2: Fluid Mechanics

2A: Surface Tension

2A10. Force of Surface Tension

Soap Film Pullup (2A10.10) -- a square wire frame with the bottom side free to slide is dipped in soap solution and pulled out; the surface tension of the soap film pulls the sliding wire up.

Floating Needle (2A10.20) -- Petri dish with a small amount of water is placed on overhead projector. A needle is gently lowered onto the water's surface with the help of a wire support, and the needle floats.

Surface Tension Disc (2A10.33) -- lift a floating disc off a water surface with a spring scale to show the force needed to overcome surface tension.

Camphor -- a piece of camphor placed in the water reduces the surface tension in the above demos.

Soap Bubbles -- small or large.

2A15. Minimal Surface

Minimum Energy Thread (Ring and Thread) (2A15.10) -- a loop of thread is tied across a rigid square frame, which is dipped in a soap solution. The thread will float limply in the soap film until the film inside the loop is punctured; the loop will then spring into a circle due to the surface tension of the soap film outside it, forming a surface of minimum energy.

Soap Film Minimal Surfaces (2A15.20) -- wire frames of various sizes and shapes are dipped into a soap solution, and form surfaces of minimum energy.

Soap Film Saddle -- a piece of flexible plastic with a circular hole cut out of the center is dipped into soap solution and emerges with a soap film filling the hole. Bend the plastic over, and the film distorts into a saddle shape to minimize surface area and energy.

2A20. Capillary Action

Capillary Tubes (2A20.10) -- glass tubes with different size bores all sit in a reservoir of colored water - the water rises to different heights in each tube, with an image of the tubes projected on a screen for easy visibility.
Capillary Action (2A20.20) -- a small capillary sits just above the surface of a container of colored water, which is raised by pushing a syringe. When the water touches the bottom of the tube it jumps up into the bore; an image of the tube is projected for easy visibility.

2A30. Surface Tension Propulsion

2B: Statics Of Fluids

2B20. Static Pressure

Pressure vs. Depth (2B20.15) -- an electronic pressure sensor is lowered into a tall column of water. As the sensor is lowered, the increasing pressure is displayed on a LED bar graph.

Pressure vs. Depth in Water and Alcohol (2B20.16) -- the electronic pressure sensor and LED bar graph display are used first in water and then in alcohol.

Hydrostatic Paradox (2B20.34) -- a truncated cone made of glass is open at both ends and fits against a flat glass plate. If the plate is held against the wide side of the cone and submerged in water, it will hold tight due to the pressure differential between the air inside and the water outside. With the plate against the small end of the cone, however, it will not stay put due to the smaller area of pressure differential.

Pascal's Vases (2B20.42) -- Tubes of various shapes rise from a common horizontal tube. When filled with water, the level is the same in each tube.

Card on Inverted Glass (2B30.45) -- Fill a glass with water, place a stiff card over opening and invert. Card remains in place due to atmospheric pressure below card.

Hydraulic Press (2B20.60) -- commercial hydraulic press with pressure indicator breaks boards and bends thick metal with the press of a finger.

Compressibility of Water and Air (2B20.71) -- A syringe filled with air is compressed when a large weight is placed on it, but a water filled syringe does not compress.

2B30. Atmospheric Pressure

Crush a 55 Gallon Drum (2B30.20) -- Boil water in a 55 gallon drum, seal, and then cool. This is by far, one of the most impressive demos that we have. Note: Our barrel supply is VERY limited so talk to us if you're interested in this demo.

Crush a Can with a Vacuum Pump (2B30.25) -- evacuate a one gallon metal can and it will collapse from the air pressure on the outside.

Magdeburg Hemispheres (2B30.30) -- two small hemispheres with handles are pressed together and evacuated; they cannot be separated by hand due to the unbalanced pressure on the outside.

Suction Cup (2B30.36) -- a large (4" diameter) suction cup of the type used to carry large panes of glass has a small hole in the top. If the suction cup is squeezed down onto a table and the hole covered with a finger, a student will not be able to pull the suction cup off the table as long as your finger covers the hole. Prove your superior strength as the student tries in vain to lift the suction cup, then remove your finger and the suction cup lifts right off.
Stool and Rubber Sheet (2B30.50) -- a square rubber sheet with an attached handle is set on top of a wooden stool or other heavy object. The weight of the sheet drives the air out from beneath it, and the air pressure on the outside holds the sheet and stool together. The stool can now be lifted by pulling up on the handle.

Adhesion Plates (2B30.55) -- two very flat glass plates will stick together without adhesives due to the unbalanced pressure on their outside surfaces.

Lift Weight with Vacuum -- an airtight cylinder fitted with a loaded piston is evacuated with a vacuum pump, raising the weight.

