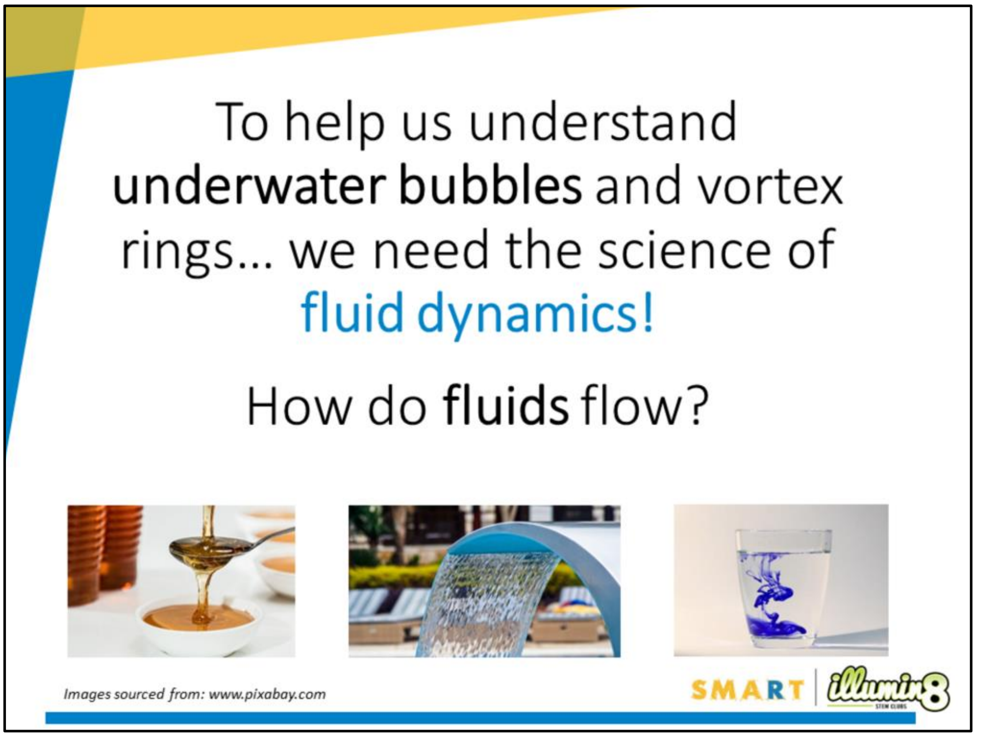
Welcome back, and welcome to new participants!
In Module 1.1, we started to explore the science around air, aerodynamics, and the forces of flight.
In Module 1.2, we looked at the science around rockets and the laws of motion. Our experiments looked at how objects move in air.
In this module, we'll explore the movement of air itself!

Lets have a look at a video to see some interesting underwater bubbles, a type of vortex ring.
A **vortex ring** is a is a swirling parcel of fluid, sometimes seen as a “bubble ring” in water, or a smoke ring in air.

Ask students if they can think of anywhere they might see vortex rings in nature, in water, or in air?
Examples:
1. Dolphins, beluga whales and humpback whales animals like whales blow bubble rings. Dolphins sometimes appear to create them on purpose to play.
2. Some scuba divers and free divers create bubble rings by blowing air out of their mouths in a particular manner (like in the video).
3. A vapour ring in the air can be formed on a cold day by blowing air out of your mouth.
4. Under particular conditions, some volcano’s produce large visible smoke rings, though this is very rare.

