

Problem 1

To accurately characterize the dependency of viscosity with respect to shear rate in a non-Newtonian fluid, a cone and plate rheometer can be used. In this device, a small amount of the sample fluid is placed in the gap between a rotating disk and a stationary cone. The flow field is such that every element of the fluid is subject to the same shear rate.

- Think about the design features and determine which parameters influence the value of the shear rate exerted on the fluid.
- Assuming the flow is laminar, calculate the velocity profile.
- What are the limits for this apparatus?. What possible effects are we neglecting that may become important, breaking the simplicity of the design and corrupting the measurements?.

Problem 2

In intermediate size arteries and arterioles, the non-Newtonian character of blood may start to be significant, but the presence of a yield stress as modeled by Casson's equation is not yet relevant. In this situation a power law maybe give a good approximation to the viscosity of blood.

$$\mu = \mu_0 \left(\frac{dV_x}{dr} \right)^n$$

- Assuming the flow is laminar, calculate the velocity profile inside the artery.
- Find experimental data on the viscosity of blood that can be fitted to a power law and determine the range of validity of this model.
- Consider the effect of the non-Newtonian character of blood on the transition of flow to turbulence, and under which circumstances this would occur (range of flow rates, artery diameter, shear rates, pressure drops, ...)

Problem 3

If a person suffers from a congenital malformation that results in the diameter of the arteries being smaller than normal, what would be the effect on the cardiac output/ arterial pressure?. You can formulate the answer in terms of a Windkessel model for the diseased case, compared to a healthy individual. Assuming that the heart can compensate for this effect (so that the flow rate is that of a healthy person) would the flow in a given artery present a higher or lower tendency towards transition to turbulence?.

What would be more relevant to determine the whether or not flow in a given artery departs from a laminar state and reaches a regime of transition to turbulence, the peak Reynolds number or the mean Reynolds number?.