A) Complete the blanks:

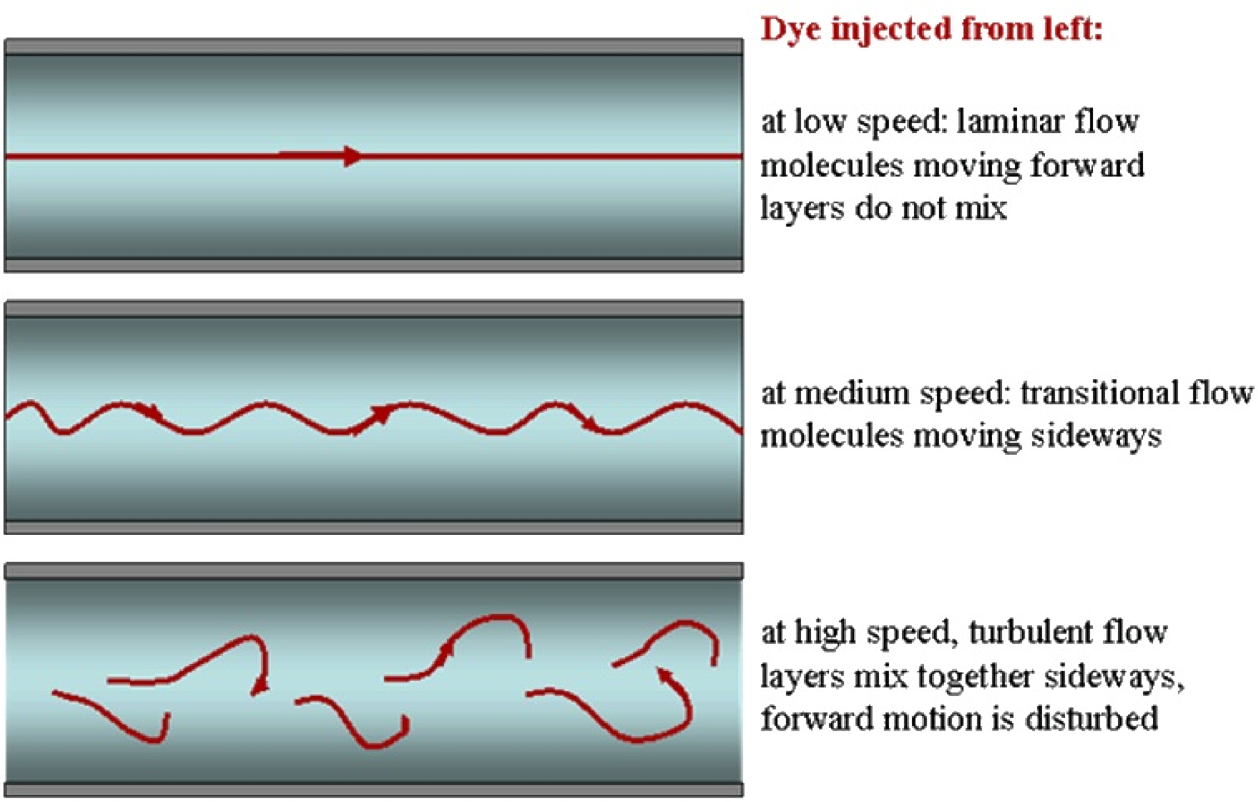
1. The branch of physics that studies fluids in motion is known as ____________________.

2. ____________ occurs when a fluid is not moving smoothly around an object or in a pipe.

3. A moving fluid that experience a lot of turbulence is said to be going through __________ flow.

4. Fast cars and planes are shaped in such a way as to minimize ____________________.

5. What do animals like the cheetah (one of the fastest mammals), birds and fish, have in common? Hint, do a quick research on "aerodynamic shapes occurring in nature" [look it up on the Internet or on an encyclopaedia, or pay a visit to the zoo.



