

14. Particles

Thursday, March 03, 2011

Today: Critique catch up

Particles

News: research independent study opportunities; see me

Particles

Last time, talked about where heavy or light particles will go

Heavier than fluid, to outside of curve

Lighter than fluid, to inside of curve.

For particles to accurately track the fluid we have

Rules of thumb:

- In water or other liquids, particles of 100 μm diameter or less, any density, will track most flows.
- In air, particles of 1 μm diameter or less, any density, will track most flows.

Similar considerations to dyes:

- 1) Particles must track with the flow
- 2) Want particles to NOT disturb flow
- 3) Want particles to show up - HIGH VISIBILITY

2) Want particles to NOT disturb flow

- As with dyes, minimize injection differential velocity; inject at local flow speed.
 - Want particles to not introduce new forces or effects. Avoid:
 - soluble particles
 - surface tension
 - chemical reactions
 - significant change of density
 - particle-particle interaction
- Number density of particles = # of particles / unit volume. (Contrast to mass/volume of solid alone). Keep low enough to avoid interactions.
 - Particle-particle interaction (collisions, drag) lead to non-Newtonian effects. Slurries, oobleck, blood, shampoo, silly putty, other polymers. Gets into 'complex fluid' categories. Interesting field.

3) High visibility

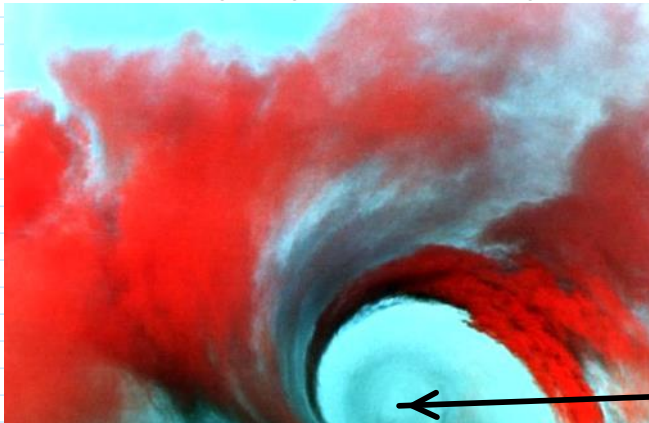
Particles only scatter light. Interaction depends on size (d) compared to λ .

Scattering = $\sum$ of reflection, refraction, diffraction & absorption

$d \sim O(\lambda)$: Mie scattering regime.

e.g. visible light $\approx 0.4 - 0.7 \mu\text{m}$, so diameters of 1 μm to 0.1 μm (100 nm, 1000 Å).

- Scattering efficiency drops as particles get smaller. Better tracking, but less light.
- Independent of wavelength; no colors from particles this small. Makes clouds white.
- Particles large enough to have color are too big to track well.



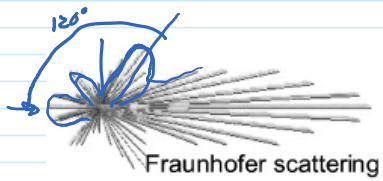
No color?



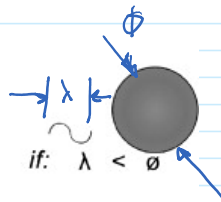
No color?

Wake Vortex Study at Wallops Island
NASA Langley Research Center 5/4/1990 Image # EL-1996-00130
"NASA wing tip vortex. Information for ID # EL-1996-00130," n.d.,
<http://lisar.larc.nasa.gov/UTILS/info.cgi?id=EL-1996-00130>.

Light is not scattered uniformly:



