Newtonian fluids:

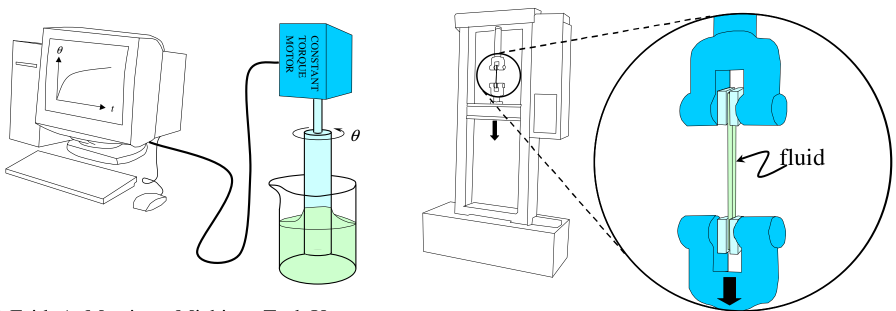
$$\underline{\underline{\tau}} = -\mu \underline{\underline{\dot{\gamma}}}$$

vs.

non-Newtonian fluids:

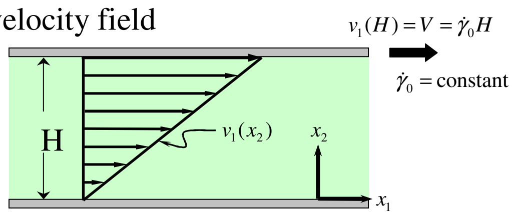
$$\underline{\underline{\tau}} \neq -\mu \underline{\underline{\dot{\gamma}}}$$

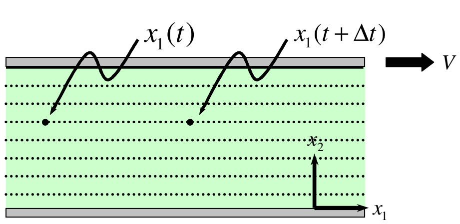
How can we investigate non-Newtonian behavior?



