

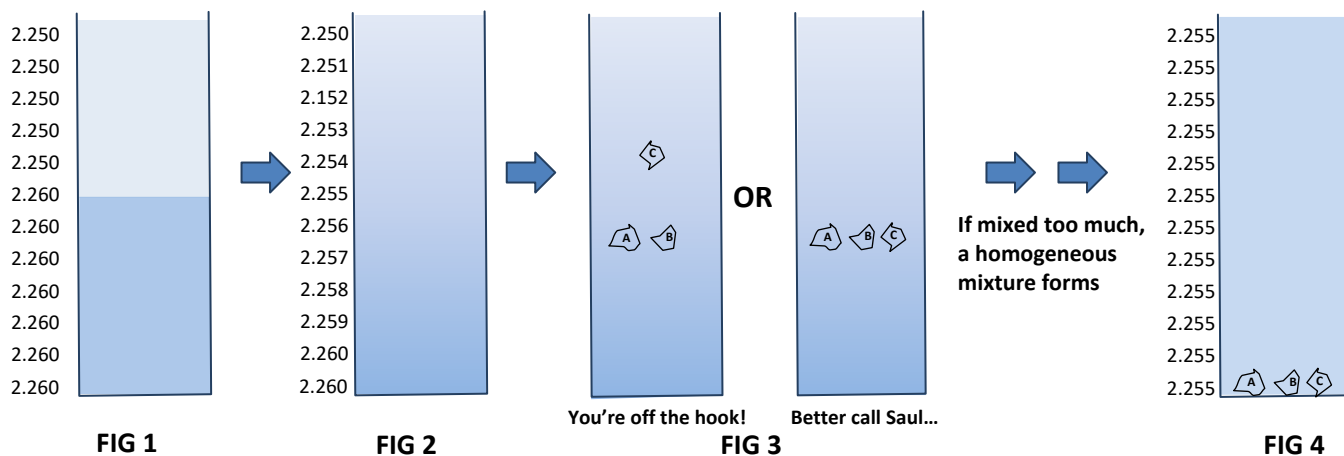
Density Stations Lab

Name: _____

Station 1: Density Gradients in Forensics

Some materials like plastic and glass have densities that vary somewhat depending on the type of glass/plastic and on the manufacturing process. If two glass fragments for example are taken from the same broken windshield they are likely to have the same density. But if they come from different windshields (even from the same make and model of car), their densities might be slightly different. Sometimes those differences might be very slight – only deviating in the ten-thousandth or hundred-thousandths place! So... imagine you are one of the suspects police are considering in a hit and run manslaughter case. The police recovered two glass fragments (A & B) from the body and one from your broken windshield (C). If those three fragment densities are all the same, it will provide fairly strong evidence that it was in fact your car that hit the victim. But even a slight difference in densities will help rule you out as a plausible perpetrator. Trying to measure the precise density of tiny shards of glass however is nearly impossible.

So the investigators instead use this creative technique: they create a very precise density gradient and drop the fragments in. First into a tall clear cylinder they pour a solution which is more dense than all three fragments (say 2.260 g/mL) and then on top they pour one that is less dense than all three (say 2.250 g/mL). (See Fig 1) Then they either stir the solutions (not too much!) or just let them sit for a while (not too long!) and eventually the two layers of the density column will diffuse and become a gradient that transitions gradually between the two densities. (See Fig 2) Each of the three glass fragments is then placed in the density gradient and sinks through the less dense layers and eventually ends up hovering at a level that exactly matches its specific density. (See Fig 3). If it is stirred too much or allowed to sit too long, eventually a gradient will turn into one homogenous mixture (with the same density throughout), and it can no longer serve the purpose of distinguishing such precise densities (see Fig 4)



Try to create a density column like the one described above by pouring 30 mL of solution A (blue) into a cylinder, then pour solution B (yellow) on top. Drop in the three glass shards (actually plastic) labeled A, B and C. Because you are in fact innocent, C does have a slightly different density than A & B, but you will need to confirm this. When you first put them in, all three should come to rest at the A-B interface. Now use the glass rod to stir the mixture for about 15-30 sec. Then wait and see what happens. Note: it may take a while (up to a minute or more) for the pieces to position themselves where they belong. If they all end up together, stir the column some more – your freedom depends on it! If they all drift to the bottom, add a few more milliliters of the more dense solution A (blue) and stir. If they drift toward the top, add a few more milliliters of the less dense solution B (yellow) and stir. See if you can recreate the sample column on the table – the one that says “do not disturb.”