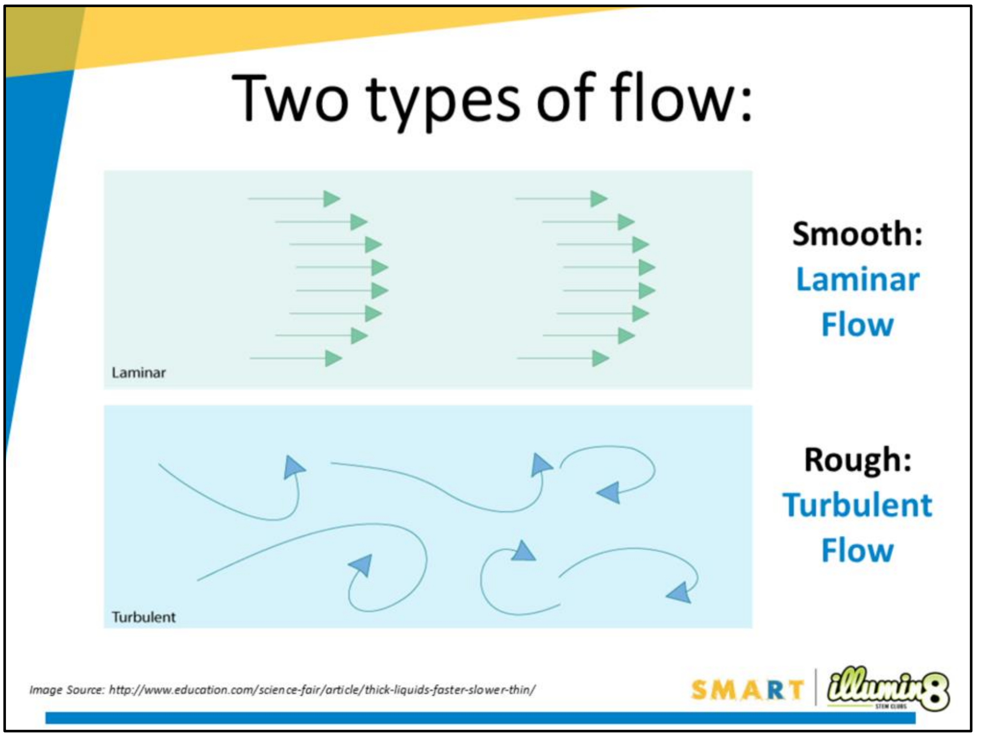
http://www.abc.net.au/science/articles/2014/04/11/3978532.htm
http://mpegmedia.abc.net.au/science/articles/mp4/bubblerings.mp4



In physics and engineering, **fluid dynamics** describes the **flow** of **fluids** (fluids are liquids **and gases**).

Ask students what different types of fluids, or liquids, they can think of.
Examples: Water, honey, oil, dishwashing liquid, milk, juice etc.
Discuss with students how different liquids flow. Do all liquids flow the same way? Different liquids flow with different speeds. Their speeds can be compared in a runniness test. We could compare how fast different liquids flow under the same circumstances, perhaps by letting them flow down a ramp and timing how long they take to reach the bottom.
Discuss which fluids might win a runniness race down a ramp – would water beat honey?

What does **Fluid Dynamics** have to do with air? The air around us is made up of different gases.
When speaking about fluids today, we are referring to both gases and liquids. The motion of gases and liquids are very similar, so they can both be categorised as fluids



