

22: Particles 2: Aerosols

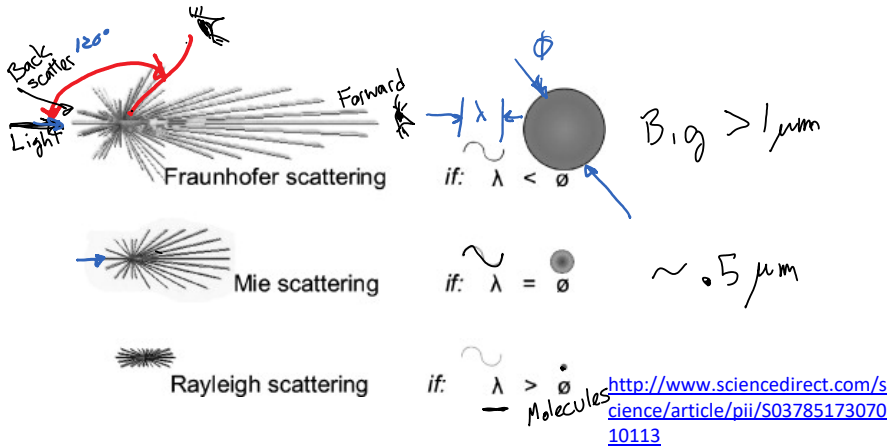
Monday, November 14, 2022 11:55 AM

Today

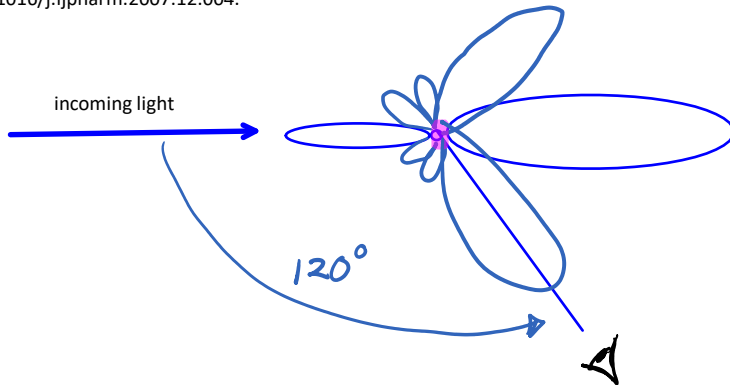
Light scattering
Sources of aerosols

Yes, clickers today

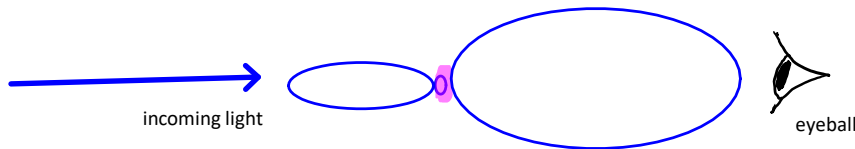
Light is not scattered uniformly:



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 + Fraunhofer 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.



Mie regime, small particles:
Back scatter < Forward scatter

Smaller particles, $d \ll \lambda$,

Rayleigh scattering regime. Elastic collision of photons with particles. No energy exchange. Blue sky is Rayleigh scattering; sunlight scattered by molecules of air, preferentially blue. Longer wavelengths are too long to interact much; are only seen at sunset due to long passage through atmosphere, and when scattered by larger molecules of pollutants or dust.

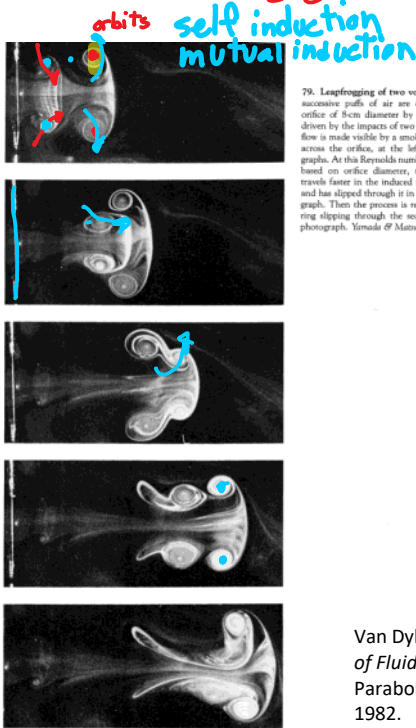
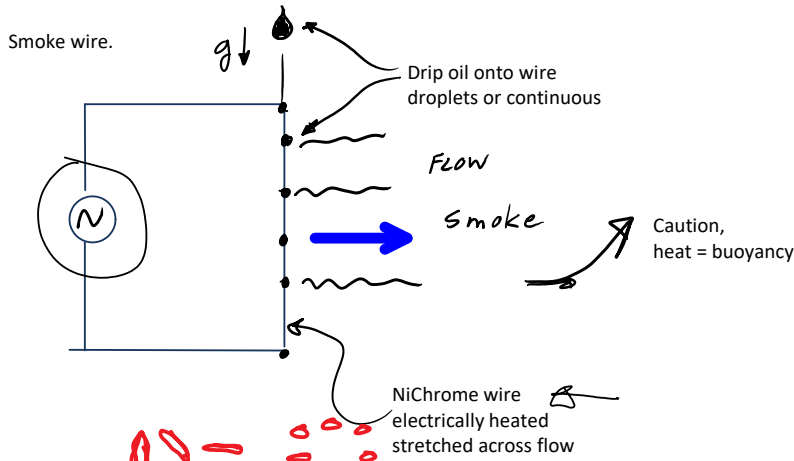
Next: How to make or get particles