Simple Shear Flow

velocity field

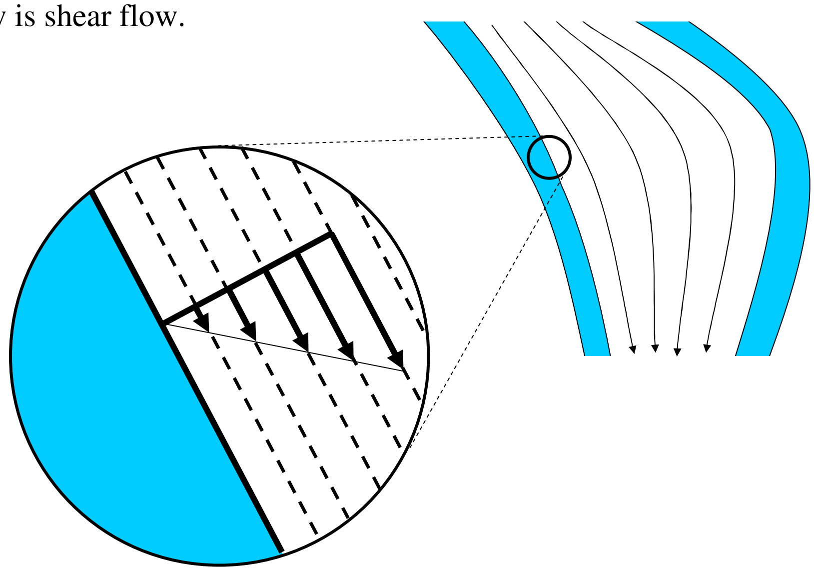




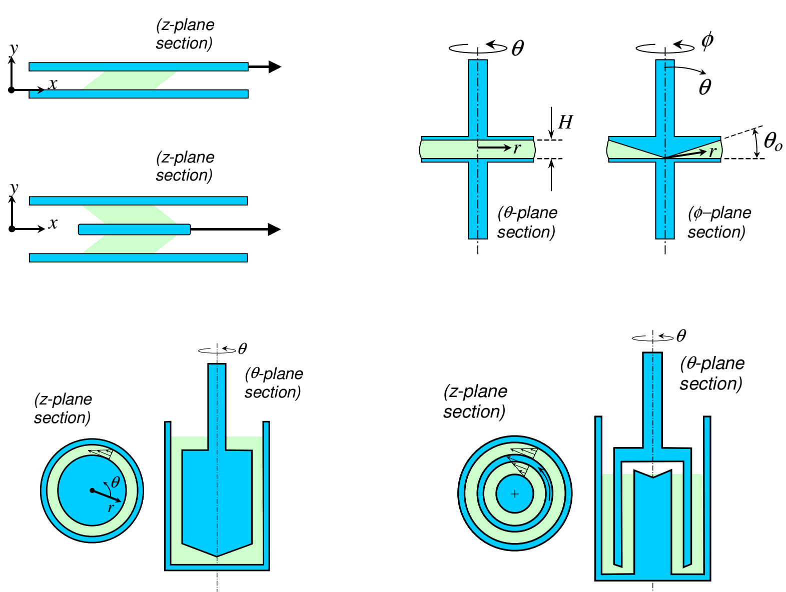
path lines

$$\underline{v} \equiv \begin{pmatrix} \dot{\varsigma}(t) x_2 \\ 0 \\ 0 \end{pmatrix}_{123}$$

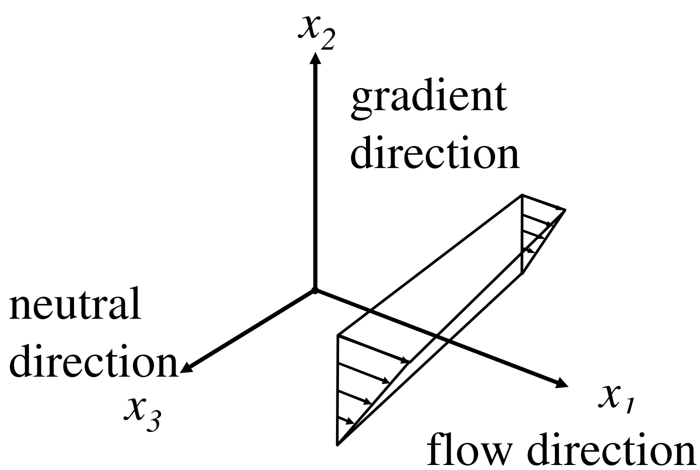
Near solid surfaces, the flow is shear flow.



Experimental Shear Geometries

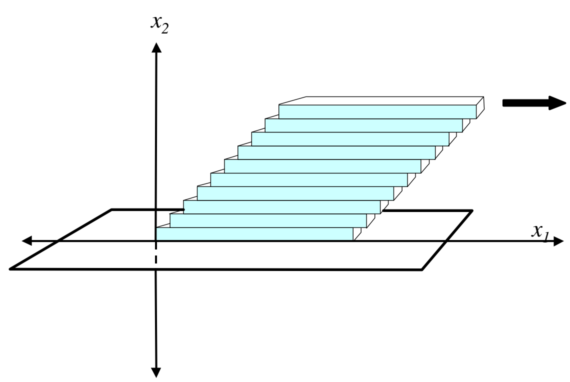


Standard Nomenclature for Shear Flow



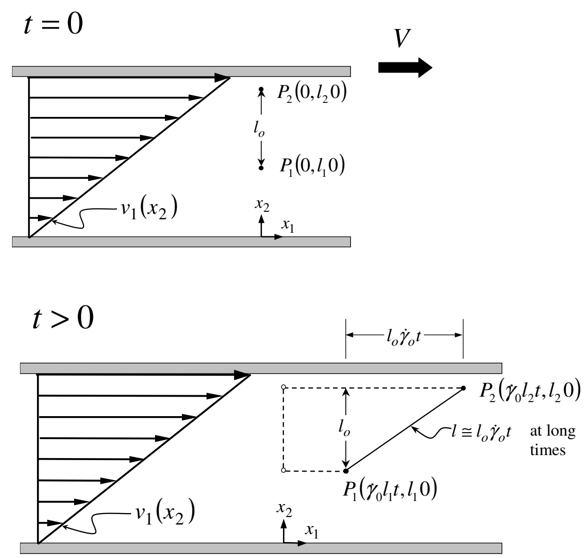
Why is shear a standard flow?