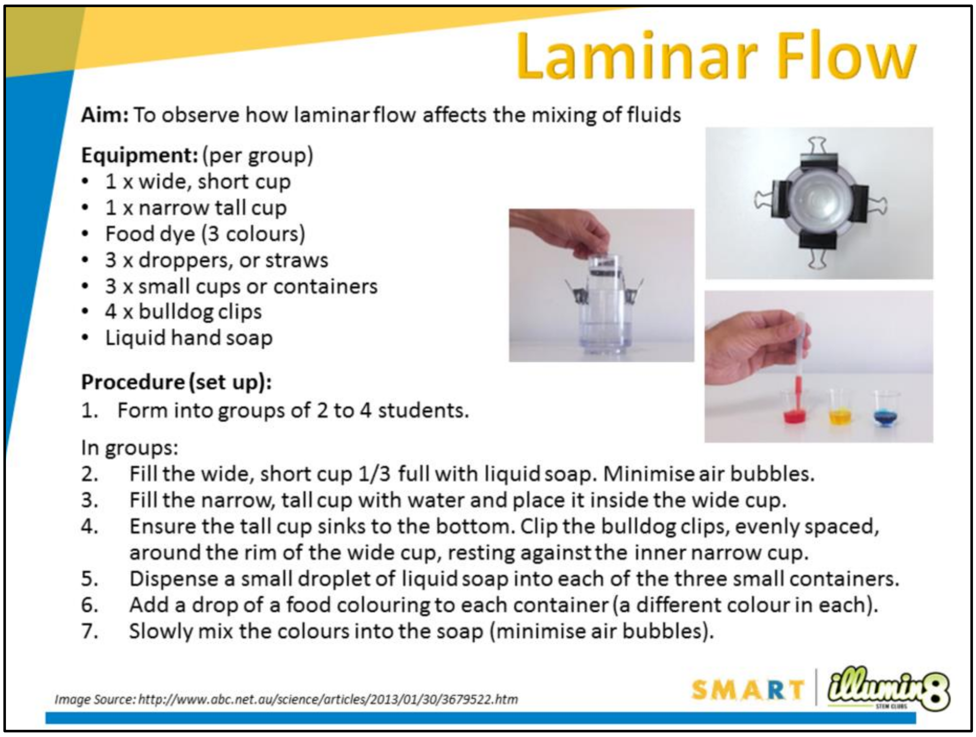
When we look at how fluids flow, or move, they can either move: Smoothly (**laminar** flow) or Roughly (**turbulent** flow).
Ask students what smooth (laminar) flow might look like, compared to rough (turbulent) flow.

Laminar flow is when each particle of the fluid follows a smooth path, and these smooth paths never interfere with, or mix with each other. Each particle of fluid moves at the same speed in the same direction. Paths of continuous flow can be called ‘streamlines’. They can be curved or straight.

In turbulent flow, fluid particles move in different directions at different speeds, mixing with and disrupting each other. The flow pattern of fluid particles is very chaotic and often forms whirlpool-like circles, called eddies.

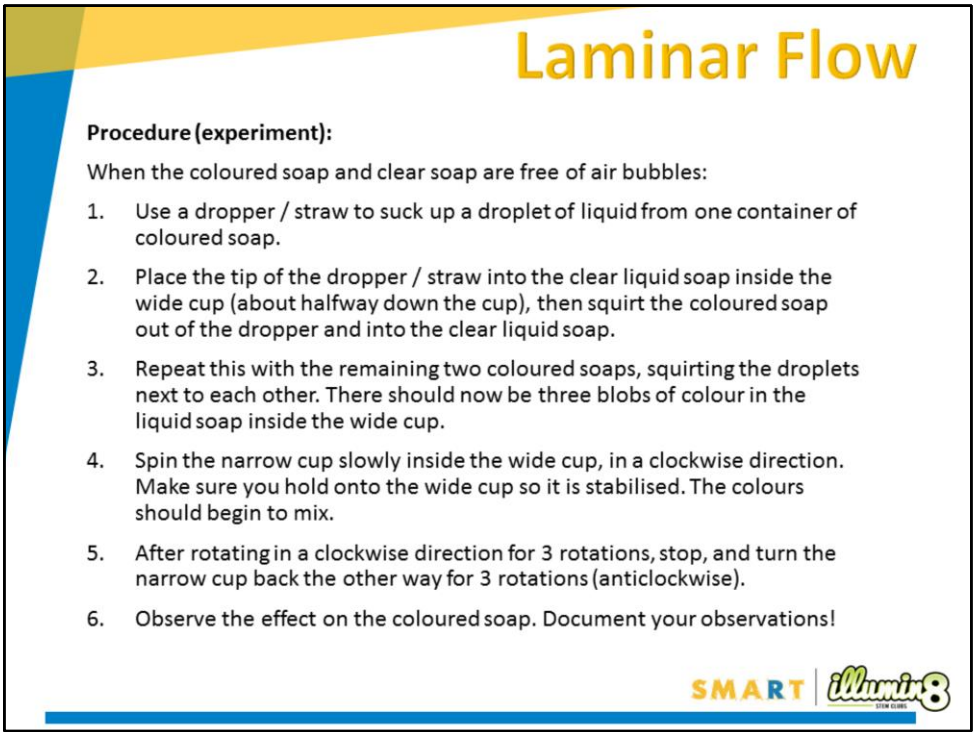
Most kinds of flow found in nature are actually turbulent!
Turbulence is commonly observed in everyday phenomena such as wind, surf, flowing rivers, or smoke from fires and chimneys.

