

Today:

Admin

particle tracking

Choices in imaging: Index of refraction, Lighting, Imaging

Admin

Overdue: Syllabus, copyright, log in to Slack and Flowvis.org
Best of Web post due Weds, in Flowvis.org only.

FB of group Flow Visualization

Voice of Chat today? Grad students are expected to show leadership...
Office hours: 10 minutes before and after class, and by appointment?

Syd

We'll be doing an iClicker cloud poll today, so please get ready.

← add to initial assignments?
Is in syllabus

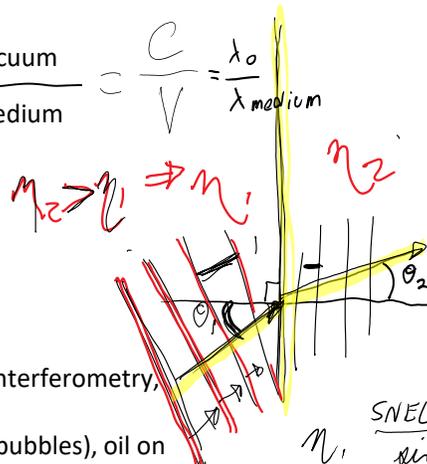
To Post: Demonstration

Overview Continued: Types of Flow Vis
Index of Refraction techniques

Index of refraction = refractive index = $n = \frac{\text{Speed of light in vacuum}}{\text{Speed of light in medium}} = \frac{c}{v} = \frac{\lambda_0}{\lambda_{\text{medium}}}$

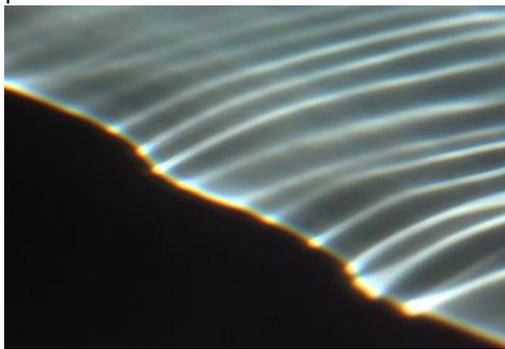
n always > 1 *oetah*

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



Frequency & color do not change
Wavelength λ shrinks
Wavespeed v slows in denser media
 $v = \lambda f$

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



CAUSTICS

DISPERSION

SNELL'S LAW
 $\frac{n_1}{n_2} = \frac{\sin \theta_2}{\sin \theta_1}$

$n(f)$
depends on frequency of light

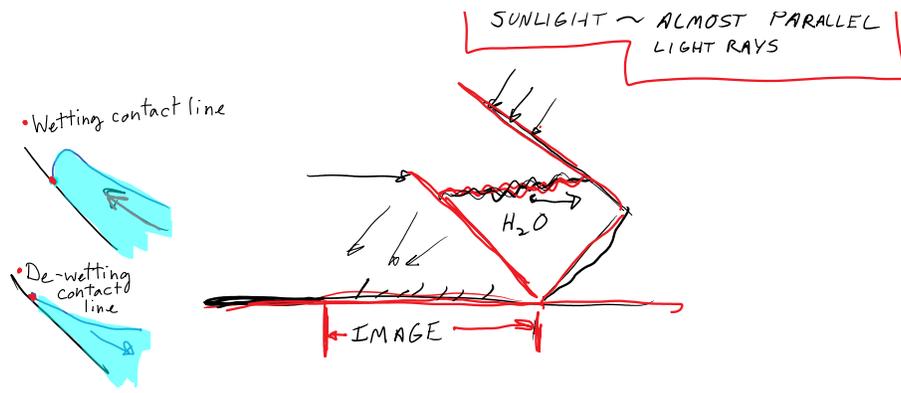
Pasted from <<http://www.colorado.edu/MCEN/flowvis/galleries/2007/assignment4/Hnath.jpg>>

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

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

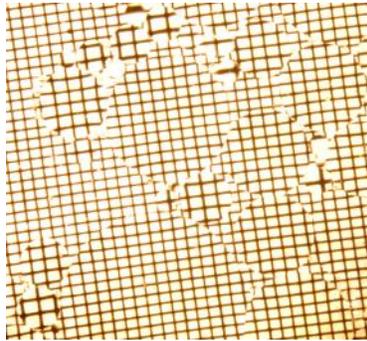
SUNLIGHT ~ ALMOST PARALLEL LIGHT RAYS

← → lines



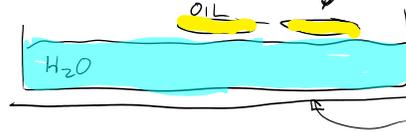
Contact line: solid, fluid and gas meet together.
 Mathematically makes a singularity; very interesting to applied math folks.