Viscosity of fluid:

Other observations show that, in addition to speed, viscosity of the fluid is also a major factor in determining fluid flow. Viscosity describes the 'stickiness' of a fluid; thick ketchup and molasses are more viscous than water - they are 'thicker' than water and pour less readily. As it turns out, the more viscous a fluid, the smoother the flow.

Viscosity is sort of like the 'friction' among the particles in the fluid itself - the 'friction' between one molasses molecule and its neighbouring molasses molecule, for example. The more viscous a fluid, the greater friction there is between layers of the fluid, and the more force required to slide into a neighbouring layer's path. Since it is more difficult for viscous fluids to interfere with adjacent layers, there is less chance of turbulence in viscous fluids.

Review Questions:

1. The image shown here is that of the cross section of an airplane's wing. Use a sketch to illustrate how air (or another fluid) would flow around the wing in: *(Drawing by L. Lista)*
(a) laminar flow and (b) turbulent flow

2. What does the term *viscosity* mean?

3. Car engine oils are classified according to their viscosities; an example is **10W-40**. Look up on the Internet or ask your mechanic about the meaning of these numbers and how different viscosities of oils affect the engine performance and why.

4. What factors determine the way fluids flow in and around objects?

5. Explain in your own words why liquids moving through pipes in laminar flow are moving faster towards the middle of the pipe than closest to the walls of the pipe.

Terms:

Fluid dynamics: the study of the motion of fluids and the factors that affect that motion

Laminar flow: the motion of a moving fluid in which the layers of fluid move forward smoothly with no mixing or interference

Turbulent flow: the motion of a moving fluid in which layers of fluid mix, disrupting the forward movement of the fluid

Viscosity: the "stickiness" of a fluid, describing its resistance to flow; a viscous fluid is thick and slow flowing

Factors that affect fluid flow:

Speed: with greater speed, there is greater turbulence

Viscosity: with greater viscosity, there is less turbulence

Drag and Streamlining:

Drag: the forces that resist the motion of an object through a fluid

Streamlining: the process of minimizing drag by design features in structure, materials, function

In the last section, we discovered that as fluids reach high speeds, flow becomes turbulent. The same turbulence results when an object moves at high speeds through a fluid - the object encounters turbulence, which produces drag. Drag is the frictional force that is acting against your motion; you can feel this drag when you walk upright through chest high water. To move more efficiently through the water, you need to make yourself more streamlined, by making yourself horizontal and pointy at both ends - like a torpedo. Streamlining refers to anything that we can do to reduce turbulence in a fast-moving object by changing the shape, the surface, the material, etc.

We see examples of streamlining in cars and trucks - wedge-shaped fronts and rears, spoilers and hoods. We sometimes learn from natural streamlined designs - a study of sharkskin, for example, revealed tiny grooves parallel to the direction of water flow. We previously thought that perfectly smooth surfaces minimize drag, but it appears that microscopic grooves insert a thin layer of air that separates the water from the skin, reducing drag from the water. This finding has been used in new materials used to make swimsuits for competitive swimmers - a proud Canadian invention.

Let's examine the design of a racing bike as an example of streamlining. You can see many of these bicycles at road races and triathlons, and, of course, at the Tour de France each summer, if you happen to be in Europe. Indeed, if you are at the Tour de France, there are numerous physics concepts to be thinking about while you enjoy the croissants.

When you ride a bicycle, you are pushing against the ground and against the air. For most common bikes, the drag from the air is significant even at low speeds - at about 12 km per hour, the air drag is equal to the ground resistance. At about 30 km/h, the air drag is four times the ground resistance. So we're spending a great deal of energy fighting the air.
What is the biggest obstacle hitting the air? Yes - the rider. Since we're essentially "swimming" through the air, we need to take a streamlined position - like we would in the water. By just crouching in a **racing position**, the biker can reduce drag by about 30%. To accommodate this position, the bike needs redesigned handlebars that keep the biker's head low and the back straight.

We also want to streamline the biker's head - more like a fish head! Smooth pointy helmets of many shapes are available; they are designed to achieve a fish-like profile when worn in the crouched position. The **helmet** also protects the racer in the event of an unexpected encounter with the hard gravel road.