The different types of flow are useful in different situations.
Ask students why understanding how fluids (liquids and gases) flow might be useful?
Examples:
1. A laminar (smooth) flow is useful in pipes so the fluid moves through the pipes uniformly without wearing down certain parts of the pipe.
2. Turbulent flow is useful when we want to mix things up! For example at water treatment plants, turbulent flow can help mix the waste and treatment chemicals.
3. Understanding turbulent air flow also helps us to design planes to travel through turbulence.
Let’s do an experiment to see if we can observe laminar flow!



Refer to RISK ASSESSMENT for Module 1 before conducting experiment.
Refer to Experiment notes (E1.3.1 in Coordinator Notes for Module 1.3)

Encourage students to form a hypothesis about what might happen to the coloured droplets, before commencing the experiment.



Tips: The students need to keep their inner, narrow cup in the centre of the wide glass, and keep it as stable as possible.

Encourage the students to spin their inner cup **very gently and slowly**, especially when it comes to reversing the direction of spin.

Ask the students if they proved or disproved their hypothesis.

Discuss that the experiment is only possible as the flow is laminar (smooth planes of fluid moving over each other).

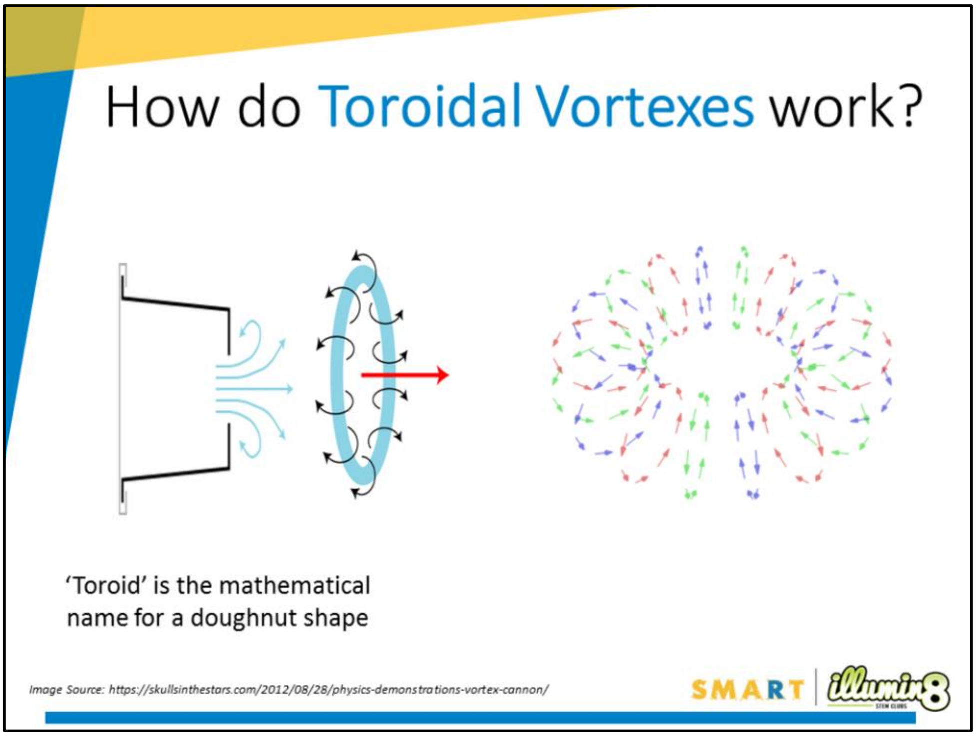
If you look down into the space between the outer and inner glass after the clockwise rotation, you will notice that the blobs are not really "mixing" together. Each one is actually dragged out to form a spiral.

