A liquid flowing in a channel has the following velocity profile:







Where z=0 is the wall of the channel (v=0) and 0.10 m is the center of the channel (v=4.5 m/min). (Note that this profile is only for ½ of the channel width, so it is symmetrical around the channel center.)

The shear stress of the fluid (kg/m-min2) has also been measured as a function of the position in the channel and is given below.







1. Using a cubic spline, model the velocity as a function of position in the channel. Provide an appropriate plot showing your model and the data.









As in the data, the velocity at the wall is zero and the highest velocity occurs in the center of the channel

1. Using your model, calculate the differential of velocity with respect to position, i.e. dVz/dz. Provide an appropriate plot of dVz/dz vs. z.

Part B



As you would expect, the highest shear rate occurs at the wall of the channel

1. Using a cubic spline, model the shear stress as a function of position in the channel. Provide an appropriate plot showing your model and the data.

Part C







As expected, the highest shear stress is at the channel wall

1. Using your models, prove /demonstrate whether this fluid behaves as a Newtonian fluid or not. Clearly explain/justify your solution using your models (provide plots, graphs, etc.) Based on your fluids class, explain the physical behavior of this kind of fluid and if possible, give examples from food/biological products.

One way to do this is to show that the viscosity is/is not constant

re-arranging the shear stress equation, u = tau/(dV/dz)



Plotting this



viscosity as a function of position in the channel



viscosity as a function of velocity



viscosity as a function of shear stress

Clearly, the viscosity is not constant, hence this is not a Newtonian fluid.

Interestingly, the model predicts that the viscosity is higher towards the center of the channel, where the shear stress is lower. This is called a shear thinning fluid (or pseudoplastic or thixotropic). This property is widely used in food products, such as ketchup or some salad dressings, where the product does not flow easily unless pressure (shear) is applied. Paints also use this property to stick to the brush but easily flow when applied to a surface.

Alternatively, and more informatively, plot shear stress vs shear rate ( tau vs. dV/dz).

If this were a Newtonian fluid, the relationship would be linear with a slope of the value of viscosity (constant). In the case given, the model almost looks like a Bingham plastic, where the material does not flow until a specific amount of stress (yield stress) is applied. Examples of this are toothpaste or a variety of biological carbohydrate polymers, such as xanthan gum.