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

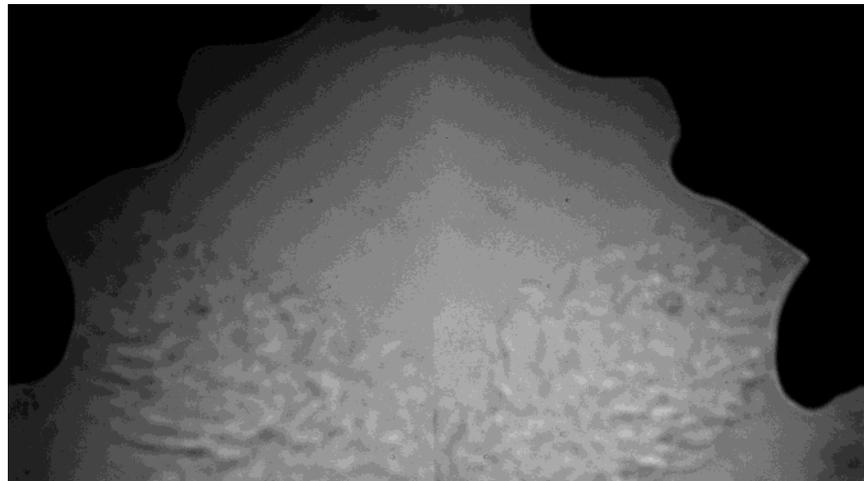


Liquid lenses formed by oil floating on water distort the grid beneath.

Tracy Eliasson
 Get Wet 07



Graph paper



Schlieren composite of two human exhalations. Owen Hnath, Group Alpha, Team 3, Fall 2007
<http://www.colorado.edu/MCEN/flowvis/galleries/2007/asignment6.html>

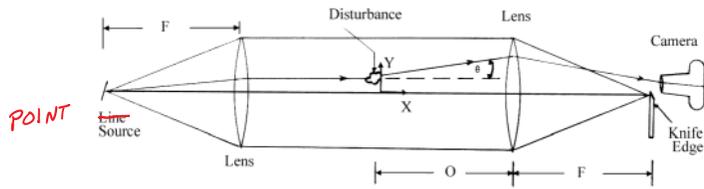
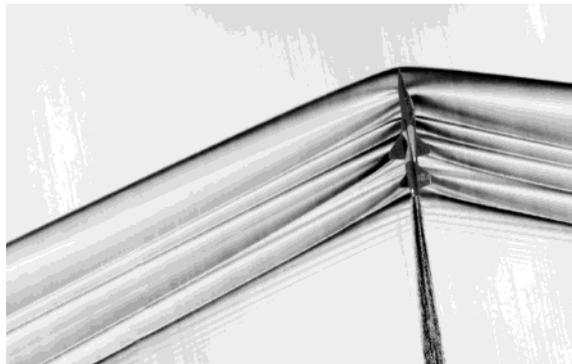


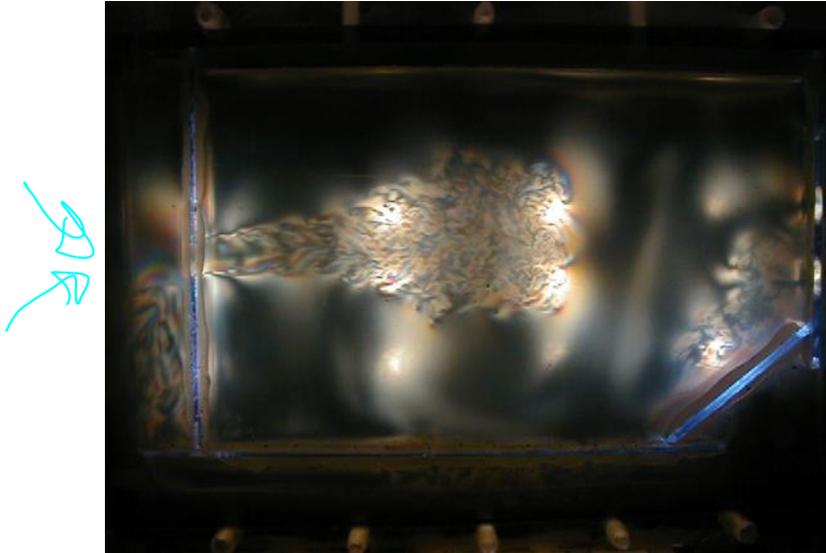
Figure 3. Schlieren System with a Small Disturbance

Copyright J. Kim Vandiver, 2002



BOS=Background Oriented Schlieren
 Uses sky light, and distance to get parallel light
 Aircraft: T-38, F-18 or F-15

http://www.nasa.gov/centers/armstrong/features/shock_and_awesome.html



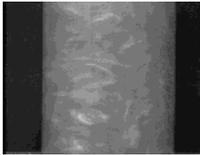
Streaming birefringence
 'Blackstock fluid' has 2 indices of refraction
 Suspension of microscale mica flakes.

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

Rheoscopic Fluids

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

*Pearl Swirl® 50/gallon
 Shiny opaque or transparent particles, crystal flakes, ~10µm size, aligns with shear gradient. Used in soaps, shampoo
 Kaleidoscope also sells it.
<http://www.stevespanglerscience.com/pearl-swirl-rheoscopic-concentrate.html>
<http://www.stevespanglerscience.com/pearl-swirl-rheoscopic-concentrate.html>



<https://doi.org/10.1063/1.5045053>

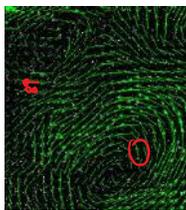
Easy to make from shaving cream:
 Borrero-Echeverry, Daniel, Christopher J. Crowley, and Tyler P. Riddick. "Rheoscopic Fluids in a Post-Kalliroscope World." *Physics of Fluids* 30, no. 8 (August 1, 2018): 087103.
<https://doi.org/10.1063/1.5045053>.