This experiment is known as the “unmixing demonstration”, first published in the April 1960 edition of the American Journal of Physics by an oil industry scientist called John P Heller.

Turbulent flow can cause vortices to form in both liquids and gases.
A vortex is formed when a fluid swirls around a central point.

Vortices can occur in nature as well as from man-made things.
Whirlpools and tornadoes are two familiar types of funnel shaped vortexes (or vortices).
You can see vortices when water goes down the drain.
Volcanic eruptions can also cause vortexes in the form of steam rings.
Vortices can travel long distances before they are disrupted.

(Image of volcanic steam ring copyright Dr Jurg Alean and Dr Marco Fulle, stromboli.net, educational usage permitted.)



The proper name for a bubble ring, smoke ring or steam ring, is a **toroidal vortex.**

They are circulating rings of fluid.

'Torus' is the name for the shape of a doughnut or a ring.

'Toroid' is the mathematical name for a doughnut shape.

How are they formed?

A toroidal vortex is a rotating body of fluid, moving like a wheel along the ground.

Toroidal vortices form due to a complicated combination of friction and pressure.

When fluid is forced out of a small round hole, the edges of the fluid are dragged backward by the friction from the still fluid beside it.

This friction makes it continue to circulate, forming a toroidal vortex.

Let's do an experiment to see if we can create a toroidal vortex!

Water Drop

Aim: To observe how toroidal vortices form.

Equipment: (per student)
- 1 x tall clear cup
- Food dye
- Dropper (or straw)
- Water
- Paper towel

Procedure:
1. Fill a cup to the brim with water.
2. Let the cup stand for at least 1 minute so the water is completely still.
3. Draw up a single drop of food colouring, and dangle it just above the surface of the water.
4. Touch the water surface with the drop of food colouring.
5. Observe closely, looking down on the water surface. Document results!

http://www.abc.net.au/science/surfingscientist/toroidalvortex.htm

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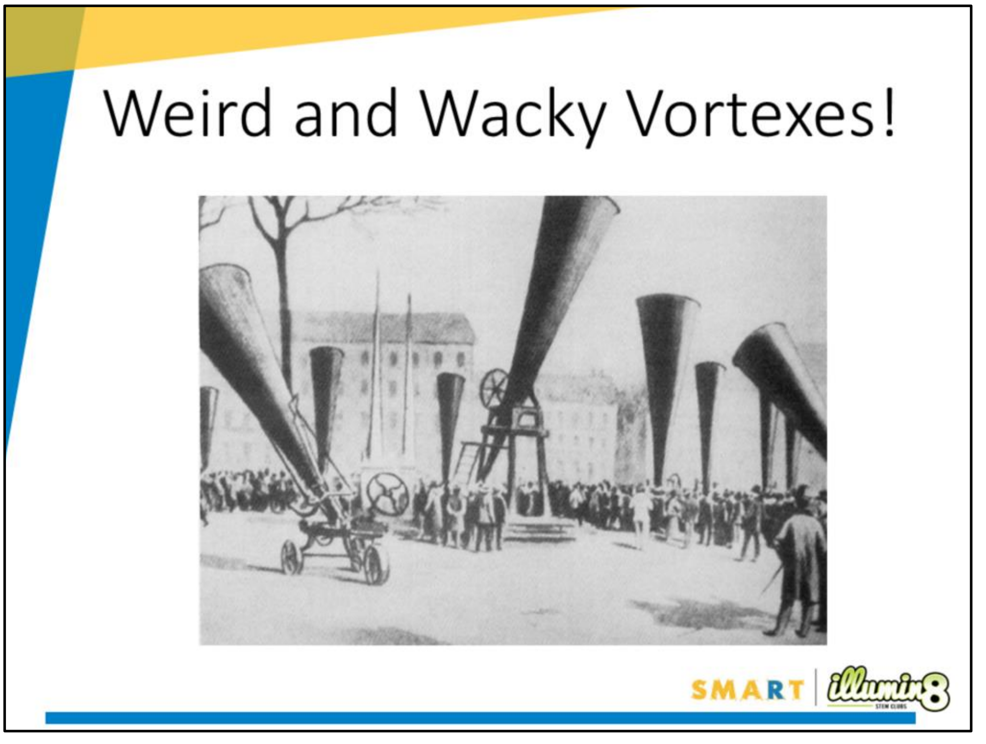
Refer to RISK ASSESSMENT for Module 1 before conducting experiment.
Refer to Experiment notes (E1.3.2 in Coordinator Notes for Module 1.3)