The bicycle **frame** itself, although narrow and thin, can be improved. The main goal is to keep the air flow laminar, not turbulent. Any obstruction causes the air flow layers to separate; the narrower the obstruction, the less separation there is, and the sooner the air layers can reunite behind the obstruction. One of the design features to streamline the bicycle frame is the use of oval tubing instead of round tubing. Also, the amount of frame tubing can be minimized by eliminating the crossbar, the seat tube, and some of the parts holding the bike chain.

The **wheels** of the bicycle go round and round, and as they do, the spokes separate the air flow. This causes turbulence and drag. To decrease the path of air layers in and out of the spinning spokes, wheels have been designed with only a few spokes, or with no spokes at all! Solid disk wheels eliminate any drag from spokes but add unwelcome weight to the bike. Newer lighter materials offer new possibilities in wheel design and a lot of research goes into these high-priced racing machines.

The most successful racers take advantage of their bike team to provide the best aerodynamic race conditions- a method called **"drafting"**. When the riders on a team ride in a pack, the rider in the front faces the air flow head on and takes the brunt of the drag. Riders in the middle of the pack suffer less resistance and can save energy. Riders on the team take turns in the lead, allowing the entire team to travel more efficiently. At just the right time, the selected team member can sprint ahead to win the race. That's team work!

Fluids Speeding Up

How do airplanes stay up in the air? They seem to defy gravity. No matter how hard we flap our arms, we have trouble staying afloat in the air, and we weigh nothing compared to a 747.

Well, let's take a look at how air flows around an airplane, and see how the air is lifting the plane. There are two main ideas to understand: *air speed* and *air pressure*. More importantly, we'll find out how air speed and air pressure are related to each other. In this section, we will look at **air speed**.

Questions: *Have you ever played with a garden hose and squirted a friend?*

What happens to the speed of the water as you change the size of the nozzle? Does the water travel a greater distance?

The diagram below shows how the speed of air flow is changed if we change the area through which the air can flow.

1. First, starting from the left of the diagram, air is flowing through a very wide pipe, at a certain 'slow' speed.
1. Then, the pipe splits into two halves. The bottom half continues as half the pipe, not changing the path width of the air in it. The air in this half continues at the 'slow' speed.
3. A change happens in the top half of the pipe. The pipe narrows.

Now, the air from the starting pipe has to 'squeeze' into a smaller area of the pipe.

The problem with this is that the air behind is not slowing down; it keeps pushing forward.

The same amount of air has to go through both halves.

The air in the upper half has to travel a greater distance in the same amount of time, to keep up with the oncoming air from behind.