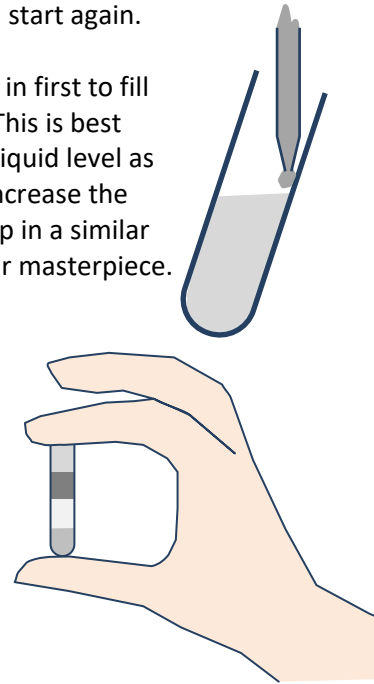
You may or may not have success with this. Either way, use the strainer to catch the three shards as you dump your density gradient into the waste beaker to leave it ready for the next group.

Station 2: Colored Density Column

Here the objective is just the opposite of the previous station. Instead of mixing a column into a gradually blended density gradient – to prove you are innocent (!), here you want to try to avoid mixing and make a column in a small test tube one with four crisp, distinct layers – to prove you are skillful! Start by using a pipet to place about 1 mL (1 cm depth) of one of the four solutions (you pick) into the test tube, then pick another and see if you can carefully layer it on top: try trickling a drop or two down the side and see what it does. Repeat with the remaining two solutions. What you observe should allow you to determine the correct order of the solutions – most dens to least dense. Write this order down here: _____ Empty out the test tube into the sink, then start again.

Now that you know the order, start by picking the solution you found to be most dense and put it in first to fill the test tube about $\frac{1}{4}$ of the way. Then VERY carefully trickle the second most dense one on top. This is best done by tilting the tube slightly and trickling the next solution down the side from just above the liquid level as shown at right. Start off squeezing very slowly, but once a crisp interface is established, you can increase the squeeze a little. Have the second layer also fill about $\frac{1}{4}$ of the tube. Then add the next layer on top in a similar manner and then finally the fourth. This should just fill the tube. If you want, take a photo of your masterpiece.

Then with your fore-finger covering the mouth of the test tube and your thumb on the bottom, try to very carefully turn the test tube completely upside down without disturbing the layers. Warning: Any air pocket at the top will become a bubble that will cause a lot of mixing as you turn it over, so try to make sure the top layer fills the test tube to the very top. Rotate especially slowly as the test tube approaches the horizontal position, and look at the layers as you do this. Then carefully flip it back over. Are the layer interfaces as crisp and distinct as they were before? Try carefully flipping it back and forth again. Can you do this five times back and forth and still have fairly distinct layers? Now try flipping it over quickly and watch what happens. Note all the schlieren* that takes place.



Dump your test tube out into sink, rinse it with tap water and leave it upside down in the rack.

***Schlieren** (from [German](#); singular "Schliere", meaning "streak") are optical inhomogeneities in transparent material. Schlieren physics developed out of the need to produce high-quality lenses devoid of these inhomogeneities. These inhomogeneities are localized differences in optical path length that cause light deviation.

Station 3: Hydrometer & Antifreeze Tester

To start off, place the soda can in solution X (in the large beaker). And then in solution Y. Can you tell which solution is more dense? _____ How? _____

Can you imagine how you could perhaps put increments on the soda so you could use it to determine the precise densities of a variety of liquids? Would the higher number increments be on top or on bottom? _____

Now check out the hydrometer. (**Be very careful with it: it's made out of glass and is fairly fragile.**) See if you can figure out how it works. Note the scale on it. What are two unusual things you should notice about the scale? _____

Now place the hydrometer in solution X (in the test tube). Take a reading: _____ Now place it in solution Y: _____

If you wanted to make a hydrometer that was very precise (one that could give a reading for example of 1.1036 g/mL) but perhaps didn't have a very large range, what would it look like. Draw it in the margin at right: Next to it draw a hydrometer that wouldn't be as precise but would cover a larger range (from 1.00 to 1.50 g/mL for example).

High precision	Large range

One place hydrometers have historically been used a lot is in wineries. How do you think a hydrometer might help with the wine making process?

