23.Particles 1

Wednesday, November 20, 2019 3:55 PM

Admin:

Today: Particles: interaction with flow
Generation

II Particles

Heavy seeding

Number density high enough to look like a dye

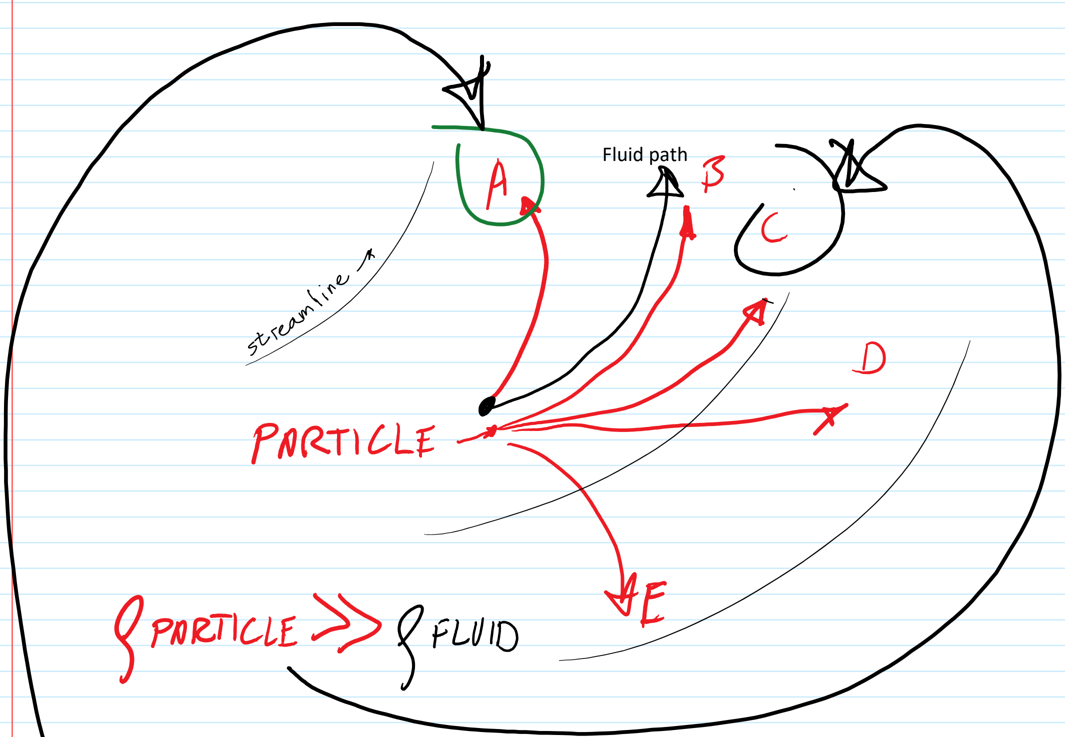
Similar considerations to dyes:
1)Particles must track with the flow ← Big difference from dyes
Dyes are molecules, track with the flow just fine.

2)Want particles to NOT disturb flow
3)Want particles to show up - HIGH VISIBILITY

1) When will particles track well, be good tracers?

Minute paper: Consider a curved streamline in a **horizontal plane.** Consider a small particle, much denser than the fluid.

What will the particle path look like compared to the fluid path?



Next, consider same scenario, but a bubble instead of a particle.

$\rho_{BUBBLE} \ll \rho_{FLUID}$ ← ?

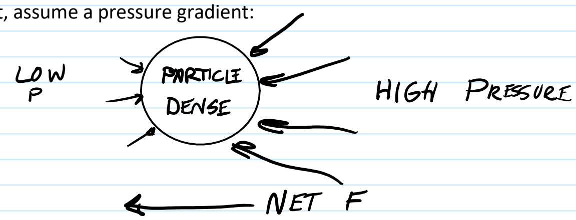
Ever been hit in the back of the head by a balloon when you are accelerating in a car?
http://www.youtube.com/watch?v=XXpURFYgR2E

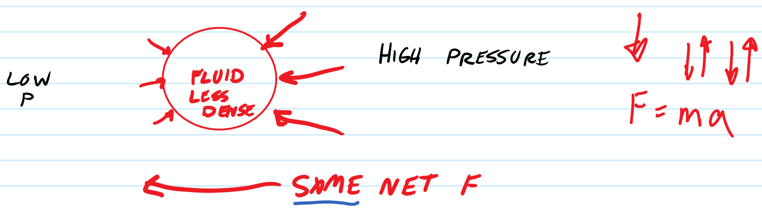
For particles (or bubbles) to track with the surrounding fluid, they must accelerate the same as the neighboring fluid

Forces **on particle**:
Body: gravity, neglect.

