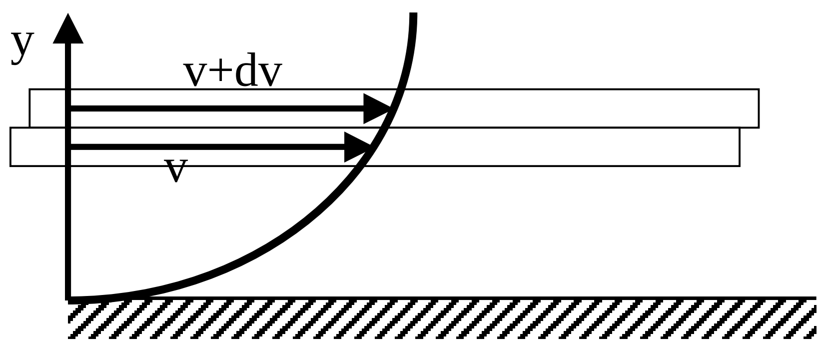
VISCOSITY

Resistance to motion in fluid.
Lets derive a mathematical description of viscosity:
Consider fluid to be made of layers. Consider motion of this fluid along a solid boundary. At the boundary fluid velocity is zero and at uppermost layer it is some finite velocity. (no slip condition) "velocity gradient" exists across distance y.



Strain = $(d_2 - d_1)/dy$
Where displacement, d=velocity X time

Hence, $$strain = \frac{dv\,dt}{dy} = \frac{dv}{dy}dt$$

And $$strain\,rate = \frac{dv}{dy}dt\frac{1}{dt} = \frac{dv}{dy}$$

For many fluid the sthear stress between layers, τ

$$\boxed{\tau = \mu\frac{dv}{dy}}$$

where μ is "coefficient of viscosity" or "viscosity", "dymanic viscosity", "absolute viscosity"
So, basis of viscosity is "fluid friction"
Note: if dv/dy =0, shear stress = 0

In the fluid where does viscosity arise from?

1. **Attraction between molecules (cohesion)**

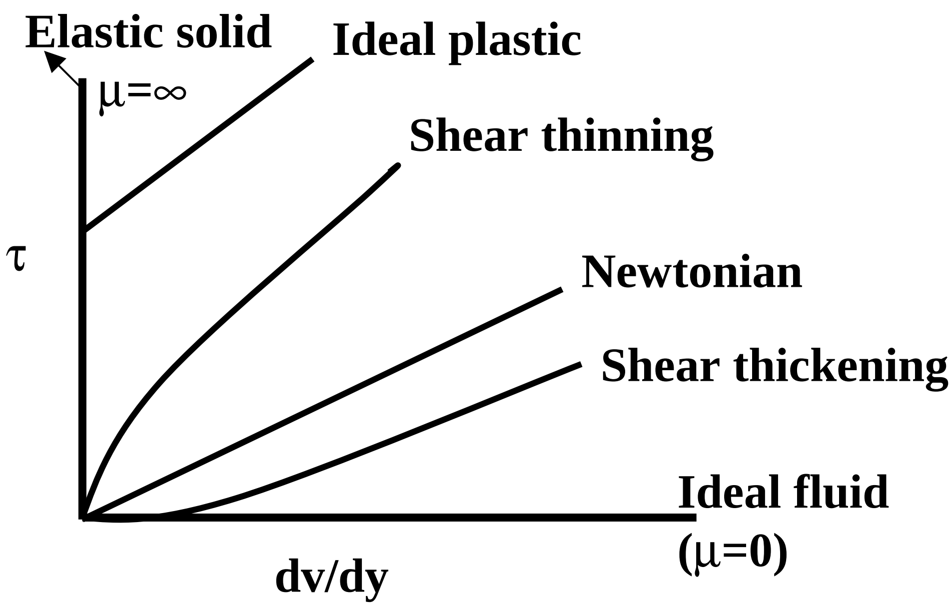
2. **Molecules in one layer move to another layer constantly. So molecule from slow layer moving to fast layer slows the layer and vice versa: momentum exchange occurs between the layers**

Notice: since $\tau = \mu \, dv/dy$
In solids, shear stress α magnitude of deformation

In fluids, shear stress α rate of deformation

Now lets plot shear stress vs dv/dy for different fluids

$$\tau = \mu \frac{dv}{dy}$$



Types of fluids depending on the shape of above plot

Newtonian: viscosity does not change with deformation
Non newtonian: slope is not a straight line

Shear thinning: slope decreases with deformation
("fluid gets thinner with shear")pseudoplastic

Shear thickening: slope increases with deformation
("fluid gets thicker with deformation) Dilatent

Ideal plastic: sustains stress before suffering plastic flow.

Applications of Non Newtonian:

Concrete flow in pumps
Polymer industry
Paints
Ceramics industry

Units of viscosity

Since τ=μ dv/dy, μ=τ/(dv/dy)

Units of m: Poise , 1 P = 0.1 Ns/m^2
CentiPoise, 1 cP = 0.01 P
Viscosity of water at 68.4 °F is 1 cP

Dimensions of μ:
=dimensions of shear stress/dimensions of dv/dy

$$= \frac{MLT^{-2}L^{-2}}{LT^{-1}L^{-1}} = \frac{ML^{-1}T^{-2}}{T^{-1}} = ML^{-1}T^{-1}$$

Define: Kinematic Viscosity: ν = μ/ρ

Unit of ν : ft^2/s or m^2/s commonly used: Stoke,
1 St = 1cm^2/s, 1 cSt = 0.01 St
Dimensions of ν : L^2T^{-1}

Variation of Viscosity with temperature and Pressure

μ is independent of pressure, ν varies with pressure

Both μ and ν vary with temperature