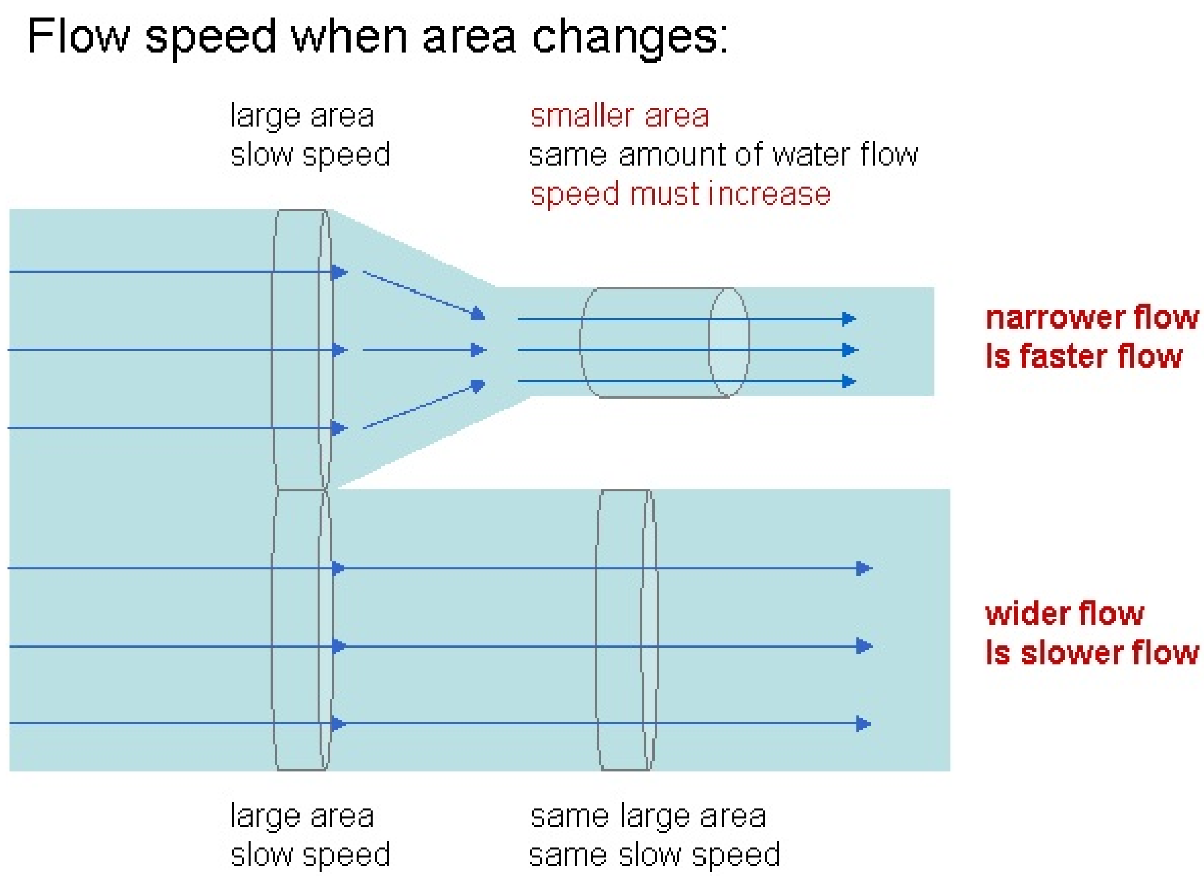
So the air in the narrow upper half has to move quicker than the air in the wide bottom half. *The narrower flow needs to have a faster flow rate*.

Does that make sense?

SKIP TO PICTURE

We can use an analogy for the diagram above. Perhaps you have driven on a multi-lane highway. What happens when six lanes have to squeeze into three lanes? In real life, there's a huge traffic jam and many unhappy commuters. Well, there is a way of avoiding this type of frustration. What is causing the gridlock is the numerical fact that the same number of cars from six lanes now has to fit into three lanes, so they are taking up more car lengths in each lane. That's what's holding up the traffic flow. To keep the traffic at the same speed, every car in the fewer lanes must drive twice as fast! It's that simple.

Next time you're in a traffic jam because of a narrowed highway, remember this lesson and step on that gas pedal. However, you may have trouble explaining your actions when you're pulled over by the highway patrol.



Terms you should know by now.... (Please note: you may need to refer back to previous activities to review some of these terms):

1. Define each of the following terms and name an application or device that uses it:

a) Pressure b) Pascal's Principle c) Hydraulic Press

d) Laminar Flow e) Turbulent Flow f) Streamlining

g) Viscosity

2. Write a brief paragraph (or two) using proper terminology and diagrams to explain how an airplane wing (also known as an aerofoil) develops lift and drag (you may need to do further research using the Internet or an encyclopaedia).

3. A Bunsen burner is a very common device used in a scientific lab. This device uses the principle that as the pressure on a fluid decreases, its speed increases. Research on the Internet and explain using drawings how a Bunsen burner (or a blow torch) works.

