22.IndexOfRefraction

Monday, November 14, 2016 7:50 AM

Today: Finish particles, then Refractive Index Methods

- Need help with final show (Dec 9) setup and cleanup, at least two people each.
- Graduate turbulence class next semester: Prof. Hamlington

Discussion art and science/engineering questions for after break

1. What is art? How do you know if an image is artistic?
2. What is science? How do you know if an image is scientific?
3. How are art and science similar?
4. How are they different?
5. What is engineering? How does it fit in compared to art and science?
6. What is filmmaking or photography? How does it fit in compared to art, science and engineering)?

Discussion structure: In your groups, discuss.
Choose a scribe.
For each question, list answers (on paper, to hand in)
A) you agree on,
B) you disagree on

Then we will compare between groups.

A few more particle techniques:

Rheoscopic Fluids

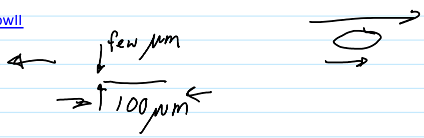
- Pearl Swirl

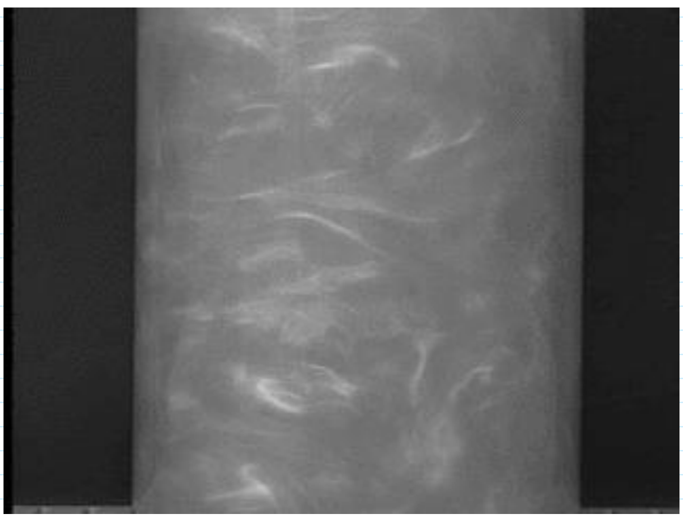
http://www.stevespanglerscience.com/pearl-swirl-rheoscopic-concentrate.html
Shiny opaque or translucent particles, crystal flakes, ~10 µm size, aligns with shear gradient. Used in soaps, shampoos

- Kalliroscope also sells it.

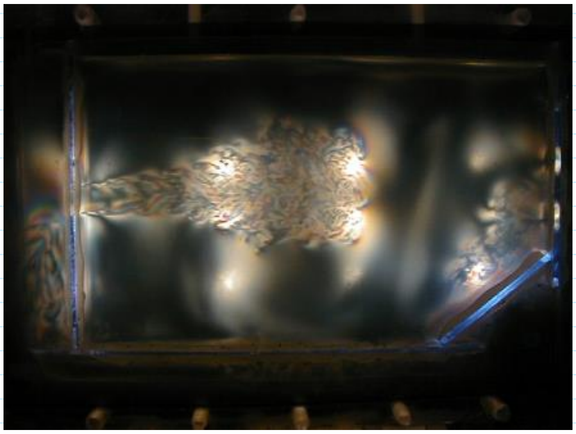
https://www.youtube.com/watch?v=vrTM9O6owlI

- Pearl Ex (art pigment, TiO2 coated mica)
- fish scales?





http://buphy.bu.edu/~duffy/thermo/4B20_77.html



Streaming birefringence
'Blackstock fluid'
Suspension of microscale mica flakes.

http://www.laminarsciences.com/

For individual particle images (PIV) Particle Image Velocimetry
https://www.youtube.com/watch?v=JbuuhpQCWz8 1 to 2 minute section air example

- Corn starch (diluted)
- Glass or polystyrene microspheres
- Latex bubbles
- Rust (filtered)
- Alumina
- Wax beads (Pine Sol)