Fraunhofer scattering



if: $\lambda < \phi$



Mie scattering

if: $\lambda = \phi$

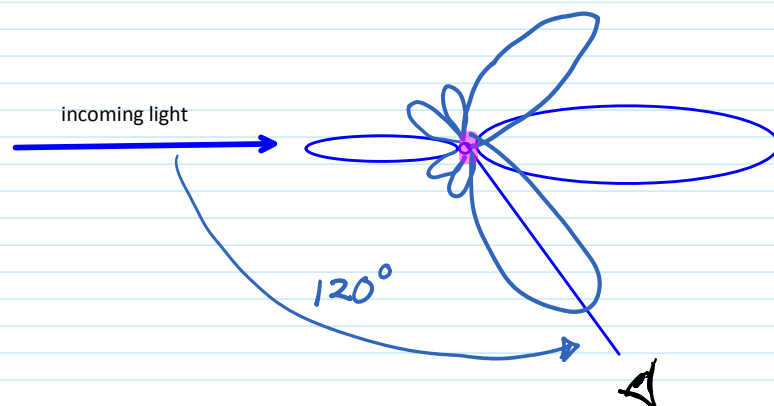
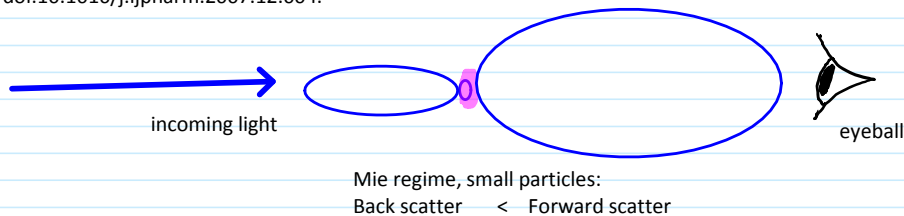


Rayleigh scattering

if: $\lambda > \phi$

<http://www.sciencedirect.com/science/article/pii/S0378517307010113>

Keck, Cornelia M., and Rainer H. Müller. "Size Analysis of Submicron Particles by Laser Diffraction—90% of the Published Measurements Are False." *International Journal of Pharmaceutics* 355, no. 1–2 (May 1, 2008): 150–163.
doi:10.1016/j.ijpharm.2007.12.004.



Mie regime, larger particles: Back scatter < Forward scatter

+

Often a strong lobe at 120 degrees to incoming light. **SWEET SPOT**
Best to play with camera-light angles.

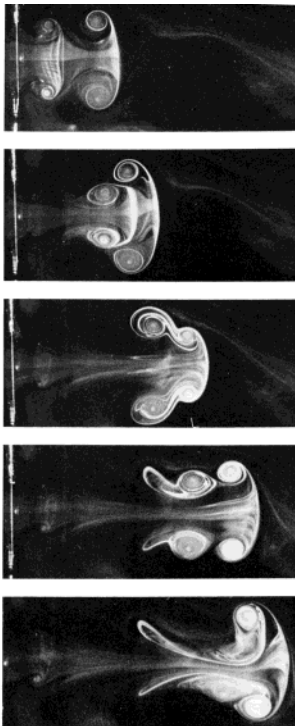
Smaller particles, $d \ll \lambda$,

N

NCFMF film 'Flow Visualization'

Hydrogen bubble technique

A) Smoke = soot usually, carbon particles

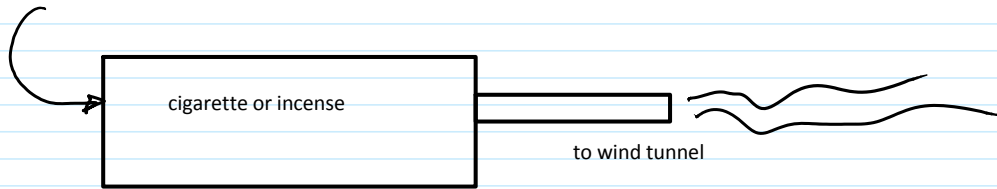


79. **Leapfrogging of two vortex rings.** Two successive puffs of air are ejected from an orifice of 8-cm diameter by a piston that is driven by the impacts of two pendulums. The flow is made visible by a smoke wire stretched across the orifice, at the left of the photographs. At this Reynolds number of about 1600 based on orifice diameter, the second ring travels faster in the induced field of the first, and has slipped through it in the third photograph. Then the process is repeated, the first ring slipping through the second in the last photograph. Yomoda & Matsui 1978

2014 Page 3

Most oils work. Veg is less toxic.
Generates $1\mu\text{m}$ particles. Penetrates into lungs, causes cancer,
regardless of composition.

