

24: Particles 2: Aerosols

Monday, November 11, 2024 11:55 AM

Today

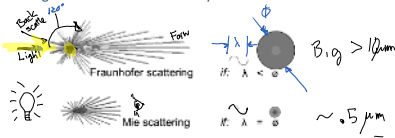
Light scattering
Sources of aerosols

Yes, clickers today

3: High visibility for particles - light scattering

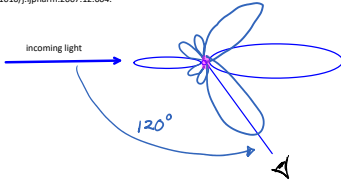
Scattering = Σ reflection, refraction, diffraction, and absorption
Complicated topic. Whole books written about it.

Light is not scattered uniformly:



<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 + 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.



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

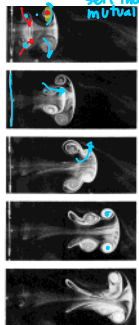
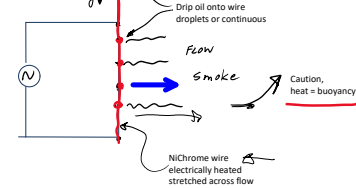
First in air, then in water

Aerosols in air: smoke and fog

Solids liquids

A) Smoke = soot usually, carbon particles

Smoke wire.



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

PM
< 2.5 μ m

Most oils work. Veg is maybe less toxic.
Generates 1 μ m particles. Penetrates into lungs, causes cancer, regardless of composition.

Payne Team Second 2009 video

[Payne Team Second 2009](#)



2.1. Visualization of Flow Direction and Flow Contours

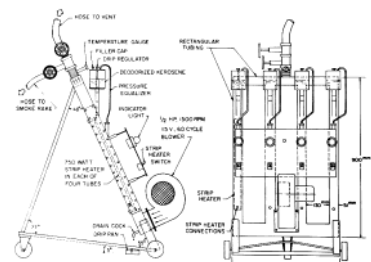
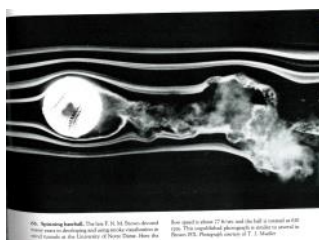
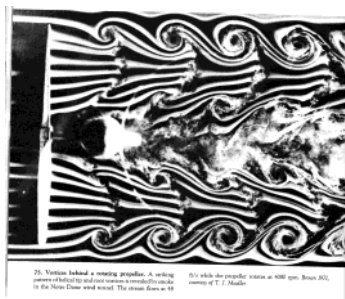


Fig. 2.6 Smoke generator designed at the University of Notre Dame. (From Mueller, Merzkirch, Wolfgang. *Flow Visualization*, Second Edition, 2nd ed. Academic Press, 1987.)



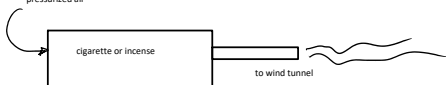
25. Nonlinear behavior of a mixing apparatus. A mixing process of light and dark smoke is visualized in a flow tank at the University of Notre Dame. Note the



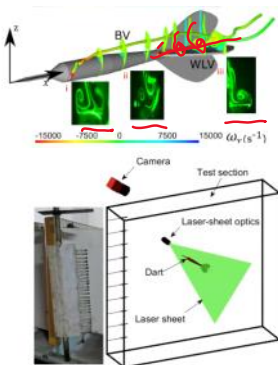
26. Vortex behind a mixing apparatus. A mixing process of light and dark smoke is visualized in the flow tank at the University of Notre Dame. Note the

27. Vortex generator. The flow is visualized around the tip of a vortex generator in a flow tank at the University of Notre Dame. Note the

Alt technique:
pressurized air



Prof Sandeep Saha's setup

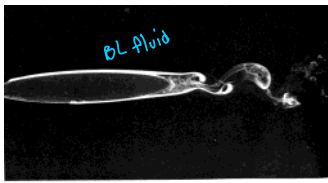


Pawar, Amit A., Kumar Sanat Ranjan, Arnab Roy, and Sandeep Saha. "Aerodynamics of a Dart-Shaped Projectile at Low Reynolds Number." *Experiments in Fluids* 65, no. 6 (June 2024): 89. <https://doi.org/10.1007/s00348-024-03824-z>

• Chemically generated particles:
Micron-sized TiO₂ Titanium dioxide particles from titanium tetrachloride + water vapor = dense TiO₂ smoke + HCl

TiCl₄

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

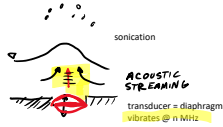


12. Laminar separation on a thin airfoil. A red dye, which allows the flow to be seen, is injected into the flow. The Karman vortex street is 180° from the leading edge of the airfoil. (Reynolds 1911)

B) Fog = aerosols of liquids

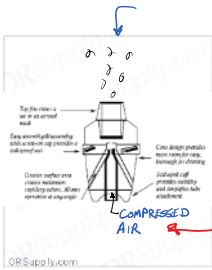
Water fog: Safe, but evaporates quickly

- ultrasonic humidifier
- http://www.youtube.com/watch?v=rkr17f10j8&feature=youtu.be_data_player with acoustic streaming
- medical nebulizer
- dry ice (solid CO₂)



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

Dry Ice



Clicker: What in the fog is scattering light?

- Water aerosol
- Dry ice aerosol
- Dry ice particles
- Carbon dioxide droplets

	2024 vote 1	Vote 2
1	25%	77
2	6	8
3	6	8
4	44	8

	2023	2022
1	63	36%
2	6	10
3	6	5
4	25	47

Dry Ice Vapor: Dry ice = solid CO₂
 Sublimates (solid to gas) at 1 atm, -78 C (-109 F)
<http://www.dryiceinfo.com/fog.htm>

Liquid form only >5 atm.
https://en.wikipedia.org/wiki/Carbon_dioxide

If it's carbon dioxide droplets, why does it need water for fog?