Encourage students to form a hypothesis about what might happen to the droplet in the water, before commencing the experiment.

If the students aren’t having luck getting rings to form as the food colouring drips into the water:
- Ensure that they have let the water settle to complete stillness.
- Try altering the height from which they are dropping the food colouring (it should be just above the surface of the water).



In the 1800s, grape growers tried to use cone shaped cannons to generate vortexes, hoping to disrupt hail cloud formation and protect their crops from hail storms. There is no scientific evidence to suggest these cannons actually worked!

Let’s build a vortex cannon to create toroidal vortexes in air.
We will test how far our vortices travel, by aiming our cannons at plastic cups, to see if we can knock them over.

Adam Spencer, Dr Karl Kruszelnicki and Ruben Meerman creating toroidal vortices.
http://www.abc.net.au/science/articles/2012/07/17/3546850.htm

Ruben Meerman and dolphins blowing bubble rings.
http://www.abc.net.au/catalyst/stories/2266199.htm

Vortex Cannon Challenge:

- Build a vortex cannon out of a cardboard box and a few other small items.
- The cannon should have a round opening for the vortex ring to come out of. When you hit the sides of the box, air will be pushed out of the opening, forming a toroidal vortex.
- The cannon will be 'fired' from on top of a table, and aimed at a stack of plastic cups on another table.
- The cannon may be filled with smoke using a smoke machine prior to firing. This can help make the toroidal vortices visible to assist with aiming.
- The further away your cannon is from the cups and the more cups you knock down – the higher your score!

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Vortex Cannon Challenge Rules:

- Your cannon must be fired from on top of a table.
- The plastic cup stack must be a pyramid shape, with a base of 5 cups in a single line on a table.
- You will have 3 official attempts at each distance. The best one is scored.
- Testing will begin at a 1 metre distance between tables, and will increase in distance by 1 metre each round. If you do not successfully knock down any cups, you cannot progress to the next distance.
- The final score will be the distance, times the number of cups from each round, added together.

References

- **Vortex Cannons:**

  http://www.abc.net.au/science/articles/2012/07/17/3546850.htm

  http://skullsinthestars.com/2012/08/28/physics-demonstrations-vortex-cannon/

- **Vortex Rings:**

  http://www.abc.net.au/science/articles/2008/02/11/2959944.htm

- **Toroidal Vortex Videos:**

  http://www.abc.net.au/catalyst/stories/2266199.htm

  http://www.abc.net.au/science/articles/2014/04/11/3978532.htm

- **Fluid Dynamics, Flow:**

  https://www.livescience.com/47446-fluid-dynamics.html

  http://www.education.com/science-fair/article/thick-liquids-faster-slower-thin/

  http://www.abc.net.au/science/articles/2013/01/30/3679522.htm

  http://www.abc.net.au/catalyst/stories/3285559.htm

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