

Please sit close!!!! Let's empty the back 4 rows.

Today:

Admin

Choices in imaging: Categories of Flow Vis

Admin:

Office Hours: Mondays at 2 pm, ECME 220

Syllabus

Initial Assignments

Schedule

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 acquisition: Still? Video? Stereo? Time lapse? High speed?
5. Post processing, final output. Edit, at least crop the image, consider contrast.

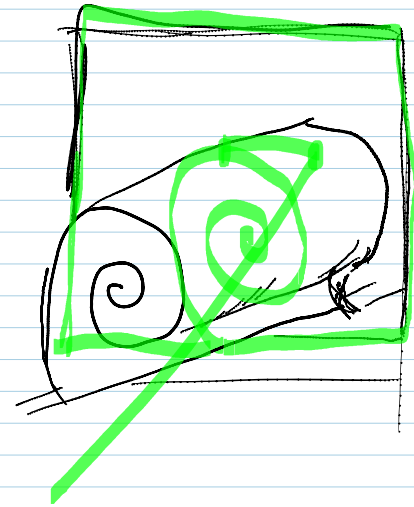
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## 2. Visualization Techniques

- 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.

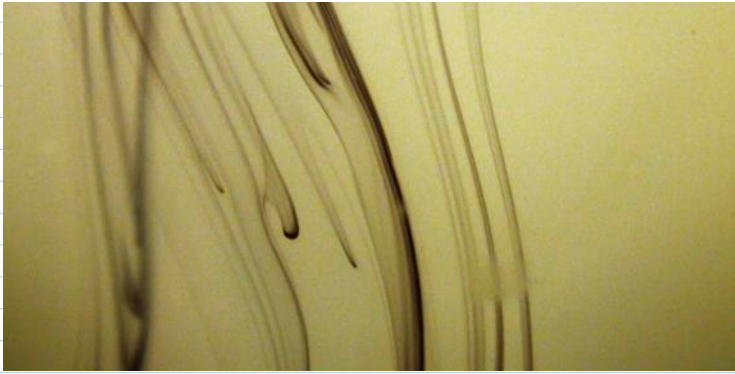


Stage fog illuminated by a sheet of laser light forms a suddenly started laminar planar jet at  $Re = 330$ . Tanner Ladtkow, Geneva Wilkesanders, Tim Read, Andrea Fabri. Team Project 3, 2006



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

Lucy Dean, Joseph Duggan, Tim Jarrell, Melissa Lucht

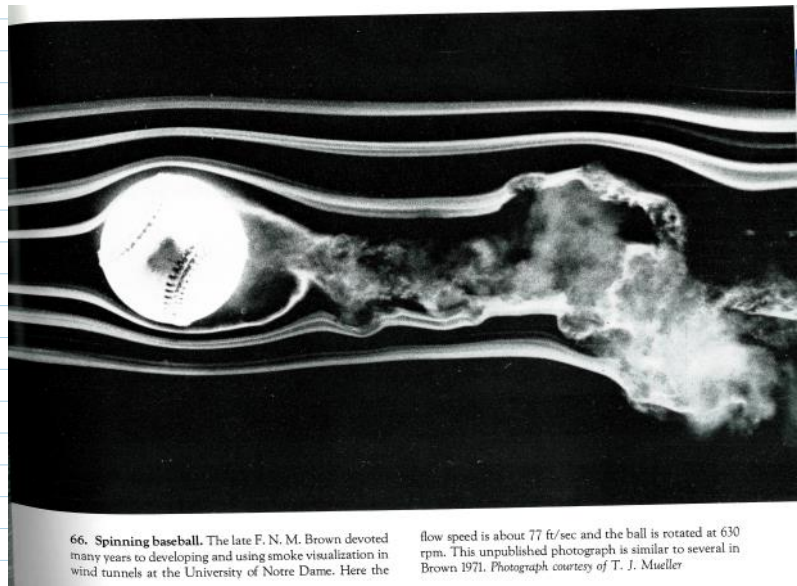
White gas (naptha) pool flame.  
Team 1 Spring 2009

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)



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.