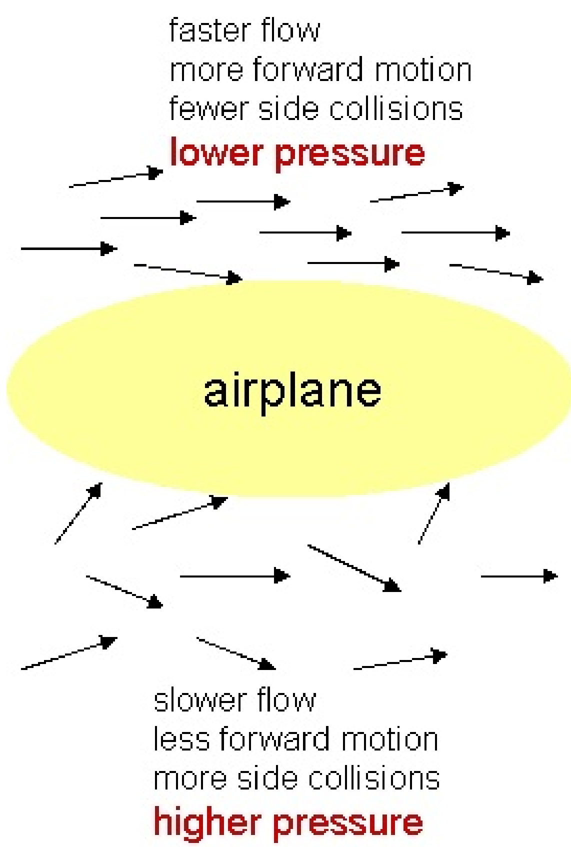
4. Find out what a sonic boom is. How does the creation of a sonic boom relate to objects moving through fluids?

5. What is a wind tunnel?

Pressure When Fluid Speeds Up

In the previous activity, we discussed how fluids move in and around objects and how the [pressure is related to the speed of a fluid](). Now let's see what happens when fluids speed up. Since we're talking about airplanes, we'll talk about air as an example of a fluid.

We know that the only thing that is holding up that tonne-of-steel airplane is air, just air. The molecules that are in the air are constantly moving in all directions, colliding with anything in its path. It is these collisions that are holding up that plane. Air travelers are advised to not think about this fact while seated in their window seat, looking out on the magnificent Rockies down below.



What we find, when we measure these things, is that **faster moving air exerts less pressure**, and, of course, **slower moving air exerts more pressure**. We use this fact to lift our airplanes up.

First, let's see if we can explain this observation.

The **pressure** of a fluid is a measure of all the **collisions** of the fluid on a surface.

When a fluid is **moving slowly**, the particles are together moving forward, but there is more tendency for each individual to have some *sideways* movement. This results in *more sideways collisions* on the plane. We call this **higher air pressure**.

When a fluid is **moving quickly**, there is more forward motion as a whole, and there are fewer individual sideways collisions on the plane. We call this **lower air pressure**

Bernoulli's Principle

Where fluids are moving slowly, the fluid pressure is high.

Where fluids are moving quickly, the fluid pressure is low

Combining Fluid Speed and Pressure - Bernoulli's Principle

A Swiss scientist named Daniel Bernoulli spent a lot of time studying fluid dynamics, and we have him to thank for many "uplifting" applications - from ski jumping to baseball curve balls... and, of course, airplanes. His conclusions are stated as Bernoulli's Principle.

In order to get 'lift', we want more pressure under the plane than above the plane. To achieve this a special wing design is required – one that forces the air flow to be faster above the wing.

How do we make the air flow faster above the plane than beneath the plane?

We design this shape for the wings of the plane: *the top of the wing is more curved than the flatter underside*:

· this forces oncoming air to travel a greater distance over the wing;

· as a result, the air must flow more quickly over the top, to keep pace with the rest of the air;

· when the upper air flows more quickly, it exerts less pressure on the wing beneath it;

· the underneath air flows more slowly, and therefore exerts greater pressure upward on the wing above it;

· the difference between the pressures below and above the wing provide the 'lift' that pushes the plane upward – amazingly with enough force to counter the enormous weight of the aircraft.