Alt technique:
pressurized air



2.1. Visualization of Flow Direction and Flow Contours

27

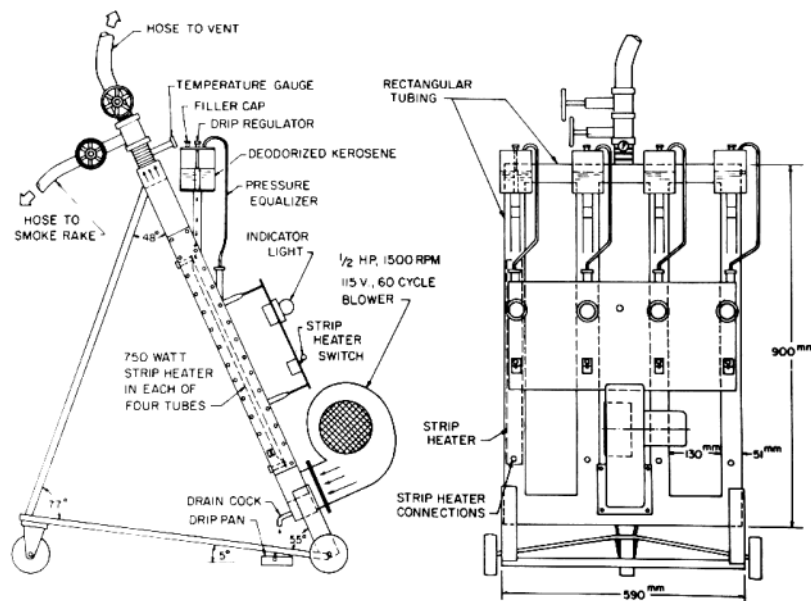
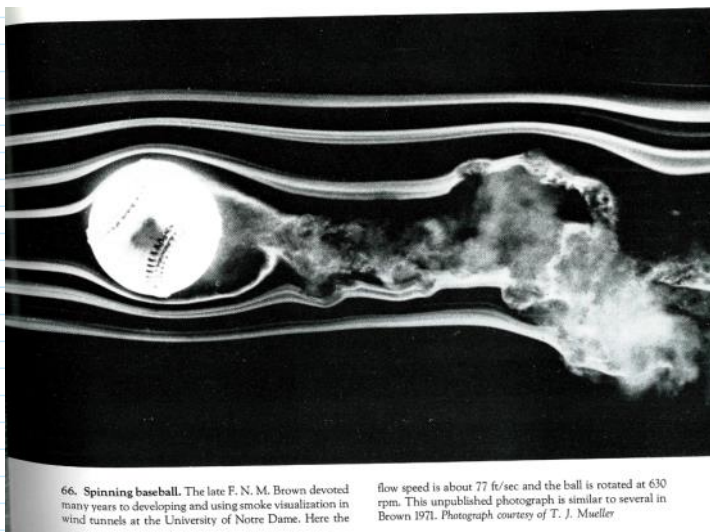


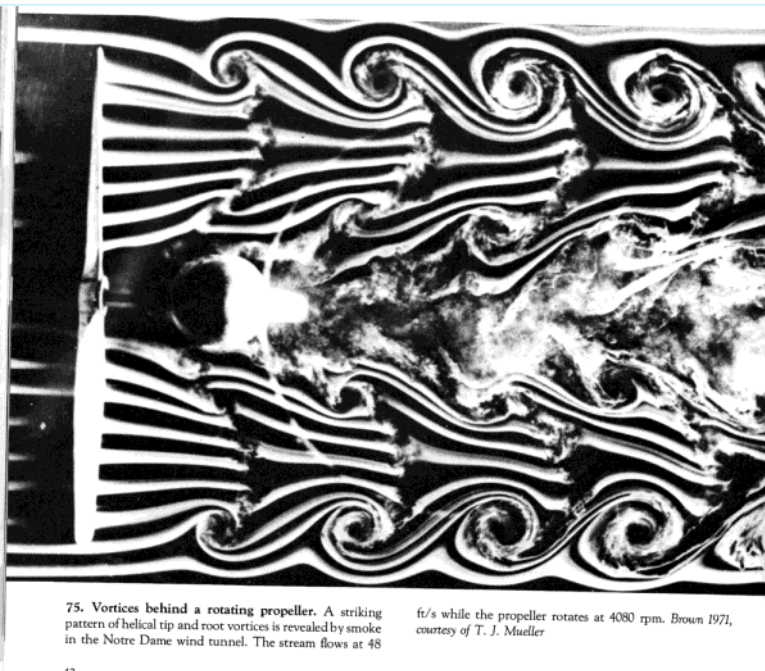
Fig. 2.6 Smoke generator designed at the University of Notre Dame. (From Mueller, 1983. Published by Hemisphere Publishing Corporation.)

Merzkirch, Wolfgang. *Flow Visualization, Second Edition*. 2nd ed. Academic Press, 1987.