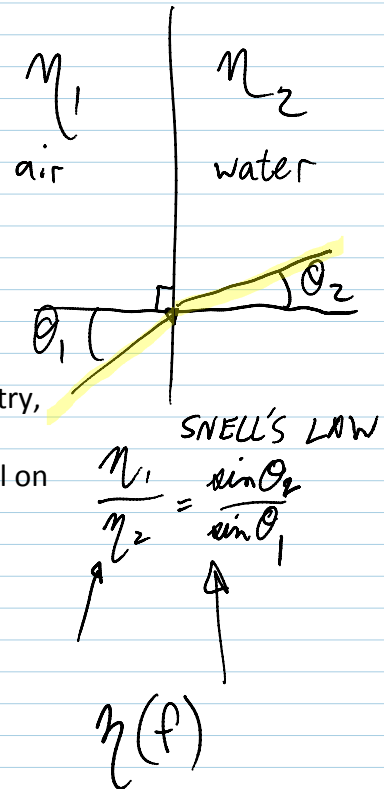
## b. Index of refraction techniques

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

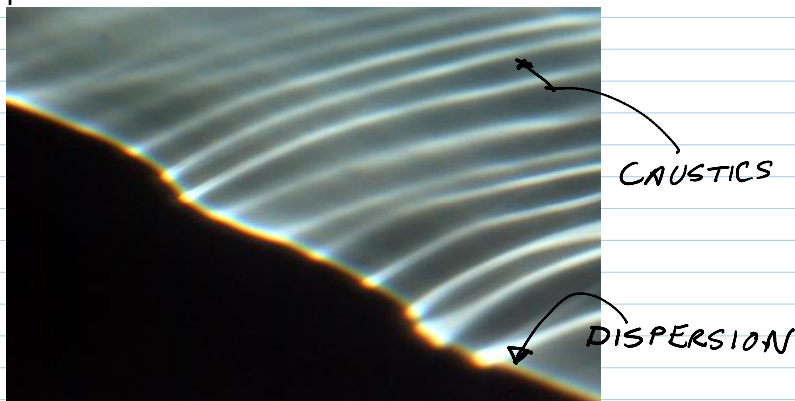
$$n = \frac{c}{v} = \frac{\text{Speed of light in vacuum}}{\text{Speed of light in medium}}$$

*cepat*

= 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

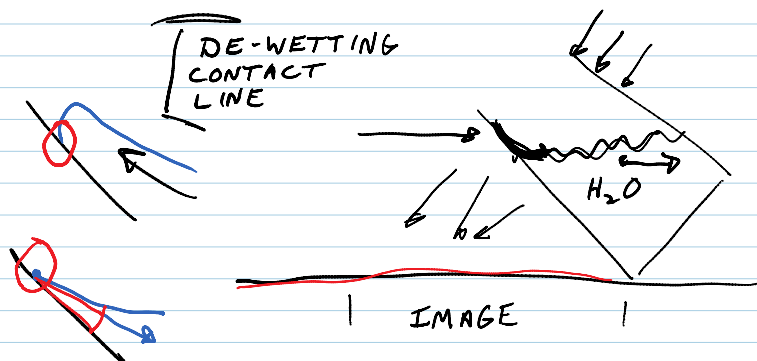


Pasted from <http://www.colorado.edu/MCEN/flowvis/galleries/2007/assignment4/Hnath.jpg>

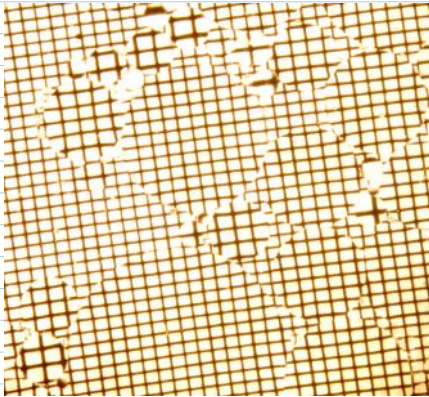
A rectangular tank, partially filled with water, was tipped on edge.  
 Sunlight projected through the water's edge to the ground, resulting  
 in Moire interference patterns : CAUSTICS.

