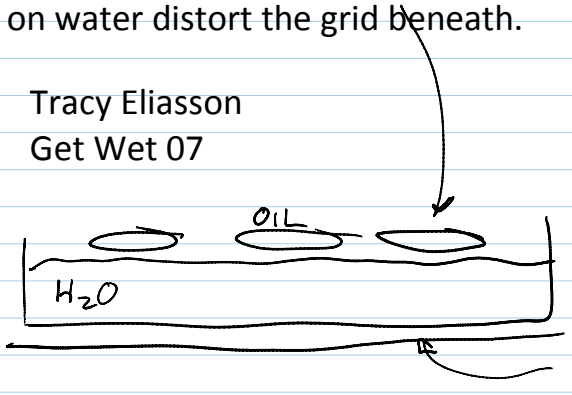
GetWet

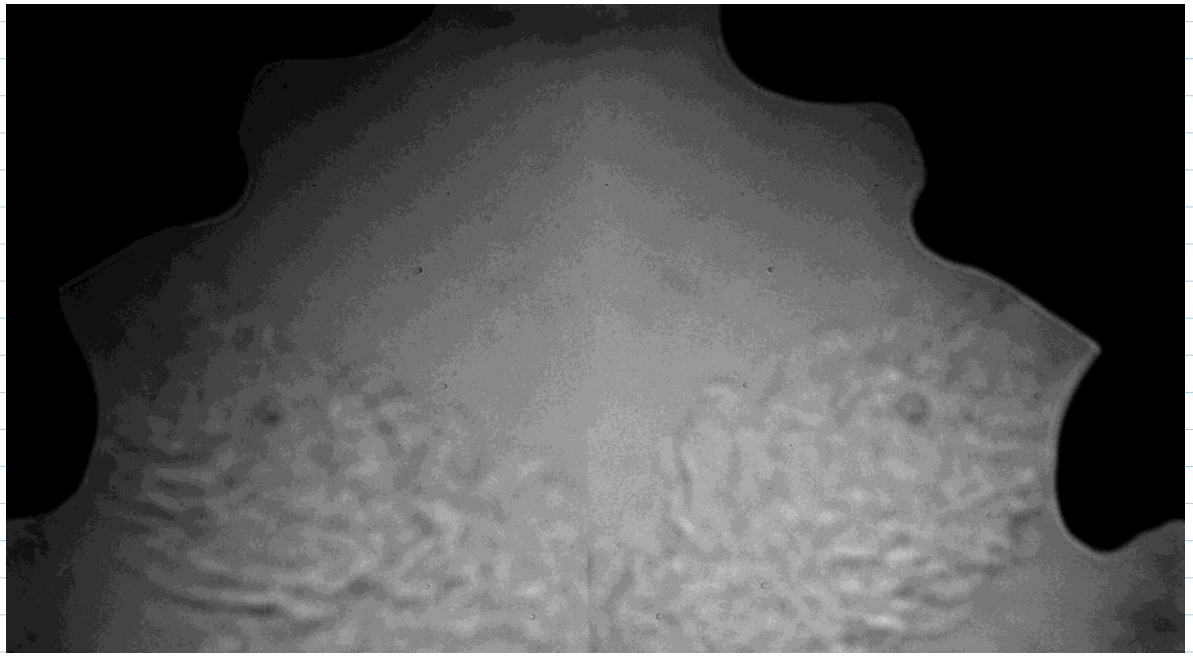
Inserted from: <file://C:\Users\hertzber\Documents\01CLASSES\FlowVis\StudentWork07\GetWet\Eliasson\GetWet.tif>



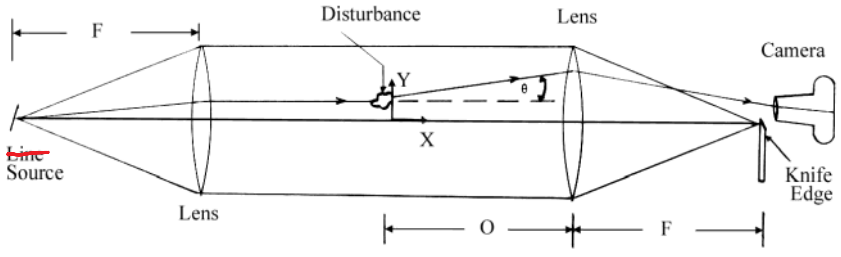
Liquid lenses formed by oil floating on water distort the grid beneath.