Vacuum Cannon (2B30.70) -- A long PVC pipe contains a ping-pong ball at one end. Both ends are sealed and the tube is then evacuated by a vacuum pump. When the seal is broken at the end with the ping-pong ball, atmospheric pressure accelerates the ping-pong ball and gives it enough kinetic energy to destroy empty aluminum cans. Rather than have a pressure reservoir that is over pressured, the emphasis of this demo is that normal atmospheric pressure can be used for impressive results.

2B35. Measuring Pressure

Mercury Barometer (2B35.10) -- a simple mercury barometer.

Barometer in Vacuum (2B35.15) -- a mercury barometer is totally enclosed in a glass tube. The tube is evacuated, and the mercury column height falls to zero.

Aneroid Barometer (2B35.40) -- has a glass back to show the mechanism.

2B40. Density and Buoyancy

Buoyant Force (2B40.14) -- two large scales show the weights of a container of water and of an aluminum cylinder. When the cylinder is lowered into the water, its weight as shown on the scale decreases; the weight reading of the water container simultaneously increases by the same amount.

Board and Weights Float (2B40.18) -- a board sinks equal amounts as equal weights are added.

Archimedes' Principle (2B40.20) -- a large-face spring scale supports a plastic bottle and an aluminum cylinder on a string. The aluminum cylinder is lowered into a glass jar filled with colored water to the height of a spillover spout, so that any water displaced by the cylinder flows out into a beaker. The weight reduction of the cylinder is noted. Then the water that was displaced is poured into the plastic bottle tied to the scale - the weight reading increases to its original value, showing that the buoyant force is equal to the weight of water displaced. Can be used to find the density of the aluminum, and an irregular cylinder of mixed density (aluminum and lead) can be used to recreate Archimedes' original experiment to determine the purity of a metal.

Archimedes' Crown -- a "gold" crown can be weighed in air and in water to calculate the density of the metal and prove that it is not (alas!) made of gold.

Float a Battleship in a Bathtub (2B40.25) -- a large block of wood will float in a container that is only slightly larger with a small amount of water.

Boat and Weights (2B40.26) -- a toy boat floating in a large jar of water can be loaded down with weights and sinks lower in the water with each addition.
**Helium Blimp** -- a Goodyear-type blimp about one meter long can be adjusted for neutral buoyancy by adding weight to the gondola. Electric fans propel the blimp at the whim of the instructor and the hardwired remote control box. A big toy for big kids, but a lot of good physics too.

**Cartesian Diver (2B40.30)** -- large, easily visible Cartesian diver is controlled by pushing in a syringe attached to the tank. Increased pressure shrinks the air volume in the diver and plummets it to the bottom. Release the pressure and the diver returns to the top. A screw gizmo allows fine adjustment of pressure if desired, and the old-fashioned “push on the top” works as well.

**Helium Balloon in Helium (2B40.43)** -- a helium balloon is placed in a large upside-down glass jar, and it floats to the top. Helium is then squirted into the jar with a hose, and when the air has all been displaced the balloon sinks to the bottom. Pick the jar up and the balloon floats on the helium/air interface.

**Helium Balloon in Liquid Nitrogen (2B40.44)** -- a helium balloon is drenched with liquid nitrogen and shrinks to about half its original volume. Because the volume of air displaced by the balloon is now low, it will not fly. As it warms up and expands, the balloon takes off due to the increased buoyant force.

**Weight of Air (2B40.45)** -- an evacuated flask is hung on one arm of a scale, and the scale is brought to balance with sliding weights. Air is then admitted to the flask, and the extra weight of the air drives the balance down on that side. The actual weight of the air can be found by rebalancing the scale and subtracting the weight of the empty flask.

**Water and Mercury in U-Tube (2B40.53)** -- measure heights of liquid boundaries and use the data to calculate relative densities.

**Density Ball (2B40.59)** -- a metal sphere barely floats in cold water and sinks in hot water.

**Hydrometer (2B40.60)** -- two identical hydrometers are floated in two different liquids to demonstrate liquid density measurement, buoyancy.

**Different Density Woods (2B40.61)** -- float blocks of balsa, pine, and ironwood in water.

**2B60. Siphons, Fountains, Pumps**

**Heron's Fountain (2B60.10)** -- A small "fountain" that shows it is possible to use air pressure to cause water to rise above its own level. Two plastic pop bottles are screwed together at their tops by a special adaptor that has two tubes passing through it, one going up into the upper bottle, the other going down into the lower bottle. Each tube also extends a short way into the other bottle, and each has small holes near the bottom. When the bottles are turned over, water flowing into the lower bottle raises the air pressure inside, the air then tries to flow up the upper tube into the upper bottle. But water is also flowing into the holes in the tube, and the flowing air pushes that water up the tube and out of the top, higher that the surface of the water in the upper bottle. Of course, only a small portion of the water is lifted in this way; the energy comes from the larger amount of water flowing downward.