Antifreeze Tester: Your car's engine has a system of pipes and channels with fluid running through them to help cool the engine off. These pipes connect to the radiator which has a lot of surface area to help dissipate that heat. Water can be put in these pipes to serve as the coolant, but water tends to boil if it gets too hot, and it can freeze if your car sits idle on a very cold day. Therefore $\text{CH}_2\text{OHCH}_2\text{OH}$ or ethylene glycol (AKA antifreeze – which could also be called antiboil!) is added to the water and this compound dissolves in the water and both lowers the freezing point and raises the boiling point. This keeps your car's engine safe from overheating over a wider range of temperatures. Usually a 50-50 mix of water and antifreeze does the trick, but if you live in an especially cold (or hot) location, you may wish to increase the concentration of antifreeze. The ethylene glycol, however, tends to deteriorate over time, so it's a good idea to check the antifreeze levels periodically. This is done by opening up the radiator cap and withdrawing a small sample of the fluid with a coolant tester (gadgets P and Q on lab bench). Draw up some water-antifreeze mixture A (bright yellow) into each tester to see how it works and to test the protection coverage (in $^{\circ}\text{C}$) of the antifreeze sample. Then make sure to squeeze out all the liquid back in the beaker and now test mixture B. Record your findings below:

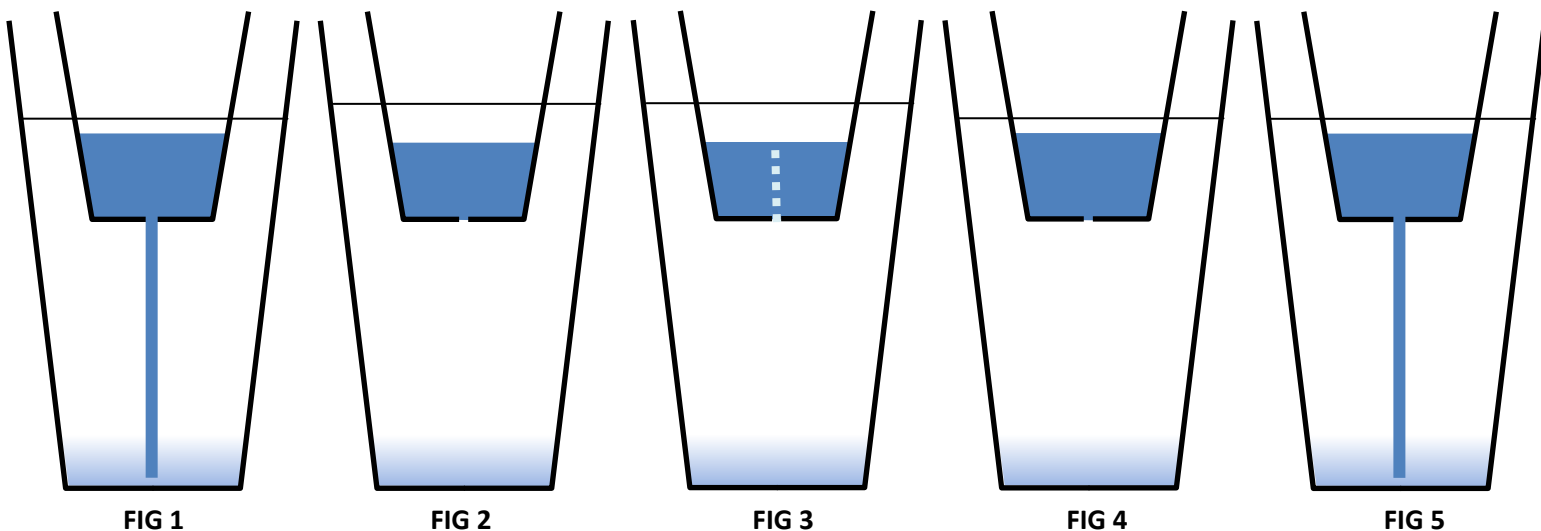
A's fp = _____ bp = _____ B's fp = _____ bp = _____

Station 4: Salt-Water Oscillating "Fountain"

This is an interesting effect that occurs when a dense liquid like salt water (colored blue) is placed in a funnel above regular water with a small pin hole separating the two. Since salt water is more dense, it trickles down through the hole to the bottom of the water (Fig 1), but as it does so, the salt water level inside the funnel goes down and the water level outside the funnel goes up (Fig 2). This increase in water level difference will eventually build up enough pressure to stop the flow and then reverse it (FIG 3): though you cannot see the regular water streaming up through the blue salt water, it is occurring, and this reverse flow will eventually restore the two solutions to more or less their original level (FIG 4), and then the cycle will start up again (FIG 5). Note: the small size of the hole ensures that the liquids can only flow through it in one direction at a time. If it were bigger, the two liquids would just pass each other and not oscillate in this manner – like a swing going back and forth. Eventually, of course the water below becomes salty enough and the salt water on top becomes diluted enough that the process stops, but this may take hours. Note also: the liquid level changes in the diagrams below are exaggerated. In the actual set up, the level changes will be too small to see.