Tracy Eliasson
Get Wet 07



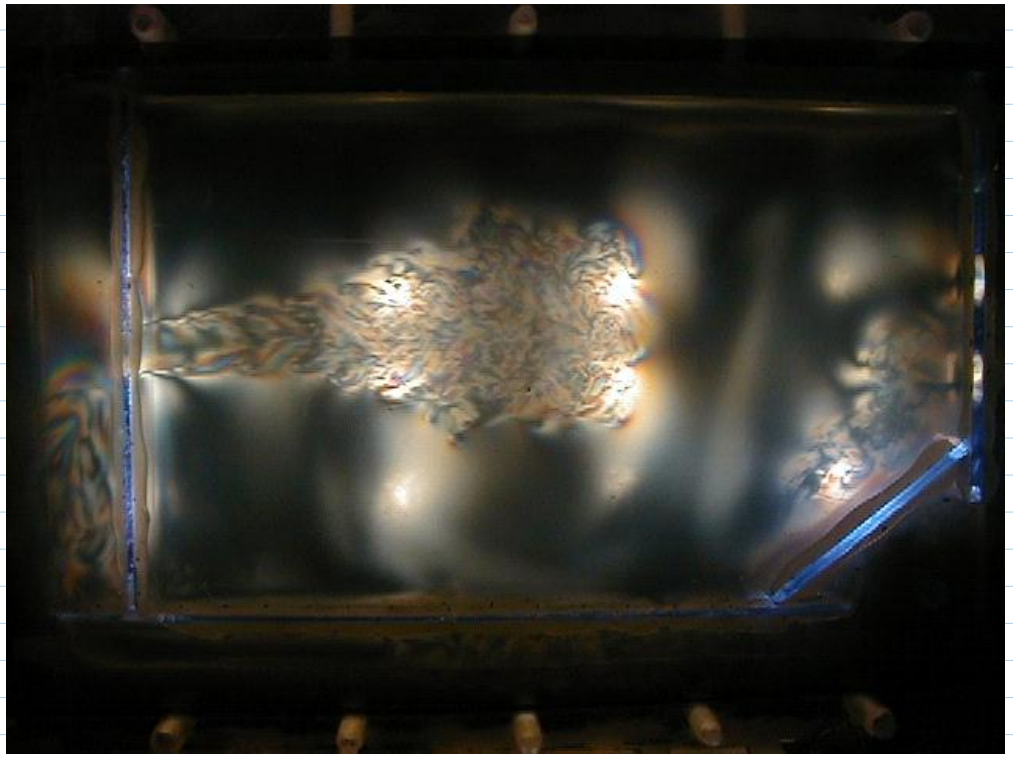


Schlieren composite of two human exhalations. Owen Hnath, Group Alpha, Team 3, Fall 2007
http://www.colorado.edu/MCEN/flowvis/galleries/2007/assignment6.html



POINT

Figure 3. Schlieren System with a Small Disturbance

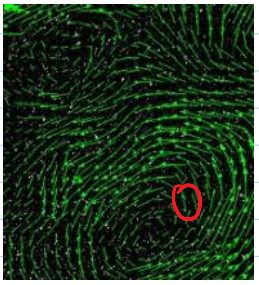


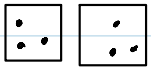
Streaming birefringence
'Blackstock fluid'
Suspension of mica flakes.

http://www.laminarsciences.com/

c. Particle tracking techniques

Individual particles are seen. Can be qualitative or quantitative (Particle Image Velocimetry, PIV).
Two images made, close together in time
http://fiji.sc/wiki/index.php/File:Surface_wave.gif

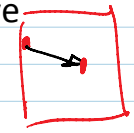




Divide image into subwindows

t1 t2

Cross-correlation give displacement vector

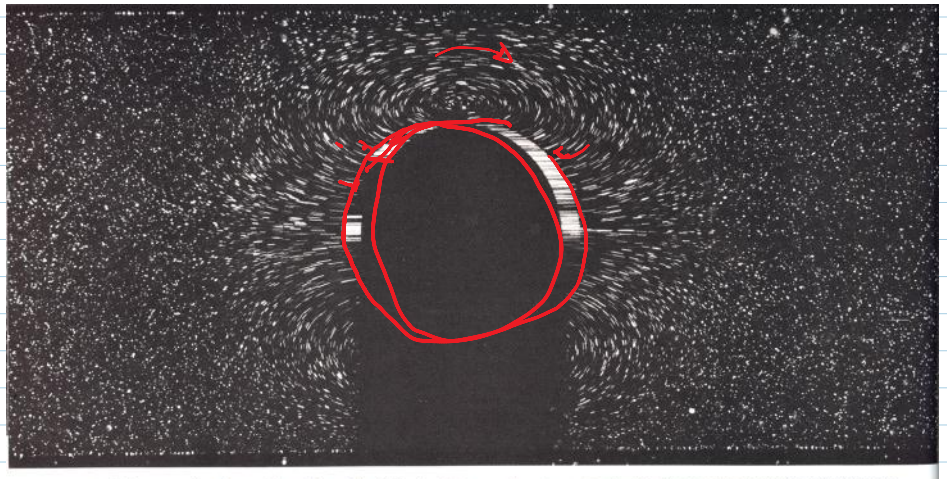


$\frac{\Delta \vec{x}}{\Delta t}$ = VELOCITY

Pasted from <http://www.google.com/images?q=particle+image+velocimetry&hl=en&client=firefox-a&hs=NUI&rls=org.mozilla:en-US:official&prmd=ivnsb&source=lnms&tbs=isch:1&ei=9CY3TcyNH8L7lweQ2uSMAw&sa=X&oi=mode_link&ct=mode&cd=2&ved=0CBAQ_AUoAQ&biw=993&bih=412>

Or, with motion blur, length of track can indicate speed.

From Van Dyke's Gallery of Fluid Motion



9. Sphere moving through a tube at $R=0.10$, absolute motion. In contrast to the photograph above, here the camera remains fixed with respect to the distant fluid. During the exposure the sphere has moved from left to right less than a tenth of a diameter, to show the absolute motion of the fluid. At this small Reynolds number the flow pattern, shown by magnesium cuttings in oil, looks completely symmetric fore-and-aft. *Coutanceau 1968*

Pearl-Ex

GUIRY's Pearl & Folsom