**Siphon (2B60.20)** -- siphon water from one container to another.

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**2C: Dynamics Of Fluids**

**2C10. Flow Rate**

**Torricelli's Tank (2C10.10)** -- water fills a vertical glass tube with four outlet ports at different depths. Water shoots out the ports at a
velocity that varies directly with depth.

**Syringe and Water (2C10.26)** -- a large syringe is used to show the change in velocity with changes in tube diameter. Fill syringe with water, then point into the air and press the plunger. Your thumb, and the water in the wide part of the syringe, are moving slowly, but the water emerging from the narrow tip has a high velocity.

### 2C20. Forces in Moving Fluids

**Venturi Tubes (2C20.10)** -- a horizontal metal pipe with a constriction in the center has four open-end manometers attached along its length. Air flows at high speed through the pipe. Pressure decreases uniformly along the pipe, as shown by three of the manometers, but the manometer attached at the constriction shows a lower pressure than expected due to the increased air velocity (Bernoulli's Principle).

**Pitot Tube (2C20.25)** -- a pitot tube is connected to a water manometer and the air stream velocity is varied.

**Balls in Air Jet (2C20.30)** -- air blowing through a hand-held nozzle at high velocity supports large Styrofoam balls and holds them in place due to the greater pressure outside the air jet.

**Ball in a Funnel (2C20.35)** -- Air blowing out an upside down funnel will hold up a ping-pong ball.

**Bernoulli Hanging Plate (2C20.40)** -- a horizontal metal plate has a hole in the center out of which air flows downward at high velocity. A second plate pushed up against the first will cling to it due to the high velocity (low pressure) of the air flowing between them.

**Card and Spool (2C20.41)** -- A card with a small pin stuck through into the spool will be suspended when you blow into the spool.

**Suspended Parallel Cards (2C20.45)** -- air passing between two hanging cards pulls them together.

**Airplane Wing (2C20.50)** -- a cross-section of an airplane wing sits in an acrylic wind tunnel tube through which air is forced by a fan. Lift of the wing can be shown, and pressure readings can be taken at three points (top, front, and bottom of the airfoil) using a small open-end manometer.

**Curve Balls (2C20.60)** -- throw a curve ball using a styrofoam ball and a cardboard tube launcher. Dramatic curves are easy to throw, but practice helps.

**Flettner Rotor (2C20.80)** -- small wheeled cart has a motorized styrofoam cylinder mounted on top. When the cylinder rotates at high speed, air from an air track blower passing around the cylinder will make the cart move at right angles to the air stream.

**Tesla Turbine** -- demonstrates the boundary layer effect (adhesion between a moving fluid and a bounding surface). Compressed air is injected tangentially across a series of very smooth discs (hard drive platters) and drags across the surfaces. The platters can reach speeds of 10-15,000 rpm. This is related to Reynold's number, and laminar vs. turbulent flow (section 2C40).

### 2C30. Viscosity

**Bubbles in Oil (2C30.25)** -- three tubes containing oils with different viscosities each have an air bubble at the top of the tube. Turn over the rack holding the tubes, and the bubbles will drift up at three different terminal velocities.
**Viscous Drag (Terminal Velocity) (2C30.50)** -- small balls slightly more dense than water are dropped into a tall cylinder of water. Viscous drag slows the balls as they sink, giving them a low terminal velocity.

**Air Friction (2C30.65)** -- drop two identical pieces of paper simultaneously, with one flat and the other crumpled into a ball. The flat piece of paper has a higher drag and takes longer to reach the floor.

**2C40. Turbulent and Streamline Flow**
See also Section 4B20: Convection in [4: Thermodynamics](https://phys.washington.edu/2-fluid-mechanics).

**Turbulence Sphere** -- a glass sphere filled with rheoscopic fluid can be spun in a rotator to produce visible turbulent (and some not-so-turbulent) flow of the fluid.

**2C50. Vorticies**

**Vortex Cannon (Smoke Rings) (2C50.15)** -- use a large barrel to generate a smoke ring and blow out a candle with the vortex.

**Tornado Tube (2C50.30)** -- two liter pop bottles joined together at the necks by a small orifice and partially filled with water. Turn the pair over and give it a swirl and a tornado will form with air coming up through the center and water going down the periphery of the orifice.

**2C60. Non-Newtonian Fluids**

**Density Balls in Beans (2C60.20)** -- a ping pong ball will rise and a steel ball will sink in a large beaker of shaken beans.