The viscosities of Earth materials largely control mantle convection and therefore volcanic activity, heat loss from the interior, and plate tectonics; how volcanoes erupt and how far lava travels; and the shapes of landforms created through weathering, to give a few examples.

More importantly, and less intuitively, at high pressures solid materials can flow like fluids rather than breaking in a brittle manner. The interior of the Earth is known to behave this way: The Earth's (and Mars' and Venus') mantle is solid, but because of high pressure and temperature it flows as a fluid over geologic time. On a large scale, it is usually thought of as a fluid with a very high viscosity.

Viscosity in SI is measured in units of $Pa \cdot s$, or Pascal-seconds, which are $\frac{kg}{m \cdot \sec}$. If a fluid with a viscosity of one Pa·s is placed between two plates, and one plate is moved laterally with a shear stress of one Pascal for the time interval of one second, the plate moves a distance equal to the thickness of the fluid layer. The cgs unit for viscosity is the poise, which equals $0.1 * Pa \cdot s$. Thus ten poise make a Pascal-second.

Stokes law, derived by George Gabriel Stokes around 1850, describes the velocity of a sphere sinking or rising through a viscous fluid under the influence of gravity. Because it has a simple formulation it is often used to measure viscosities of fluids in labs.

The original formulation of Stokes law simply described the force needed to drive a sphere through a quiescent, continuous, viscous fluid is

$$F = 6\pi r v_S, \qquad 1.$$

where a sphere of radius r is moving with velocity v_S. This law can be rewritten as

$$v_S = \frac{2\left(\rho_{solid} - \rho_{liquid}\right) g r^2}{9\eta} \ \frac{m}{s}. \qquad 2.$$

to describe how a sphere moves under the influence of gravity. The velocity of the sinking (or rising) sphere, therefore, is directly controlled by its density and that of the fluid, gravity, the radius of the sphere (all measureable), and the fluid viscosity, which we would like to know.

Equation 2 can be solved for viscosity:

$$\eta = \frac{2\left(\rho_{solid} - \rho_{liquid}\right) g r^2}{9 v_S} \ Pas. \qquad 3.$$

By measuring the velocity of the sinking sphere using a ruler and a stopwatch, this equation can be used to calculate the viscosity of the fluid.

Note for advanced users:

Our spheres are not sinking through a continuous fluid, though, and nor do they have an infinite distance to sink. Stokes velocity can be tempered for edge effects, which are a critical consideration in all fluid tank experiments. Experimentalists have found that the best correction for edge effects is called the Faxon correction, as follows:

$$\eta = \left[\frac{2gr^2\left(\rho_{solid} - \rho_{liquid}\right)}{9v_s\left(1 + \frac{3.3r}{h_c}\right)} \right] \left[1 - 2.104\left(\frac{r}{r_c}\right) + 2/09\left(\frac{r}{r_c}\right)^3 - 0.95\left(\frac{r}{r_c}\right)^5 \right] \text{poise}, \qquad 4.$$

where rc is the radius of the container, and hc is the distance the sphere sinks.
Note: this equation is written for cgs units, NOT SI units.