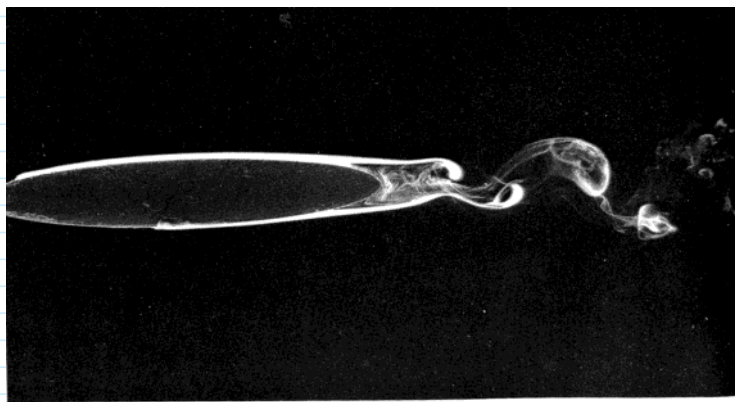


66. Spinning baseball. The late F. N. M. Brown devoted many years to developing and using smoke visualization in wind tunnels at the University of Notre Dame. Here the

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



Chemically generated particles:
 TiO_2 Titanium dioxide particles from
 titanium tetrachloride + water vapor = dense TiO_2 smoke + HCl
 HCl + water vapor = hydrochloric acid vapor
 Spectacular smoke, but toxic, and hard on equipment, corrosive



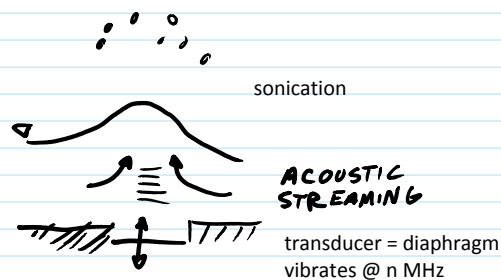
32. Laminar separation on a thin ellipse. A 6:1 elliptic cylinder is held at zero angle of attack in a wind tunnel. The Reynolds number is 4000 based on chord. Drops of titanium tetrachloride on the surface form white smoke, which shows the laminar boundary layer separating at the rear. Bradshaw 1970

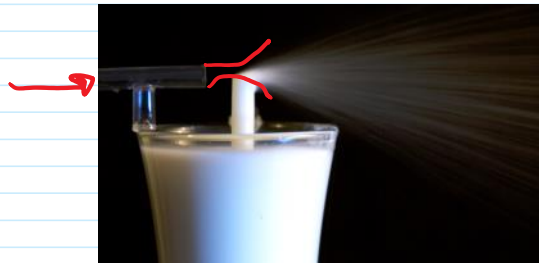
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B) Fog = aerosols of liquids

Water fog: Safe, but evaporates quickly

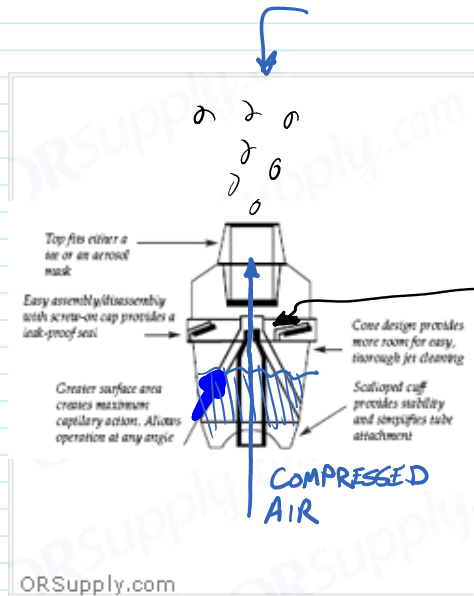
- ultrasonic humidifier http://www.youtube.com/watch?v=rN-OcMSwS2I&feature=youtu_gdata_player
- http://www.youtube.com/watch?v=rkrLl7tJOIg&feature=youtu_gdata_player with acoustic streaming
- medical nebulizer
- dry ice (solid CO_2)





Matt Blessinger
Get Wet 2009

Bernoulli atomizer
Jet nebulizer
Small Volume Nebulizer (SMN)



Inexpensive: \$3
Makes 1 μm to 100 μm droplets
Larger droplets impact on surfaces, can't exit device.

Dry Ice Vapor: Dry ice = solid CO_2

Sublimates (solid to gas) at 1 atm, -78°C (-109°F)

<http://www.dryiceinfo.com/fog.htm>

Submerge in hot water: much water fog created.

Fog production drops for water temperature $< 50^\circ\text{F}$

60 Pounds of Dry Ice and a Swimming Pool, 2007. http://www.youtube.com/watch?v=uhXA9ON6igk&feature=youtu_gdata_player

Yes at King Soopers
Arup, Table Mesa 2013