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

SUNLIGHT ~ ALMOST PARALLEL  
 LIGHT RAYS

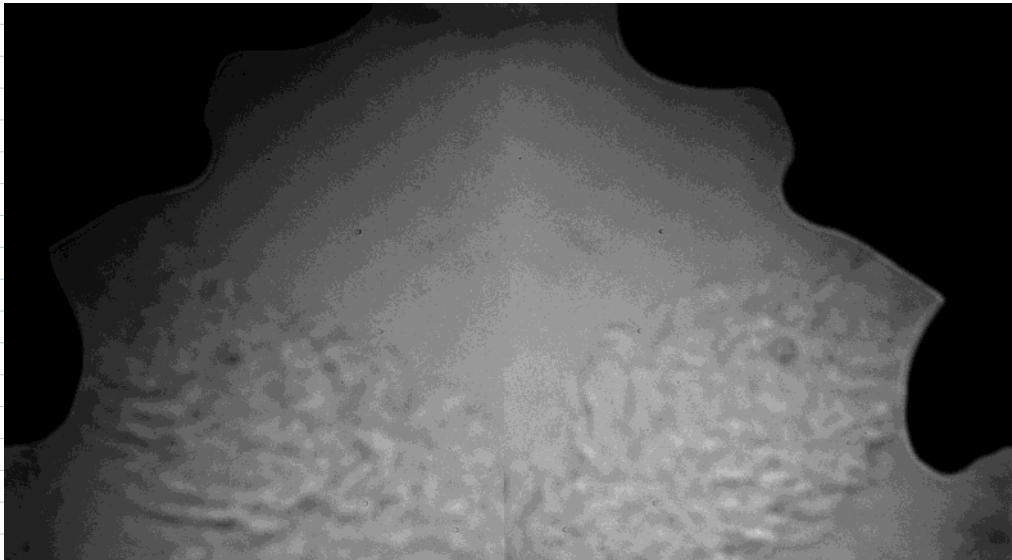
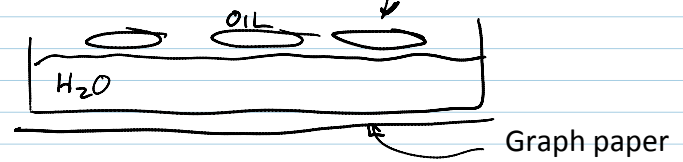


Inserted from: <file:///C:/Users/hertzber/Documents/01CLASSES/FlowVis/StudentWork07/GetWet/Eliasson/GetWet.tif>



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/as  
signment6.html](http://www.colorado.edu/MCEN/flowvis/galleries/2007/as<br/>signment6.html)



POINT

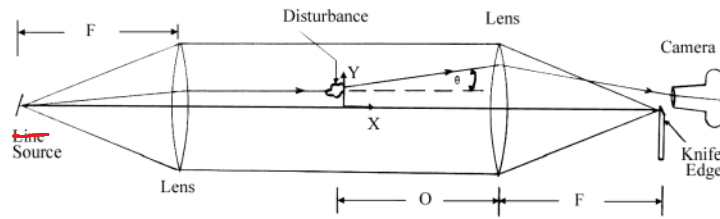
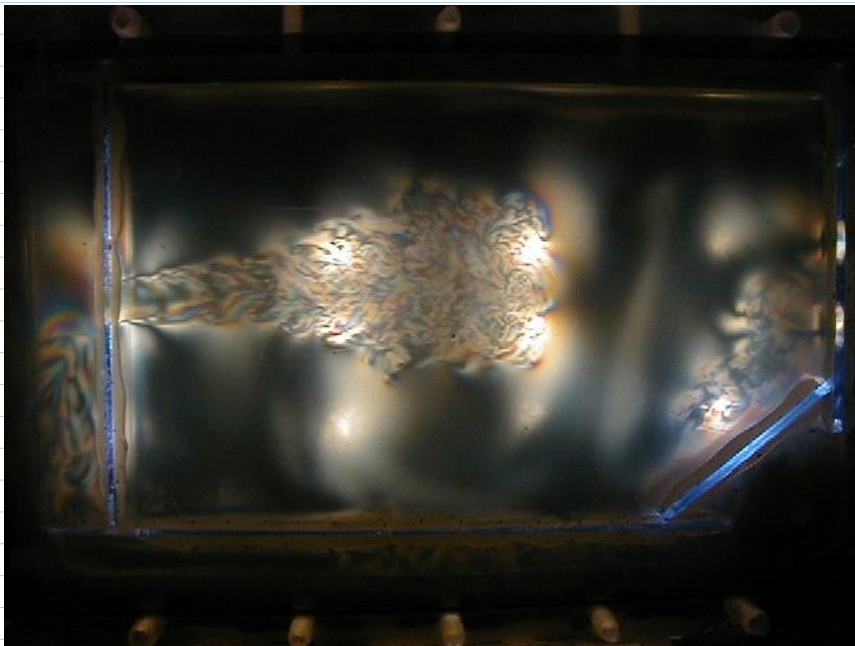


Figure 3. Schlieren System with a Small Disturbance

Copyright J. Kim Vandiver, 2002



Streaming birefringence  
'Blackstock fluid'  
Suspension of mica flakes.

