17.Particles 1

Thursday, April 11, 2013 3:55 PM

Admin:

Today: finish light-matter interaction
Particles: interaction with flow
Generation

Chemoluminescence - Cyalume: chemical reaction releases photon, which then drives fluorescence. Needs mix of chemicals for reaction, and choice of color.
Flames: C_2, CH^+ , radicals = highly reactive intermediate molecules (between reactant and product species) that only exist in the thin reaction zone. Excited by reactions, emit blue photons to get to lower energy state. Also, hot soot gives off black body radiation; yellow glow.

http://www.sciencefriday.com/video/06/08/2012/what-is-a-flame.html

Bioluminescence - Fireflies, deep sea fish, worms. Good for flow vis?

Electroluminescence - LEDs, sodium vapor, mercury vapor lamps etc. Specific λ.

E.g. electric pickle http://www.youtube.com/watch?v=tMhXCG6k6oA

Laser : population inversion, specific λ, resonant cavity with mirrors. Gas dynamic laser: after supersonic expansion, lower vibrational states relax before higher ones = inversion. A type of 'chemical laser'

II Particles

Heavy seeding

Number density high enough to look like a dye

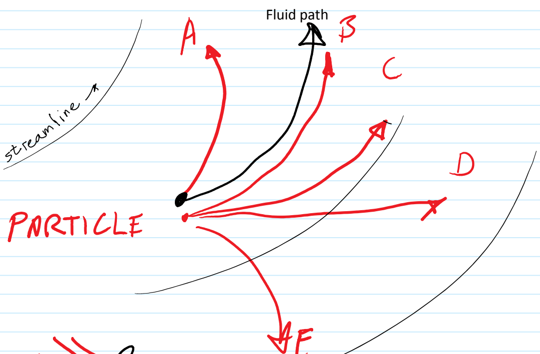
Similar considerations to dyes:
1)Particles must track with the flow ← Big difference from dyes
Dyes are molecules, track with the flow just fine.

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. Consider a small particle, much denser than the fluid, BUT small enough that gravity is negligible compared to forces of the fluid on the particle. (diameter ~ 100 μm in water) ← human hair diameter

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



$\rho_{PARTICLE} \gg \rho_{FLUID}$

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

$\rho_{BUBBLE} \ll \rho_{FLUID}$

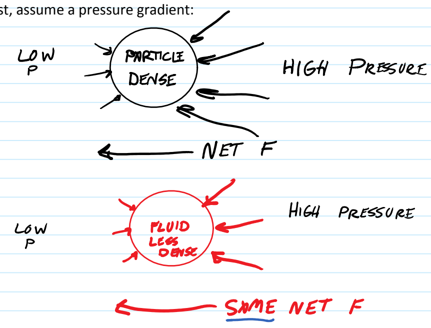
Ever been hit in the back of the head by a balloon when you are accelerating in a car?
http://www.youtube.com/watch?v=XXpURFYgR2E

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

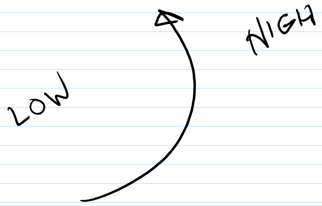
First, assume a pressure gradient:



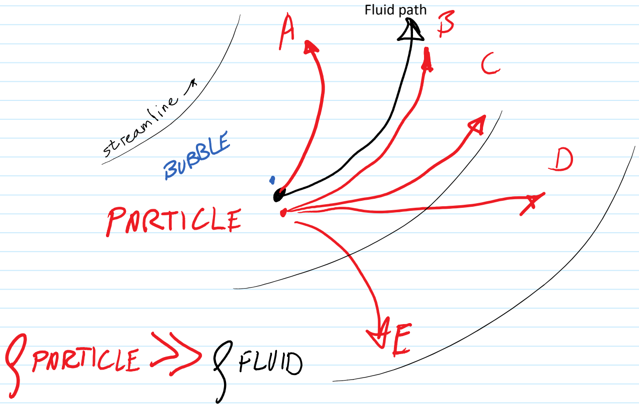
Which particle will accelerate more?
Newton's Second Law: $\sum F = ma$

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

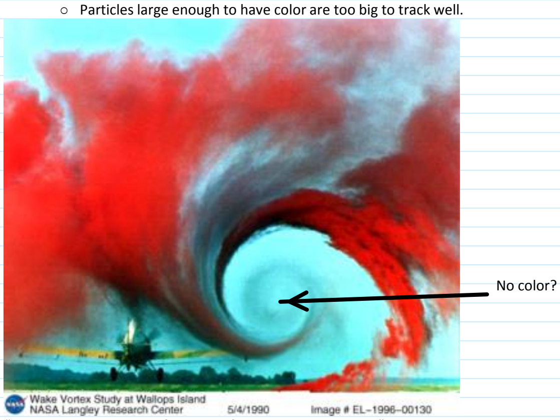
- surface tension
- chemical reactions
- significant change of density
- particle-particle interaction
    - Number density of particles = # of particles / unit volume. (Contrast to mass/volume of solid alone). Keep low enough to avoid interactions.
    - Particle-particle interaction (collisions, drag) 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

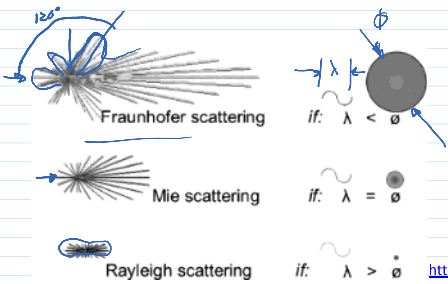
d ~O(λ) : Mie scattering regime.
e.g. visible light =0.7 - 0.4μm, so diameters of 1 μm to 0.1μm (100 nm, 1000 A).

- 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.



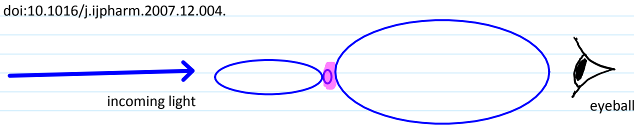
“NASA wing tip vortex. Information for ID # EL-1996-00130,” n.d., http://lisar.larc.nasa.gov/UTILS/info.cgi?id=EL-1996-00130.

Light is not scattered uniformly:

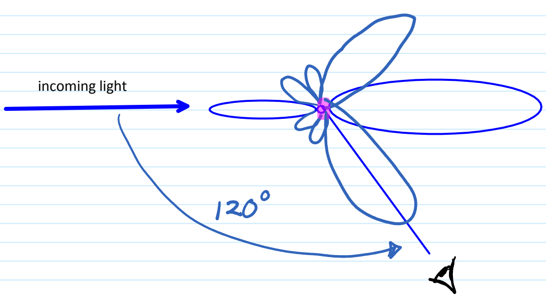


http://www.sciencedirect.com/science/article/pii/S0378517307010113

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 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

http://www.youtube.com/watch?v=DOUfyDHxkYQ&feature=related
NCFMF film 'Flow Visualization'
Hydrogen bubble technique

— got to streakline defn