Surface:	normal = pressure parallel = shear	} from fluid

First, assume a pressure gradient:



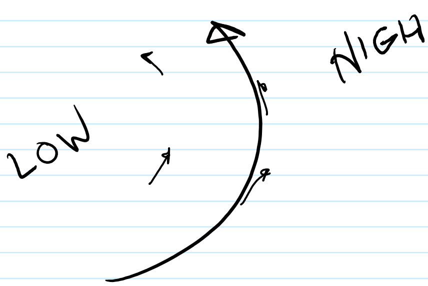


Which particle will accelerate more?
Newton's Second Law: $\sum F = ma$

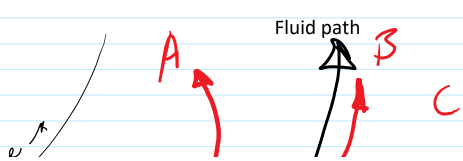
Same force – Dense BUBBLE – which will accelerate more?

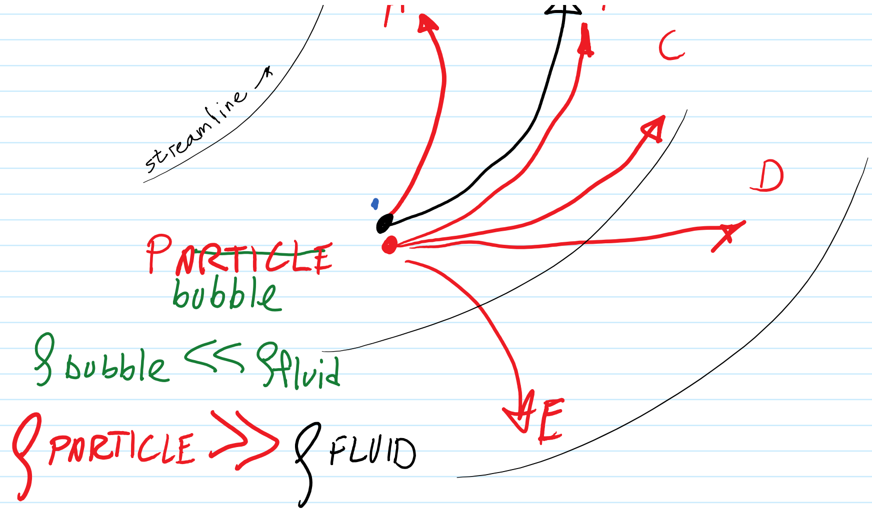
What makes streamlines curve?

(what is a streamline?)



Streamlines curve because of pressure gradient. Low P is inside 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 = ∑ of reflection, refraction, diffraction & absorption

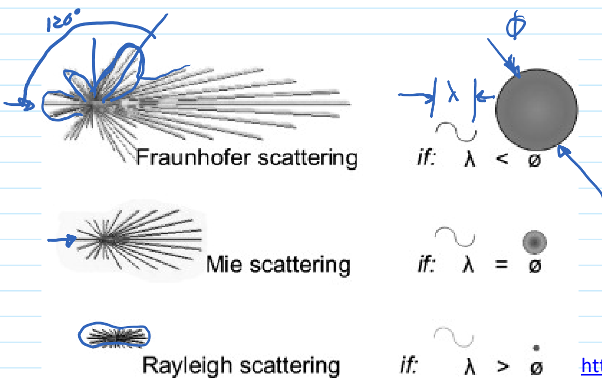
λ = wavelength of light
d or ϕ diameter of particle

d ~O(λ) : Mie scattering regime.
e.g. visible light =0.7 - 0.4µm, so diameters of 1 µm to 0.1µm (100 nm, 1000 A).