Pine pollen (floats on surface)
$26 for 4 oz. http://www.hybridherbs.com/pine-pollen-powder/?gclid=CjwKEAiA3qXBBRD4_b_V7ZLFsX4SJAB0AtEV55ervl82KH_8gK_7JUjGkdR87CdEj5QdOPp80RJnvhoCKfHw_wcB Found outdoors

http://gfm.aps.org/meetings/dfd-2015/55eead3769702d060dd80100

Lycopodium powder (also used as flash powder):
It is composed of the dry spores of clubmoss plants, various fern relatives principally in the genera *Lycopodium* and *Diphasiastrum*. When mixed with air, the spores are highly flammable (combustible ?) because of their high fat content and their large surface area per unit of volume — a single spore's diameter is about 33 micrometers (µm).[

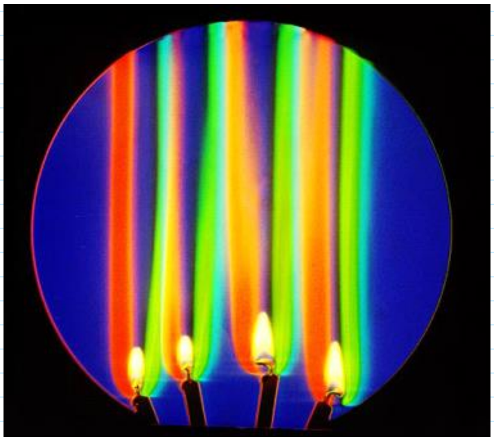
From <https://en.wikipedia.org/wiki/Lycopodium_powder>

https://vimeo.com/74130357 Cymatics by Susie Sie
http://vimeo.com/89491724 essence of sound

Index of refraction techniques

Requires no seed. Can visualize differences and gradients in temperature and chemical concentration,
as both change the index of refraction of the media.
Examples first, then techniques discussed in detail: schlieren and shadowgraphy

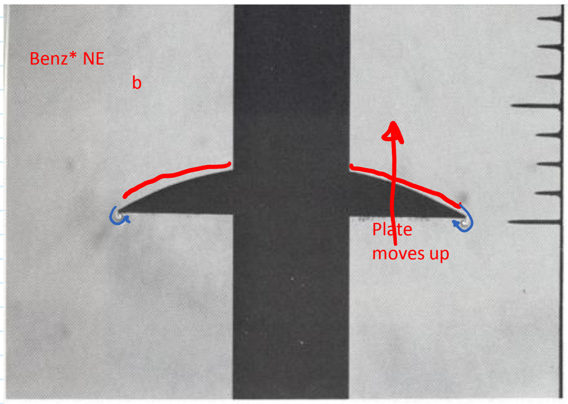
Color schlieren



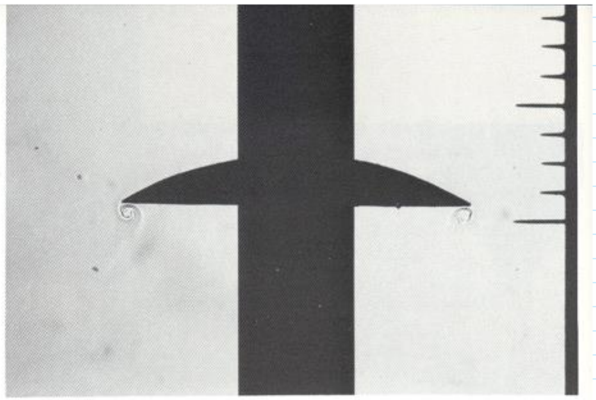
Pasted from <http://www.compadre.org/informal/images/features/schlierenlarge-11-29-06.jpg>

A. DAVIDHAZY (retired now),
RIT = Rochester Institute of Technology,
offers engineering and BS through PhD in
Imaging Science.