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

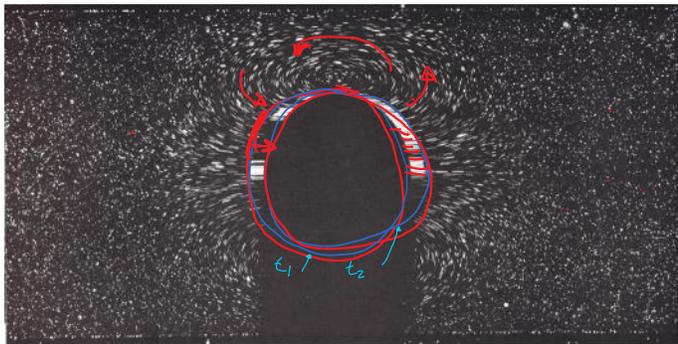
Cross-correlation give displacement vector

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

Pasted from http://www.google.com/images?zuparticle=image+velocimetry&hl=en&client=firefox-a&hs=NtU&rlsorg.mozilla:en-US:official&prms=ivms&source=lmns&tsisich=1&tc=9CY3TcyNH8L7weQ2uSMaw&sa=X&oi=image_link&ct=image&cd=2&ved=0CBAQALUoAO&biw=993&bih=412

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

From Van Dyke's ~~Gallery~~ ^{Album} of Fluid Motion

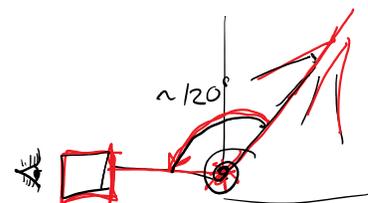


9. Sphere moving through a tube at $R=0.10$, absolute motion. In contrast to the photograph above, here the camera remains fixed with respect to the distant fluid. During the exposure the sphere has moved from left to right less than a tenth of a diameter, to show the absolute motion of the fluid. At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

Small glitter particles: Pearl-Ex. Sold as iridescent pigment in art supply stores. McGuckin's or Guiry's, at Pearl and Folsom. Pearl-Ex is mineral (TiO_2 coated mica), not plastic, maybe safer for environment. Don't breathe it, or any dust, or get it in your eyes.

OVERVIEW Part 3: Lighting

Your camera can only see light. Think about where it comes from and how (reflection, refraction, scattering) it gets into your lens.



For now, let's look at some examples from the Best of Web

selections. More on light/matter interactions on next iteration.

OVERVIEW Part 4: Image Acquisition.

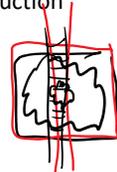
We'll do this section in more depth than in the rest of our Overview.

Good digital photography references:

Thousands of books are out there. Do you have a preference? Do you want a book? Choose something recent; technology is changing rapidly. We'll cover basics here to get you started.

Linked In Learning

- Lynda.com: online video tutorials for photography and video production
CU has a site license: lynda.colorado.edu
Log in with identikay



4.1) Framing/Composition

- #1 rule of photography: Make The Subject Fill The Frame**
Yes, you can crop to achieve this, but image dimensions of less than 700 pixels won't be accepted. Use your real estate well.
- Know your scale. Take an **extra** image with a ruler in it.
You'll need to specify your FOV = Field of View
i.e. "top to bottom was 10 cm"
Sometimes the image will supply the scale, such as the diameter of a jet.
- Work it.** Take many images, from varied POV = Points of View
 - Get close, pull back. Move around the sides.
 - Try a mirror to see the back.
 - Consider making a stereo image
 - Try video, a few seconds or minutes
 - Change the lighting.
 - Try time lapse (smartphone camera app is easy to use)
 - Consider the motion: Capture the whole track, and also zoom in on a particular moment/location
 - Plan lots of attempts. **Look at results at full resolution first**, not just on camera LCD. Takes time.



4.2) Cameras: Roughly 4 common types, but technology is changing quickly

All have

- AE = Auto Exposure. Automatically sets shutter time, aperture, ISO (sensor sensitivity) according to varied programs
- AF = Auto Focus. May be contrast focus and/or phase detection technology. See <https://www.jmpeltier.com/2017/12/08/difference-phase-detection-contrast-detection-autofocus/>

DSLR <i>A</i>	Mirrorless <i>B</i>	Point and Shoot <i>C</i>	Fil <i>D</i>	Phone camera only <i>E</i>
Digital Single Lens Reflex Optical viewfinder <i>54%</i>	Interchangeable lens but no viewfinder, just LCD <i>21%</i>	PHD Push Here Dummy. LCD viewer, fixed lens <i>14%</i>	<i>4%</i>	<i>7%</i>

Here 2020

Who has what?