- •simple velocity field
- •represents all sliding flows
- •simple stress tensor



How do particles move apart in shear flow?

Consider two particles in the same x_1-x_2 plane, initially along the x_2 axis.



How do particles move apart in shear flow?

Consider two particles in the same x_1-x_2 plane, initially along the x_2 axis (x_1=0).

$$\underline{v} = \begin{pmatrix} \gamma_0 x_2 \\ 0 \\ 0 \end{pmatrix}_{123}$$

Each particle has a different velocity depending on its x_2 position: $v_1 = \gamma_0 x_2$

$$P_1: \quad v_1 = \gamma_0 l_1$$

$$P_2: \quad v_1 = \gamma_0 l_2$$

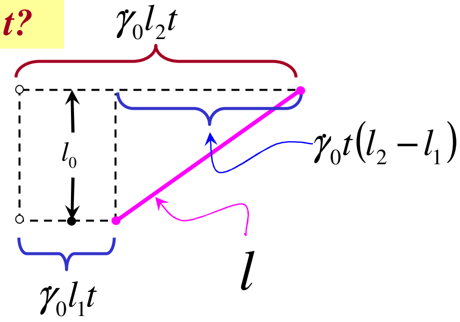
The initial x_1 position of each particle is $x_1=0$. After t seconds, the two particles are at the following positions:

$$P_1(t): \quad x_1 = \gamma_0 l_1 t$$

$$P_2(t): \quad x_1 = \gamma_0 l_2 t$$

$$location = initial + \left(\frac{length}{time}\right)(time)$$

What is the separation of the particles after time t?



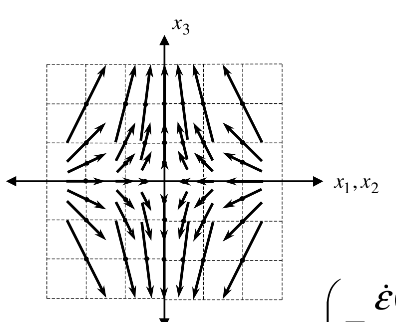
$$l^2 = l_0^2 + [\gamma_0 t(l_2 - l_1)]^2$$
$$= l_0^2 + \gamma_0^2 t^2 l_0^2$$
$$= l_0^2 (1 + \gamma_0^2 t^2)$$
$$l = l_0 \sqrt{1 + \gamma_0^2 t^2} \quad \approx l_0 \gamma_0 t$$

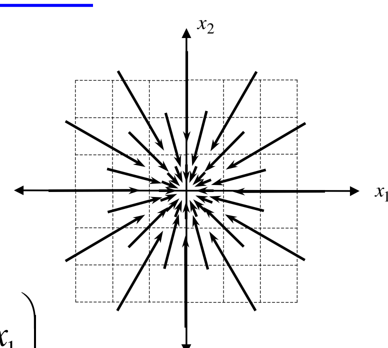
negligible as $t \rightarrow \infty$

$$l \approx l_0 \gamma_0 t$$

In shear the distance between points is directly proportional to time

Uniaxial Elongational Flow

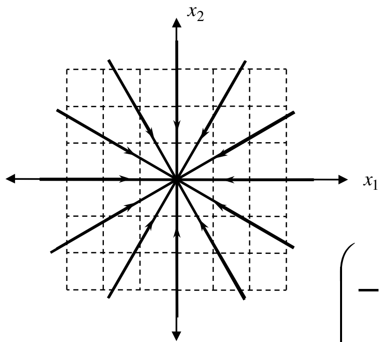


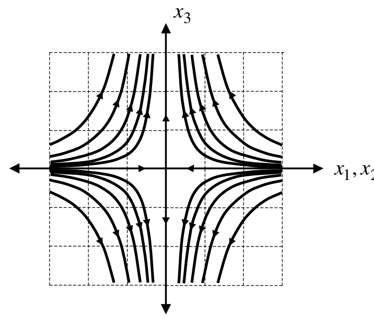


$$\underline{v} \equiv \begin{pmatrix} -\frac{\dot{\varepsilon}(t)}{2} x_1 \\ -\frac{\dot{\varepsilon}(t)}{2} x_2 \\ \dot{\varepsilon}(t) x_3 \end{pmatrix}_{123} \qquad \dot{\varepsilon}(t) > 0$$