<http://www.laminarsciences.com/>

## Rheoscopic Fluids

<http://www.stevespanglerscience.com/pearl-swirl-rheoscopic-concentrate.html>



## Rheoscopic Fluids

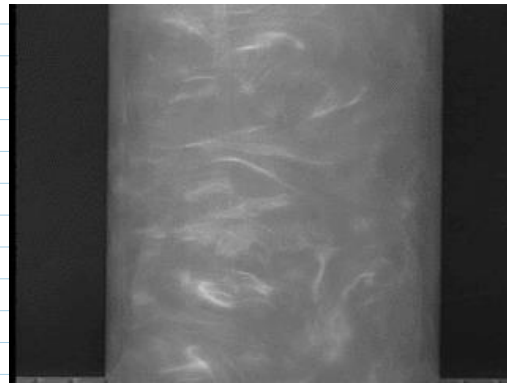
<http://www.stevespanglerscience.com/pearl-swirl-rheoscopic-concentrate.html>

'Pearl Swirl' \$5/gallon

Shiny opaque or translucent particles, crystal flakes, ~ 10  $\mu\text{m}$  size, aligns with shear gradient. Used in soaps, shampoos

Kalliroscope also sells it.

<https://www.youtube.com/watch?v=vrTM9O6owII> Pe



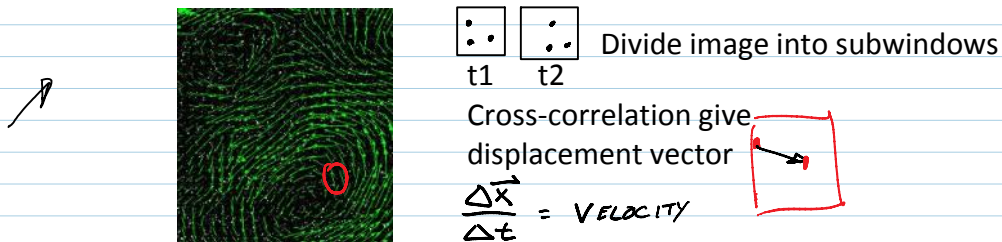
<http://buphy.bu.edu/~duffy/thermo/4B2077.html>

### c. Particle tracking techniques

Individual particles are seen. Can be qualitative or quantitative (Particle Image Velocimetry, PIV).

Two images made, close together in time

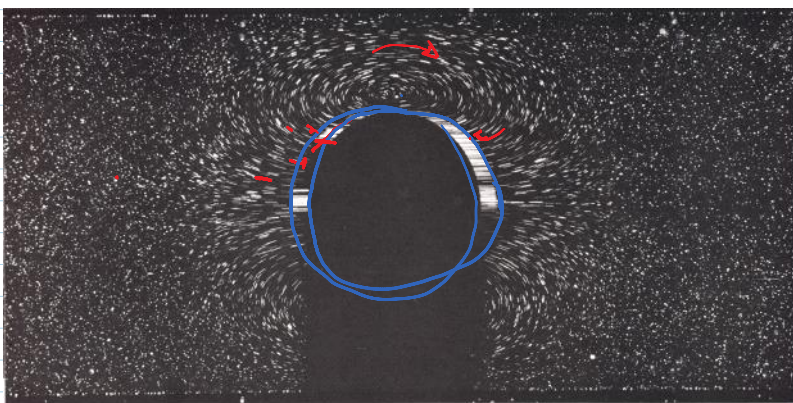
[http://fiji.sc/wiki/index.php/File:Surface\\_wave.gif](http://fiji.sc/wiki/index.php/File:Surface_wave.gif)



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=sch:1&ei=9CY3TcyNH8L7IweQ2uSMaw&sa=X&oi=mode\\_link&ct=mode&cd=2&ved=0CBAQ\\_AUoAQ&biw=993&bih=412](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=sch:1&ei=9CY3TcyNH8L7IweQ2uSMaw&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. Couetteau 1968

Small glitter particles: Pearl-Ex. Sold as iridescent pigment in art supply stores. Try Guiry's, at Pearl and Folsom.

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### OVERVIEW Part 3: Lighting

Skip for now. We'll come back to Lighting after Photog Basics and Postprocessing .

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### OVERVIEW Part 4: Image Acquisition.

Good digital photography reference:

David Fearon, *The Ultimate Guide to Digital Photography* 4, 4th ed. (Dennis Publishing, 2010).

<http://www.docstoc.com/docs/8819795/The-Ultimate-Guide-To-Digital-Photography>

Free download (ads)

<http://magbooks.org/post-10428/the-ultimate-guide-to-digital-photography-4>