- 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.

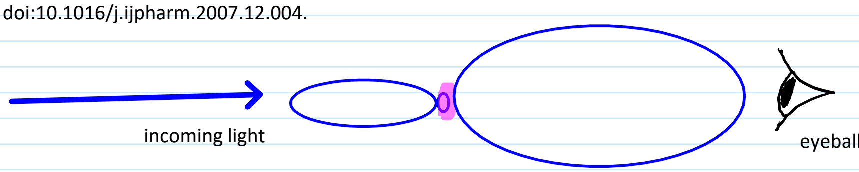
"NASA wing tip vortex. Information for ID # EL-1996-00130," n.d., http://lisar.larc.nasa.gov/UTILS/info.cgi?id=EL-1996-00130.

Light is not scattered uniformly:

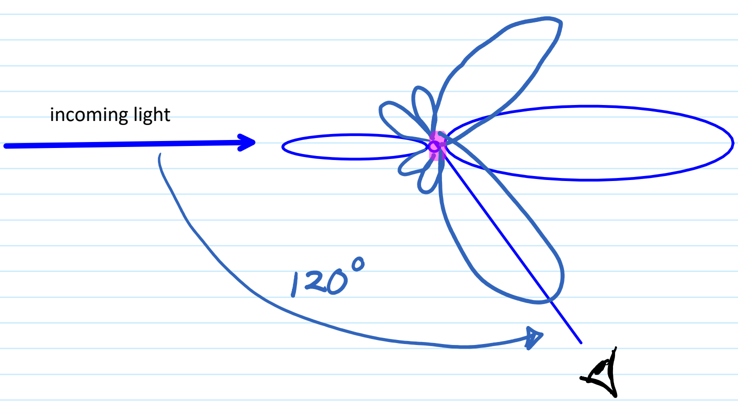


http://www.sciencedirect.com/science/article/pii/S0378517307010113

Keck, Cornelia M., and Rainer H. Müller. "Size Analysis of Submicron Particles by Laser Diffractometry—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, small particles:
Back scatter < Forward scatter



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 << λ,
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

http://www.youtube.com/watch?v=DOUfyDHxkYQ&feature=related
NCFMF film 'Flow Visualization'
Hydrogen bubble technique, but also discusses streamline vs streakline vs pathline

Available in lab

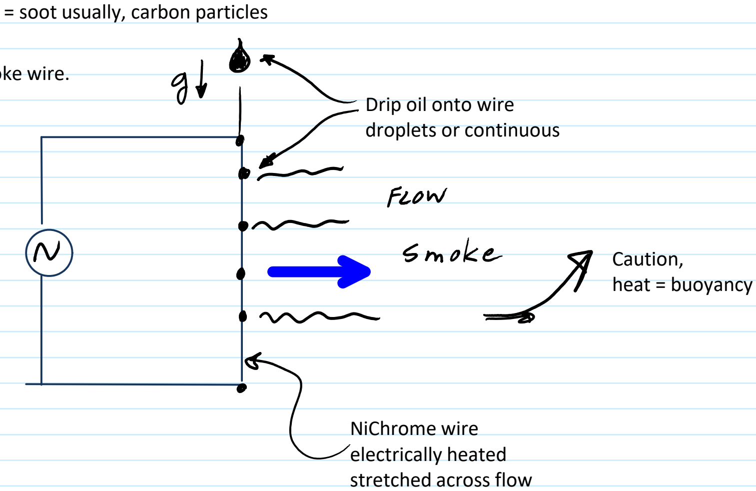
Aerosols in air: smoke and fog

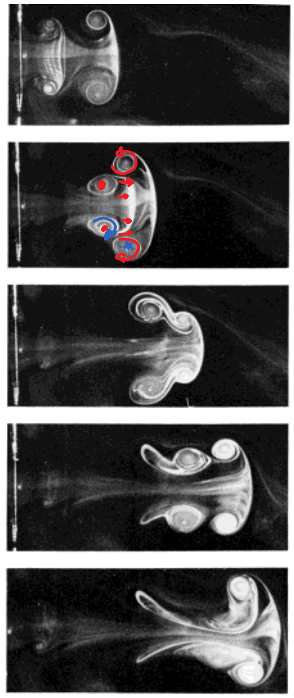
Solids liquids

Today:
Particles - how to get/make them

A) Smoke = soot usually, carbon particles

Smoke wire.



