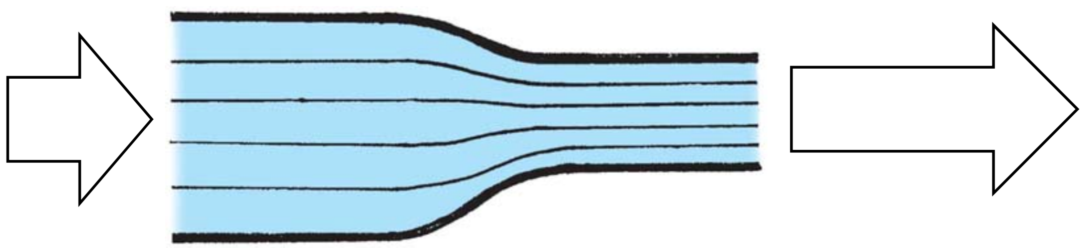
PHYS:1200 LECTURE 15 – FLUIDS (4)

In this last lecture on fluids we will discuss some of the applications of Bernoulli's principle and two additional properties of fluids – viscosity and surface tension.

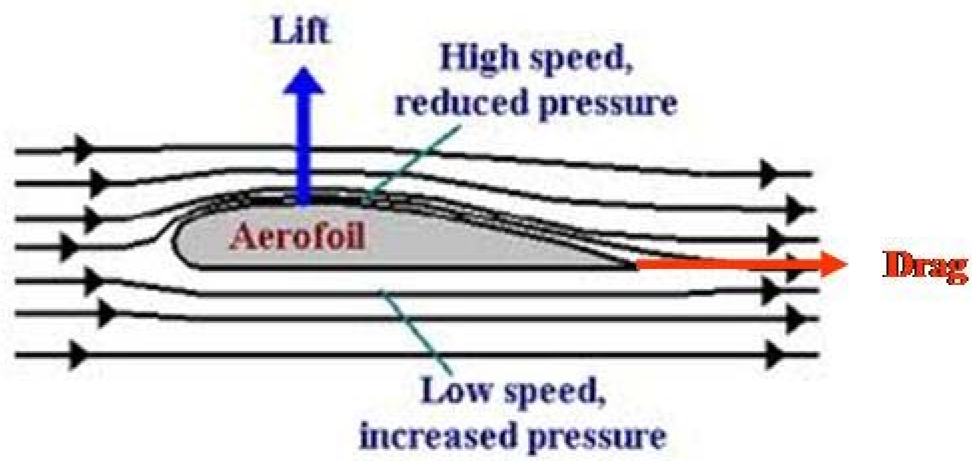
15-1. Applications of Bernoulli's principle.—Bernoulli's principle was introduced in Lecture 14. It states that there is a relation between the flow speed of a fluid and its internal pressure. **The pressure in a moving fluid is lower than if the same fluid were at rest.**

Fluid flow is best visualized using the construction of **streamlines**. In steady flow, one small piece of a fluid follows along the same path as the piece of fluid in front of it. We say that the motion of a fluid follows these streamlines of the flow. **The streamlines are the smooth paths followed by the small pieces of fluid.** An example of the streamlines of a fluid flowing through a pipe with a constriction is shown below. The streamlines are the thin black lines. Notice that



necessarily, since all the fluid entering the left side must exit the right side, the streamlines are bunched together in the constriction. Recall that the continuity principle requires that the fluid must flow faster in the constricted region, then, according to Bernoulli, the pressure of the fluid in the constricted region must be lower because the fluid speed is higher there. **So we can associate the bunching of the streamlines with higher speed flow and therefore lower fluid pressure.**

The figure below shows streamlines for an airplane wing. The shape of the wing and the angle of attack of the wing with the horizontal direction cause a bunching of the streamlines on the upper side. The bunching of the streamlines indicates that the air flow past the upper side of the wing



is faster than on the lower side, so that according to Bernoulli, the air pressure will be lower on the upper side compared to the pressure on the lower side**. The higher pressure on the lower side is what provides the lift force which keeps the plane up in the air**. [Of course, the plane is moving with respect to the air, but from the frame of reference of the wing, the air is flowing past it.] **Slides 12 and 13** explain how these ideas apply to a non-spinning or spinning baseball, and thus how a curveball curves.