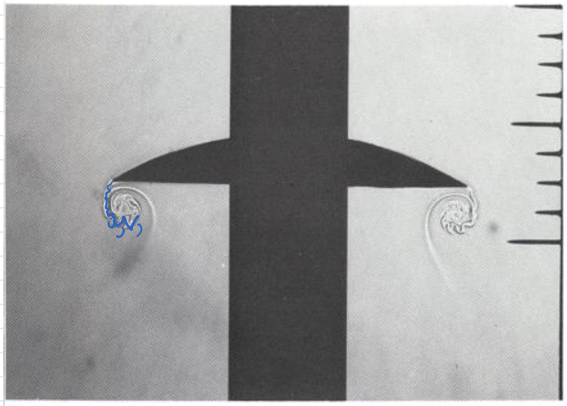
SHADOWGRAPH



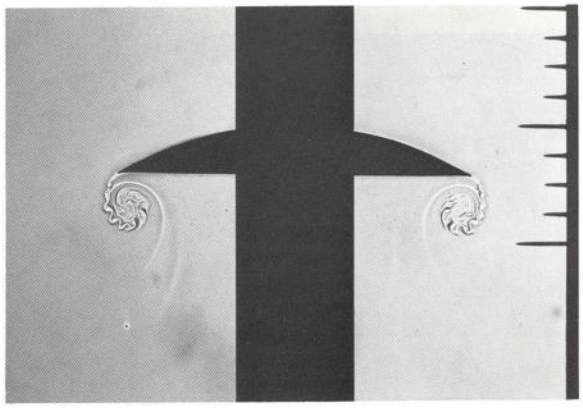
$t=1.05$ ms, $v=5.5$ ft/s



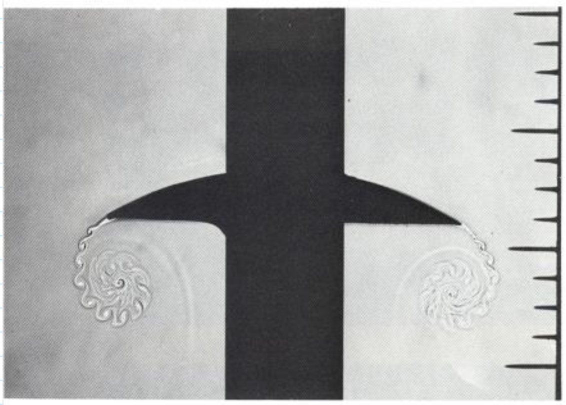
$t=2.14$ ms, $v=11.1$ ft/s



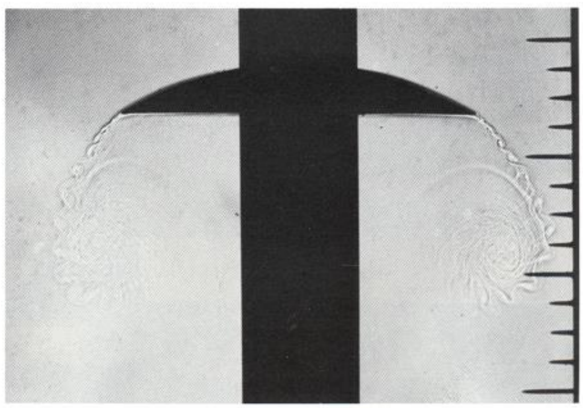
$t=3.22$ ms, $v=16.9$ ft/s



$t=4.30$ ms, $v=21.0$ ft/s

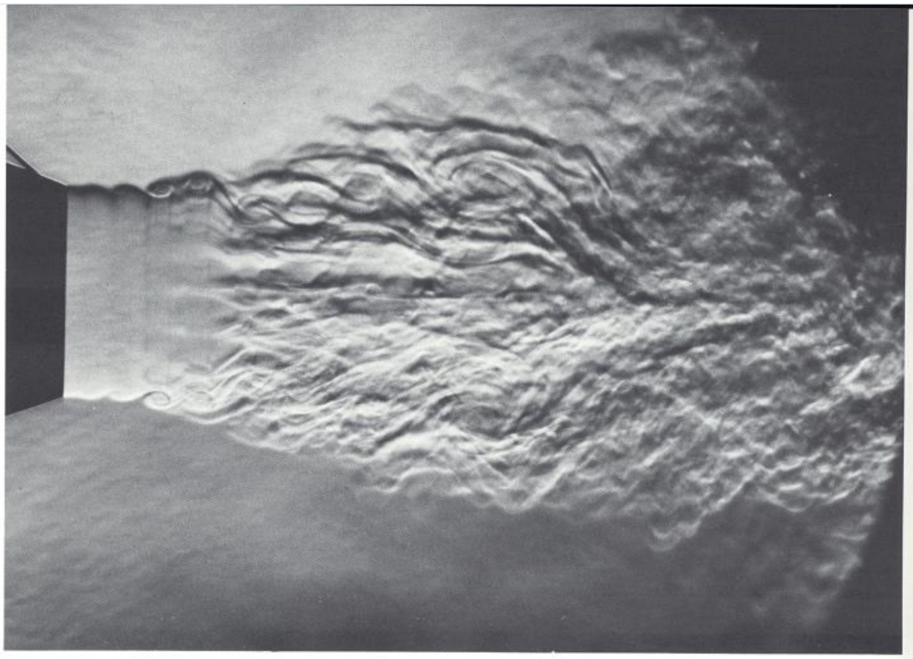


$t=6.53$ ms, $v=24.0$ ft/s

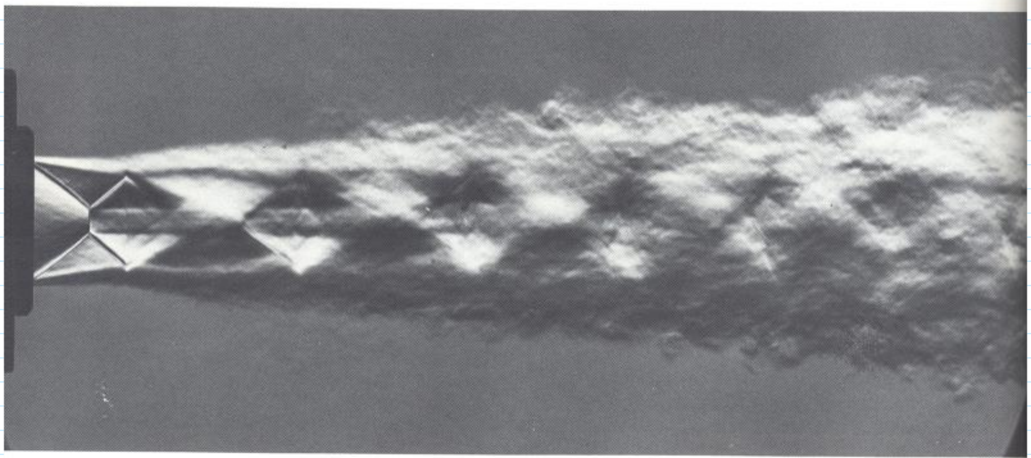


$t=10.66$ ms, $v=24.0$ ft/s

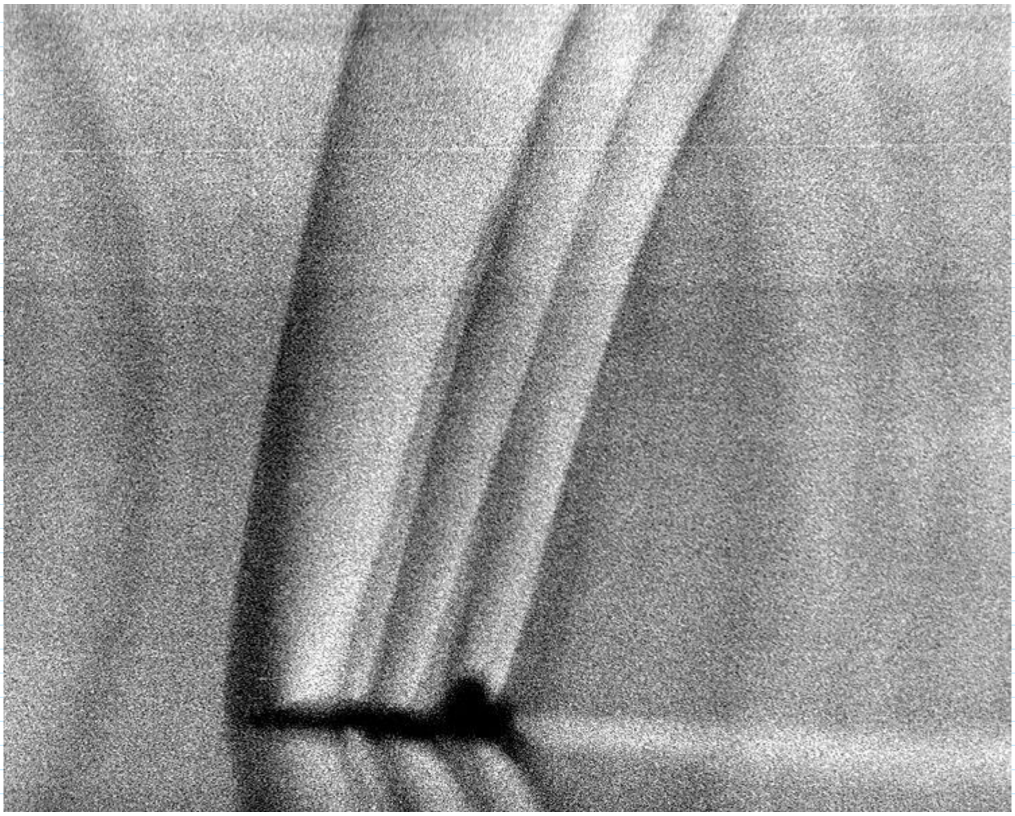
81. Growth of vortices on an accelerated plate. Spark shadowgraphs show the history of a 3-inch-square plate in air, accelerated from rest to 24 ft/s. The sharp edge of the plate is initially opposite the first of a series of pins spaced ¼ inch apart. The motion is actually vertical, and the flow is visualized by painting a narrow band of benzene across the center of the balsa-wood plate, so that when the plate accelerates benzene vapor is drawn into the vortex sheet. The difference in density between the vapor and the air makes the paths of their boundaries visible. Care was taken to ensure that the undulations observed in the vortex sheet were not caused by vibrations of the model. *Pierce 1961*