Without disturbing the set-up, use the stop watch to time this oscillation. Have one person record the lengths of the downward flow periods. Have another person record the pauses in between (when the water is flowing up into the funnel.) Record these times below:

Flow: _____ Pause: _____ Flow: _____ Pause: _____ Flow: _____ Pause: _____ Flow: _____ Pause: _____



Station 5: Four Types of Wood and Camp Stove Canister

Place each of the four wood samples in the tank of water. What do you notice about how they float?

Now pick up the camping stove fuel canister and give it a shake. Inside you can feel the liquid fuel sloshing around, but how much is in there. When you bought it, the canister was full, but you have used it for cooking the past three days of your camping trip. Will it last the remaining seven days at this rate, or do you need to start cutting back a bit on how much you use each day to ensure you have enough? Wouldn't it be great if the canister manufacturer had put some kind of gauge on the canister so you would know at any point in time how much fuel you have left? Look carefully because they have. Figure out how to read the gauge and then decide whether or not you will need to start cutting back on your cooking fuel consumption. Explain:

Station 6. Lava Lamp & Galileo Thermometer

Though there is nothing to manipulate at this two-part station, there is plenty to think about. First the lava lamp. It is comprised of two immiscible liquids. Immiscible means they do not mix (like oil and water). Why they do not mix has to do with the attractive forces between their molecules, and we will learn more about that later. Anyway, a more dense, opaque (can't see through it) liquid is on bottom and a less dense, transparent (clear) liquid is on top. Watch the lava lamp for a while. What causes the opaque liquid on the bottom to rise upward through the clear liquid?

What causes the opaque liquid to cycle back down to the bottom?

What do you think would happen if the whole lamp were heated up in an oven? Why?

Now look at the Galileo thermometer. It consists of several sealed glass bulbs filled with various amounts of colored liquid with weights hanging down. These are all placed in a sealed glass cylinder filled with a clear liquid (perhaps water?). As the temperature of the whole thing changes, different bulbs float or sink, with one usually "flinking" temporarily in the middle. Explain how you think it works?

Are the total masses of the sealed bulbs changing appreciably? ____ Why or why not?

Are the total volumes of the sealed bulbs changing appreciably? ____ Why or why not?

Is the mass of the clear liquid in the cylinder changing appreciably? ____ Why or why not?

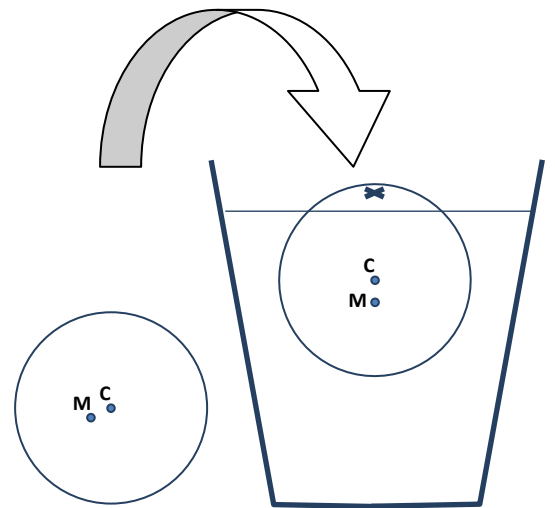
Is the volume of the clear liquid in the cylinder changing appreciably? ____ Why or why not?

You may think that manufacturing these devices would be rather tricky – to get the densities of the glass bulbs just right. That’s probably true if you were making just one or two, but if you were making thousands of these, there is a very different approach you might take. Can you think of what that might be?