15-2. Properties of Real Fluids.— Thus far, we have implicitly been discussing "ideal fluids" – fluids which flow without any resistance to the flow.

a. Viscosity.—Real fluids have a property called **viscosity which is the tendency of the fluid to resist flowing**. For example, we have all experienced the fact that a "thick" liquid like ketchup or pancake syrup does not flow as easily as water. This is because syrup and ketchup have higher values of viscosity than water. The viscosities of various substances are listed on **slide 17**. **The viscosity of a fluid depends on its temperature** and for most liquids, its viscosity decreases as its temperature increases. **Slide 19** shows an experimental arrangement that can be used to determine the viscosity of a liquid.

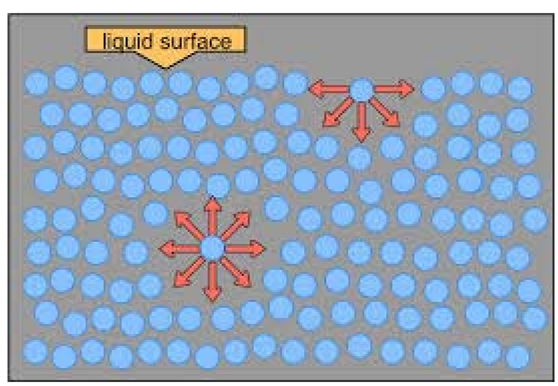
Viscosity plays a very important role in determining the flow rate of a liquid in a pipe, or blood through an artery. The formula for the volume flow rate of a liquid through a pipe is

Poiseuille's law	$Q_V = k\dfrac{(P_2 - P_1)D^4}{\eta L}$,	[1]

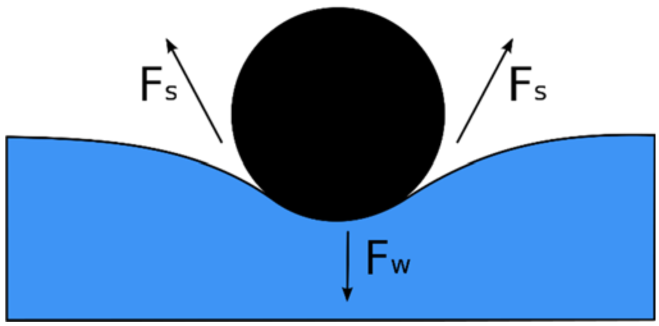
where $P_2 - P_1$ is the pressure difference across the ends of the pipe which has a length L and diameter D. The viscosity of the liquid is given by the symbol η, and k is a constant. Notice that: (a) the flow rate is directly proportional to the 4th power of the diameter, and inversely proportional to the viscosity. For the same values of the other parameters, a pipe having twice the diameter of another pipe, has a flow rate that is 2^4 = 16 times as large; and (b) a fluid with a higher viscosity flows more slowly than one with a smaller viscosity (the viscosity is in the denominator of the formula). The fact that the flow rate depends on the diameter to the 4th power is particularly significant for clogged arteries. Even a small obstruction of an artery can produce a critical drop in blood flow.

*b. Surface tension.***—**The photo on the right shows a paper clip resting on the surface of water. Paper clips are made of steel and do not float in water so the force which suspends the paper clip is not a buoyant force. What is the origin of this force? The force responsible for preventing the paper clip from sinking is called surface tension. Surface tension is an attractive force between the molecules at the surface of a liquid. Any portion of a liquid surface exerts a tension upon adjacent potions or upon other objects with which it is in contact.

The origin of the surface tension force is illustrated in the diagram to the right. The molecules in the liquid exerts attractive forces on each other. A molecule in the body of the liquid is attracted to all the molecules surrounding it, so that the net force on a particular molecule is small and there is no tendency for a given molecule to be pulled in any particular direction. However a molecule at the surface has no molecules above it, so there is a



net force on the molecules at the surface. This is the microscopic explanation of surface tension. The surface tension force also allows insects to sit on the surface of a puddle of water. The indentation of the water surface by the feet of the insect produces an upward component of surface tension which balances the weight of the insect or the paper clip shown above.



Surface tension also causes liquid droplets to be spherical, and it is the force responsible for the formation of bubbles, and the reason why bubbles tend to clump together, and why water tends to coalesce into beads on surfaces.