velocity field

Uniaxial Elongational Flow

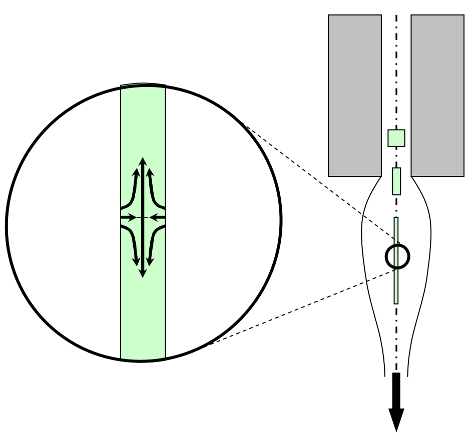


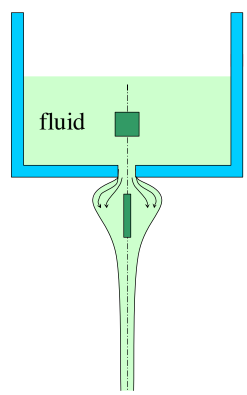


$$\underline{v} \equiv \begin{pmatrix} -\frac{\dot{\varepsilon}(t)}{2}x_1 \\ -\frac{\dot{\varepsilon}(t)}{2}x_2 \\ \dot{\varepsilon}(t)x_3 \end{pmatrix}_{123} \qquad \dot{\varepsilon}(t) > 0$$

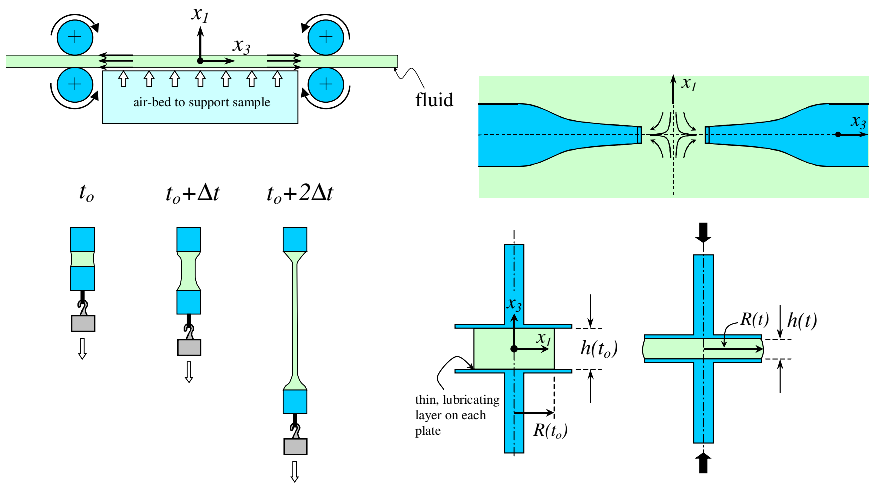
path lines

Elongational flow occurs when there is stretching - die exit, flow through contractions



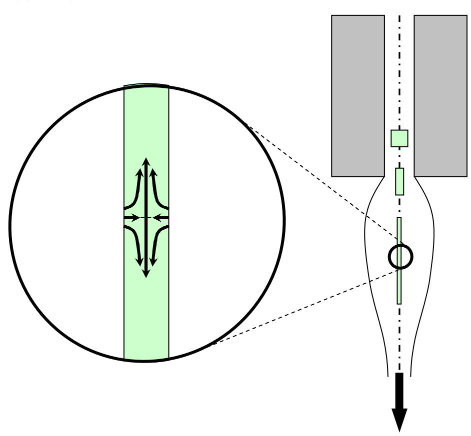


Experimental Elongational Geometries



Why is elongation a standard flow?

- simple velocity field
- represents all stretching flows
- simple stress tensor



How do particles move apart in elongational flow?

Consider two particles in the same x_1-x_3 plane, initially along the x_3 axis.