167. Subsonic jet becoming turbulent. A jet of air from a nozzle of 5-cm diameter flows into ambient air at a speed of 12 m/s. The laminar interface becomes unstable as in figure 102, and the entire jet eventually becomes turbulent. *Bradshaw, Ferriss & Johnson 1964*



168. Supersonic jet becoming turbulent. At a Mach number of 1.8 a slightly over-expanded round jet of air adjusts to the ambient air through a succession of oblique and normal shock waves. The diamond-shaped pattern persists after the jet is turbulent. *Oertel 1975*



Pasted from <http://commons.wikimedia.org/wiki/File:Schlieren_photograph_of_T-38_shock_waves.jpg>

Mach 1.1, full size T-38 in flight, 1993. L. Weinstein, NASA
example of Background Oriented Schlieren (BOS). Correlate patterned background from image to get schlieren

http://fuckyeahfluiddynamics.tumblr.com/post/47622561173/this-high-speed-video-shows-schlieren-photography

CO_2 bottle rocket video. Shows Mach diamonds and expansion fans.

How it works:

http://www.npr.org/2014/04/09/300563606/what-does-sound-look-like
Michael Hargather, New Mexico Tech

$$\eta = \frac{C_{VACUUM}}{C_{MEDIUM}}$$

n = index of refraction

Light is deflected towards more dense medium

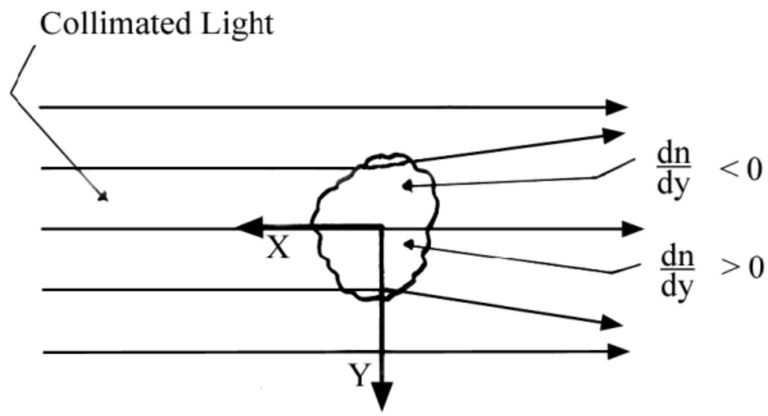


Figure 1. Disturbance in Collimated Beam

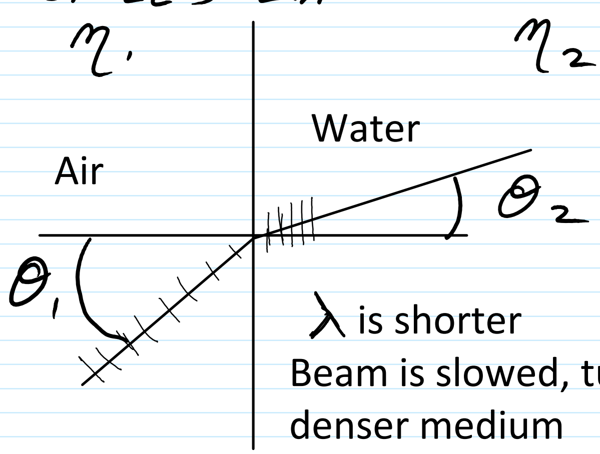
Shadowgraphy:

constructive and destructive interference from disturbed parallel light

$$\frac{1}{\eta}\frac{\partial \eta}{\partial y} = \frac{\partial^2 y}{\partial x^2}$$

curve of disturbed line

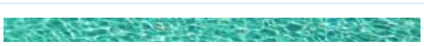
SNELL'S LAW

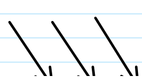


λ is shorter

Beam is slowed, turns into, i.e towards the denser medium

like a caustic sunlight





like a caustic sunlight

http://www.shutterstock.com/video/clip-3174052-stock-footage-dappled-pool-water-ripple-background-swimming-pool-water-abstract-background-with-seamless-loop.html