First in air, then in water

Aerosols in air: smoke and fog

Solids liquids

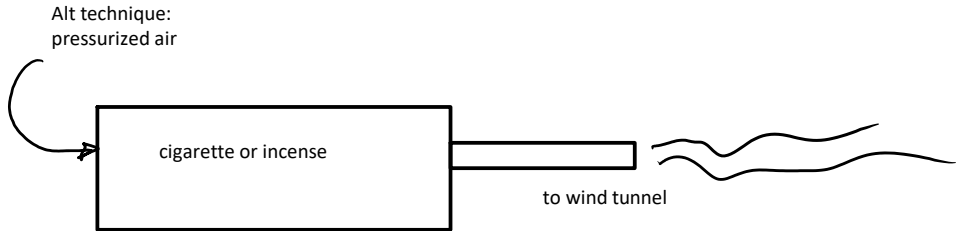
A) Smoke = soot usually, carbon particles



Van Dyke, Milton. *Album of Fluid Motion*. 10th ed. Parabolic Press, Inc., 1982.

PM
 $< 2.5 \mu\text{m}$

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



2.1. Visualization of Flow Direction and Flow Contours

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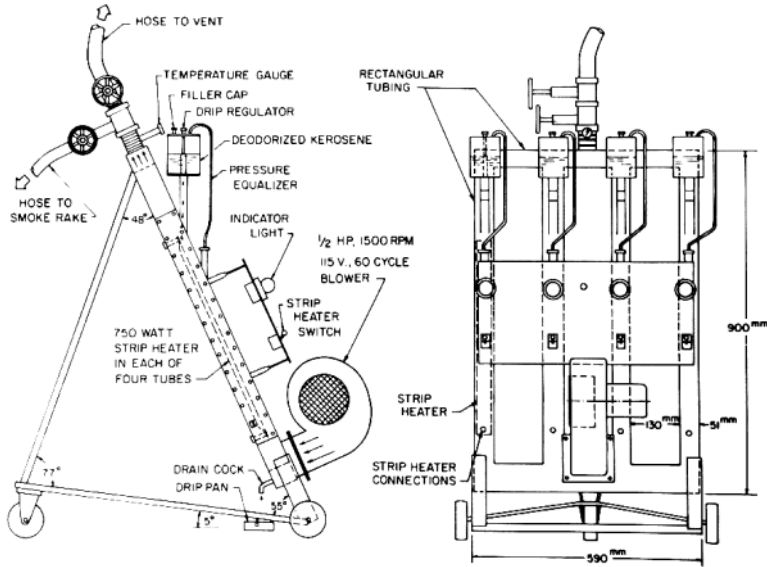
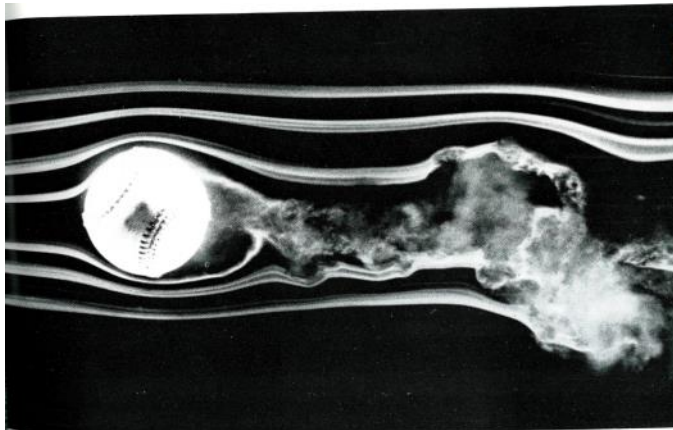


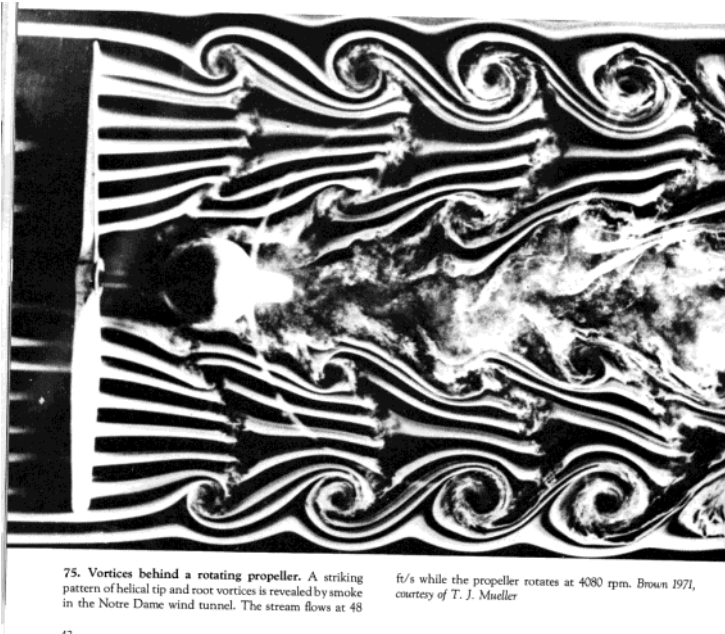
Fig. 2.6 Smoke generator designed at the University of Notre Dame. (From Mueller, 1983. Published by Hemisphere Publishing Corporation.)

