SECTION OVERVIEW

20.4: Viscosity

Consider a river flowing over a smooth bed, as in Figure XX.9.

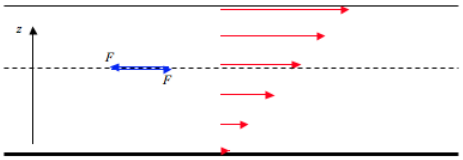

FIGURE XX.9

There will be a *transverse velocity gradient* dv/dz, with the liquid stationary at the river bottom, and the speed becoming faster as we ascend from the bottom. As a consequence of the transverse velocity gradient, the liquid below the dashed line will be dragged forward by the tangential force of the faster liquid above it, and the liquid above the dashed line will be dragged backward by the tangential force of the more sluggish liquid below it. The ratio of the tangential force per unit area to the transverse velocity gradient is called the coefficient of *dynamic viscosity*, for which the usual symbol is η. The dimensions of dynamic viscosity are $ML^{-1}T^{-1}$. The CGS unit of dynamic viscosity is the *poise*. The abbreviation for the unit is P – though it would be well to define it if you use it, since not everyone will recognize it. The unit is named after a nineteenth century French doctor, Jean Poiseuille, who was interested in blood pressure and hence in the rate of flow of liquids through tubes. That is to say, if, for a transverse velocity gradient of 1 cm s^{-1} per cm, the tangential force per unit area is 1 dyne cm^{-2}, the dynamic viscosity is one poise. The SI (MKS) unit is the decapoise (also spelled dekapoise), though the SI unit the pascal second (Pa s), which is dimensionally correct, is also seen. If, for a transverse velocity gradient of 1 m s^{-1} per cm, the tangential force per unit area is 1 N m^{-2}, the dynamic viscosity is one decapoise. The dynamic viscosity of water varies from about 1.8 centipoise at 0○ C to about 0.3 centipoise at 100○C.

The ratio of the coefficient of dynamic viscosity to the density is the coefficient of *kinematic viscosity*, for which the usual symbol is the Greek letter ν. The dimensions of kinematic viscosity are L^2T^{-1}. The CGS unit of kinematic viscosity is *the stokes* (abbreviation St). It is named after nineteenth century British physicist, Sir George Stokes, who made major contributions to diverse areas of physics. The SI unit of kinematic viscosity is usually given simply as m^2 s^{-1}, and 1 m^2 s^{-1} = 104 stokes. The kinematic viscosity of water varies from about 1.8 centistokes (1.8 - 10^{-6} m^2 s^{-1}) at 0○ C to about 0.3 centistokes (3 - 10^{-7} m^2 s^{-1}) at 100○C.

Hydrodynamics is a huge and very difficult subject (at least I think it is), but there are a couple of simple problems that, if nothing else, make good homework problems. These are Poiseuille's law and the Couette viscometer.

Topic hierarchy