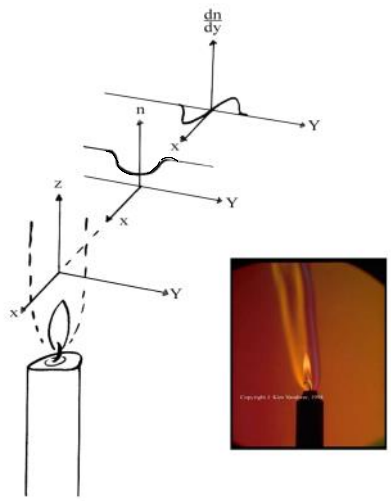


Figure 2. The Refractive Index Gradient Above a Candle

http://web.mit.edu/Edgerton/www/schlieren5.html

Shadowgraphy:

constructive and destructive interference from disturbed parallel light

schlieren:

Selectively remove constructive or destructive interference from disturbed parallel light.
Higher contrast, controlled sensitivity to gradient directions

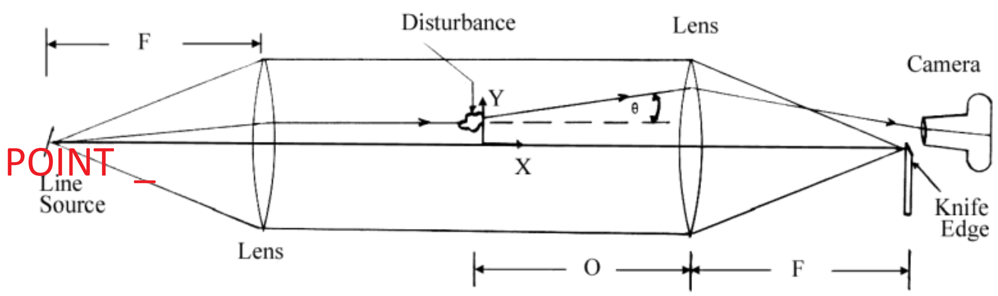
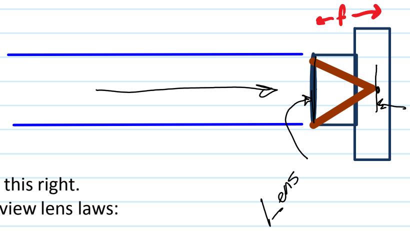


Figure 3. Schlieren System with a Small Disturbance

Minute paper: What would camera see looking at parallel light, camera lens focused at infinity?
Hint: what light sources do you know that emit parallel light? What do they look like?



1/2 got this right.
Let's review lens laws:

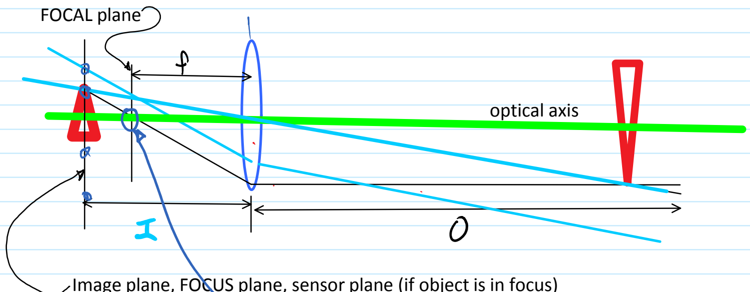


Image plane, FOCUS plane, sensor plane (if object is in focus)

Lens Laws

1) light through center of lens is undeflected
2) light parallel to axis goes through focal point

≠ focus point

Lens Laws

1) light through center of lens is undeflected
2) light parallel to axis goes through focal *point* ≠ focus point
3) all light entering lens at a given direction ends up at the same point in the *focal* plane (**not** *focus* plane)

Focus equation

$$\frac{1}{f} = \frac{1}{O} + \frac{1}{I}$$

f = focal length
O = dist. Lens → object
I = dist. Lens → image (sensor)