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

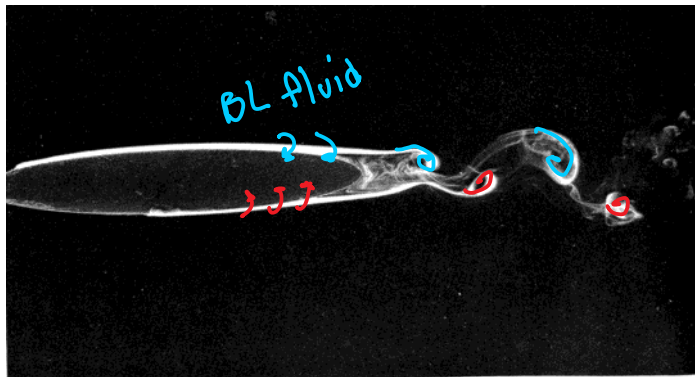
flow speed is about 77 ft/sec and the ball is rotated at 630 rpm. This unpublished photograph is similar to several in Brown 1971. Photograph courtesy of T. J. Mueller



75. Vortices behind a rotating propeller. A striking pattern of helical tip and root vortices is revealed by smoke in the Notre Dame wind tunnel. The stream flows at 48 ft/s while the propeller rotates at 4080 rpm. Brown 1971, courtesy of T. J. Mueller

- Chemically generated particles:
 Micron-sized TiO_2 Titanium dioxide particles from titanium tetrachloride + water vapor = dense TiO_2 smoke + HCl
 HCl + water vapor = hydrochloric acid vapor
 Painted on a surface will identify vortical boundary layer fluid
 Spectacular smoke, but toxic, and hard on equipment, corrosive

TiCl₄



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

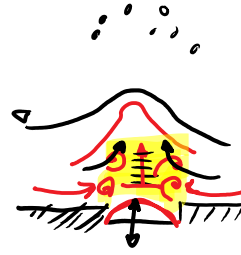
Karman Vortex Street

B) Fog = aerosols of liquids

Water fog: Safe, but evaporates quickly

- ultrasonic humidifier http://www.youtube.com/watch?v=rN-OcMSwS2I&feature=youtu.be_gdata_player
- http://www.youtube.com/watch?v=rkr17t1Olg&feature=youtu.be_gdata_player with acoustic streaming - DEAD LINKS
- medical nebulizer
- dry ice (solid CO_2)

Low P



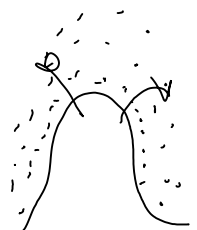
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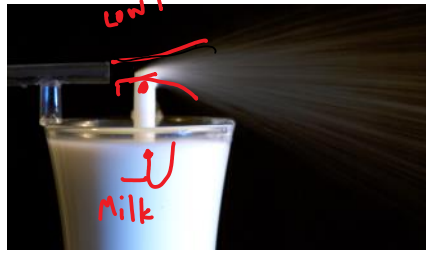
ACOUSTIC STREAMING

transducer = diaphragm vibrates @ n MHz

Request slow mo

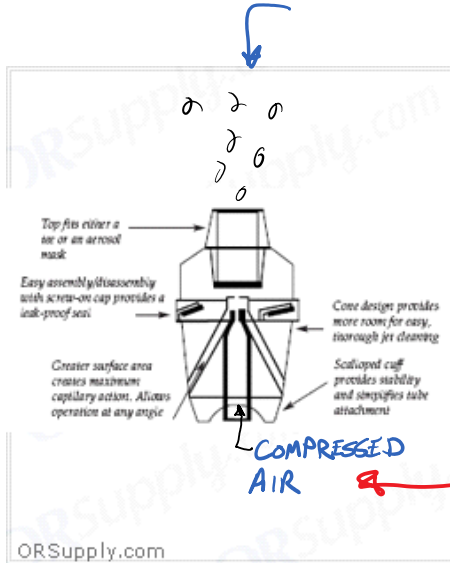
Synthetic Jet





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.

Liquid is delivered to jet exit by capillary action

COMPRESSED AIR for checkout

Dry Ice



Clicker: What in the fog is scattering light?

- 1. Water aerosol 36%
- 2. Dry ice aerosol 10%
- 3. Dry ice particles 5%
- 4. Carbon dioxide droplets 47%