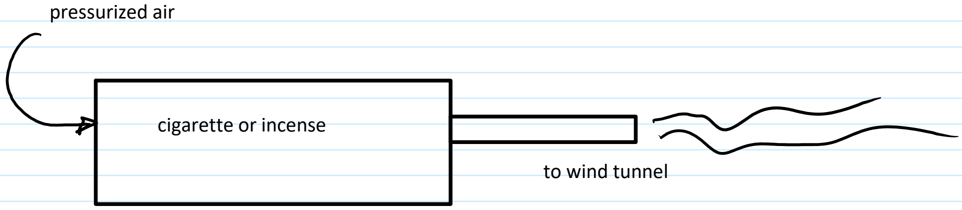


79. Leapfrogging of two vortex rings. Two successive puffs of air are ejected from an orifice of 8-cm diameter by a piston that is driven by the impacts of two pendulums. The flow is made visible by a smoke wire stretched across the orifice, at the left of the photographs. At this Reynolds number of 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. *Yamada & Matsui 1978*

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

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

Alt technique:
pressurized air



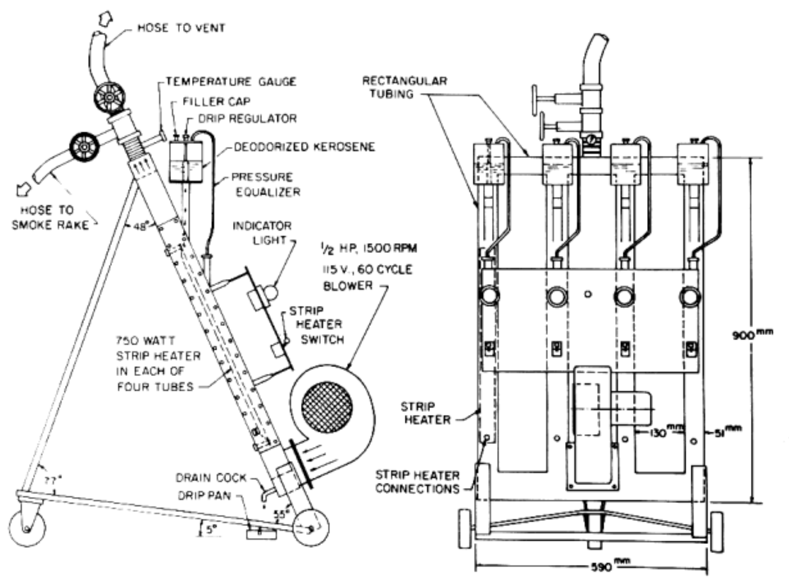
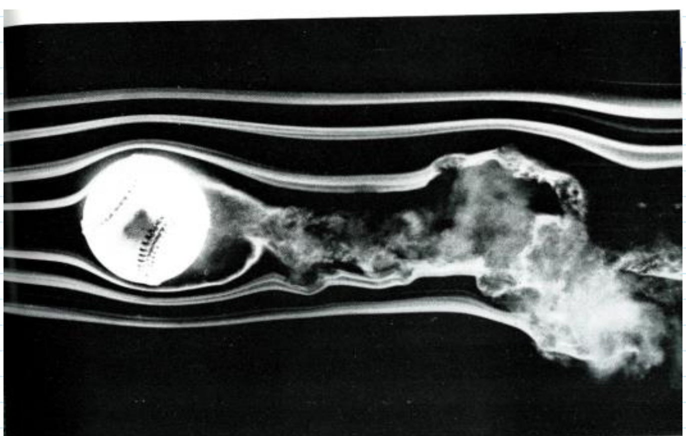


Fig. 2.6 Smoke generator designed at the University of Notre Dame. (From Mueller, 1983. Published by Hemisphere Publishing Corporation.)

Merzkirch, Wolgang. *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*