Station 7: Golf Ball floating

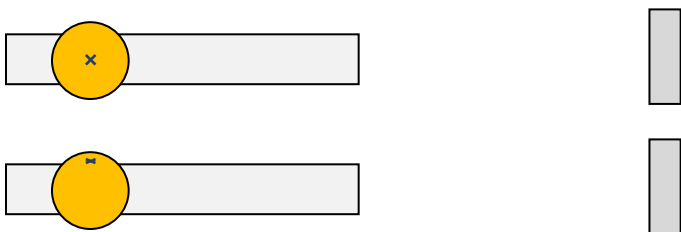
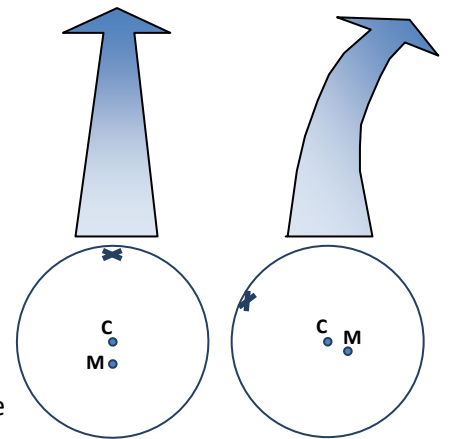
As you can imagine, the machines that are used to manufacture golf balls are not perfect, and thus the weight distribution in a golf ball may not be exactly even. And if the golf ball’s center of mass is not in the exact center of the ball, this could cause the ball to veer left or right during a long put or when you tee off through the air. It may be a very slight effect, but in a game won or lost by centimeters, pros can’t afford to take a chance. So what some of the more serious golfers do is to float their golf balls in a dense liquid (like salt water) and they mark the point on the ball that ends up on top. It should make sense that this mark will always be the point opposite the center of mass on the ball.

In the figure at right, C represents the center of the ball and M represents the center of mass. When floated in salt water, the ball will obviously rotate into a position which places M directly below C as shown above. So when a mark (X) is made on the top of the floating ball, it will be directly opposite M. Try putting the golf ball in the salt water and giving it a bit of a spin. Does it still end up with the X on top every time?



When the golfer then goes to use that ball, she will want to place that X on top so that when she hits it, the path of the ball will not be affected by an off centered weight distribution. If the X is placed for example on the left side relative to where the club contacts the ball, then the ball is likely to swerve to the right a little.

To illustrate this, some metal shot was glued to the inside wall of a Ping-Pong ball to give it a very uneven weight distribution. This ball was floated on water and an X was then placed on the point that was on top. There is a ramp on the floor that is angled downhill and aimed at a wooden block about 50 cm away. Place the Ping-Pong ball on the ramp, with the X on top (as a golfer would do) and let it go. (You may need to nudge it down the ramp since the weight distribution is so lopsided!). If this is done correctly, the ball should roll straight and hit the block. Now try it again, but this time have the X off to one side (on the left, for example, for the ball facing the block target).



Station 8: Diet or Regular

You are at a big outdoor picnic and the soda cans are all in a huge cooler filled with ice water. But when you go over to get an ice-cold Dr Pepper and all you see is diet Dr. Pepper – which you can't stand! Don't despair: there may be plenty of regular Dr. Peppers: you just have to reach down to the icy depths to get them! You may or may not have noticed this, but diet sodas float and regular sodas sink. Go ahead and verify this with the soda that are there. Can you tell the difference between a diet and regular soda with your eyes closed. Close your eyes and have your partner hand you a soda without telling you whether it is diet or regular. Figure out what it is without opening your eyes!

Why does this happen? When sugar (sucrose ($C_{12}H_{22}O_{11}$)) is dissolved in water, it makes a solution that is more dense than water. That's true of sugar, salt, and almost every solid solute, and the more solute that is dissolved, the more dense the solution is. Nutrasweet (also known as aspartame ($C_{14}H_{18}N_2O_5$) – or methyl L-a-aspartyl-L-phenylalaninate to organic chemists!) also creates a solution that is more dense than water. BUT, nutrasweet is approximately 200 times sweeter than sugar.

A typical soda like Mountain Dew contains as much as 46 g of sugar per 12 oz can, and this raises the density substantially – to about 1.08 g/mL. A comparable diet soda would only contain about 0.23 g (230 mg) of nutrasweet, and this only raises the density a tiny amount. In addition to the soda, there is obviously the can which is made of aluminum and paint and is more dense than water and there is also the gas pocket inside the can (pressurized CO_2), which is less dense than water. If it was just the water and the can and the gas pocket, the entire combination would be just barely less dense. Adding 46 g of sugar is enough to make the entire thing come out more dense than water, but adding only 0.23 g of nutrasweet isn't enough.

Station 9: Soy Sauce Under Pressure

The 1-L plastic bottle is filled with water and five soy sauce packets. Using just one hand, squeeze the bottle. Can you make just one packet sink to the bottom? How about two? Three? Four? All five? Can you explain why squeezing the bottle causes the packets to sink? Look carefully at the soy sauce packets. In what way are they similar to the soda cans from the previous station? Try to relate your explanation to how tightly packed particles are in the solid, liquid and gaseous phases.

