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Transcript – Lecture 27

Today we're going to change topics.

I'm going to talk to you about fluids, hydrostatic pressure and barometric pressure.

If, for now, we forget gravity and I would have a compartment closed off and filled with a fluid--

could be either a gas or it could be a liquid--

this has area A, here--

and I apply a force on it in this direction, then I apply a pressure.

Pressure is defined as the force divided by area--

has units newtons per square meter which is also called pascal.

One newton per square meter is one pascal.

Now, in the absence of gravity, the pressure is, everywhere in this vessel, the same.

And that is what's called Pascal's principle.

Pascal's principle says that the pressure applied to an enclosed fluid is transmitted undiminished to every point in the fluid and to the walls of the container.

Keep in mind, pressure is a scalar, it has no direction.

Force has a direction and the force exerted by the fluid on anything--

therefore also on the wall--

must be everywhere perpendicular to the wall, because if there were any tangential component, then the fluid would start to move.

Action equals minus reaction, so it starts to move and we are talking here about a static fluid.

So if I take any element--

I take one here at the surface, little element delta A and the force must be perpendicular to that surface, delta F, and so delta F divided by delta A--

in the limiting case for delta A goes to zero--

is, then, that pressure P.

This has some truly amazing consequences which are by no means so intuitive.

This is the idea of an hydraulic jack.

I have here a vessel which has a very peculiar shape.

Ooh, ooh, an opening here.

And let there be here a piston on it with area A1 and here one with area A2.

It's filled with liquid everywhere and I apply here a force F1 and here a force F2.

So the pressure that I apply here is F1 divided by A1.

So according to Pascal, everywhere in the fluid, that pressure must be the same.

For now, I just assume that the effect of gravity, which I will discuss shortly, doesn't change the situation very significantly.

But I will address the gravity very shortly.

So the pressure, then, will be the same everywhere, but the pressure due to this side is F2 divided by A2...

and so the two must be the same, if the liquid is not moving.

So what that means is that if A2 over A1 were 100, it means that this force could be a hundred times less than that one.

In other words, I could put on here a weight, a mass of ten kilograms, and here I could put 1,000 kilograms and it would be completely in equilibrium.

That's not so intuitive.

This is used in all garages.

What they do is, they put on top of this--

if I blow that up here, so this is this platform, there's a rod here and on top of it is a car.

And someone pushes here and then this goes up.

The car goes up.

If I push here with a force a little bit more than ten kilograms--

so that would be 100 newtons--

this level would go up.

And so your first thought may be, "Gee, isn't that a violation of the conservation of energy? Am I not getting something for nothing?" Well, not really.

Suppose I push this down over a distance d1, then the amount of fluid that I displace--

that is, the volume, is A1 times d1.

That fluid ends up here.

So this one will go up over a distance d2.

But the same amount of fluid that leaves here adds there.

In other words, Al d1 must be A2 times d2.

Now, if the force here is a hundred times less than the force there, the work that I am doing on the left side is F1 times d1.

If the force here is a hundred times less than that, the distance that I move is a hundred times larger than d2, because A2 over A1 is 100.

And so F1 d1 will be the same as F2 d2--

100 times lower force but over 100 times larger distance, and so the product is the same.

So the work that I do when I push this down I get back in terms of gravitational potential energy by lifting the car.

So if I wanted to move the car up by one meter and if the ratio is 100 to one I would have to move this down by 100 meters.

That's a little bit impractical so these hydraulic presses are designed in such a way that you can just jack it like that and every time that you bring it up, that liquid flows back in again into this side of the hydraulic jack.

But, indeed, you will have to go effectively 100 meters, then, for that car to go up by one meter if the ratio is 100 to one.

Now, gravity, of course, has an effect on the pressure in the fluid.

If you go down into the oceans, we know that the pressure will go up, and that is the result of gravity.

And I would like to derive the pressure increase.

Let this be the direction of increasing y, and I choose a liquid element, so this is in the liquid itself.

I can choose it in any shape that I want to.

I just take a nice horizontal slab.

And this is area A so the bottom is also A.

And let this be at height y plus delta y and this is at height y.

And the pressure here is P y plus delta y and the pressure here is P of y.

And this object has a mass, delta m, and the liquid has a density, rho, which could be a function of y--

we will leave that open for now.

And so this mass--

the mass that I have here--

is the volume times the density.

And the volume is A--

this area--

times delta y, and then times the density, which may be a function of y.

So if now I put in all the forces at work here, there is gravity, which is delta m times g in this direction.

Then I have a force upwards due to the pressure of the fluid.

That's what we want to evaluate.

It's always perpendicular to the surfaces.

We talked about that earlier.

So in this side, it comes in like this and here it comes in like this, the force.

From the bottom, it comes in like this and from the top, I call this F2.

I only consider the vertical direction, because all forces in the horizontal plane will cancel, for obvious reasons.

So, now, there has to be equilibrium.

This fluid element is not going anywhere--

it's just sitting still in the fluid.

And so I now have that F1--

which is in this direction--

minus F2 minus delta mg must be zero.

Only then is the fluid element in static equilibrium.

But F1 is this pressure times the area--

so that is P at level y times the area, and F2 is P at level y plus delta y times the area, minus delta m is A delta y times rho, so I get minus A times delta y, which could be a function...

rho could be a function of y times g, and that equals zero.

Notice I lose my area.

I'm going to rearrange this slightly and divide by delta y.

And so I get that P at the level y plus delta y minus the pressure at level y divided by delta y equals--

if I switch that around, so I bring this to the other side--

equals minus rho y times g.

And if I take the limiting case of this--

for delta y goes to zero--

then we would call this dP/dy.

And this tells you that when you go to increasing values of y, that the pressure will go down, it's a minus sign.

Very natural.

If you go with decreasing values of y, then the pressure will go up.

And we call this hydrostatic pressure.

So it's due to the fact that there is gravity; without gravity, there is no hydrostatic pressure.

Now, most fluids, most liquids are practically incompressible.

In other words, the density of the liquid cannot really change.

And so therefore, you could remove this and simply always use the same density.

It's exceedingly difficult.

It takes horrendous forces and pressures to change the density of a liquid, unlike that of a gas.

A gas is compressible and you can very easily change the density of gas.

So liquid is incompressible.

If I have here a piston and I have here a liquid and I put a force on here, it would be impossible for me to make that volume smaller--

even by a fraction of a percent, it would be impossible.

If this, however, were gas, then it would be very easy for me to push that in and to change the volume, make the volume smaller and thereby make the density of the gas go up.

If I took a sledgehammer and I would hit a plastic pillow, just bang, and the pillow was filled with air, it acts like a cushion and I could squeeze it.

If I hit the sledgehammer on the marble floor, I could not squeeze it and the force on the marble floor and on the hammer would be way higher, because I don't have this cushion action.

If I take a paint can--

and we have one here, we have two--

and this paint can is filled to the brim with water and another one is filled with air and I hit it with a sledgehammer, then this acts like a cushion.

This one, however, doesn't want the volume to be decreased, so the force, like on the marble floor, would be way higher.

But remember that force divided by area is pressure, and according to Pascal, that pressure propagates undiminished in the whole fluid.

And so if I would shoot a bullet through here, then I get a huge force--

extremely small area of the bullet.

And so the pressure inside the liquid would go up enormously, and the can might explode, provided that it's really filled to the brim with water, because if there is air left, then you have this cushion action.

Now, I don't remember whether there's air in here or whether there's air in there.

I'll leave you to decide.

So we'll fire a bullet from this side, and then we'll see which can explodes and which does not.

And the one that doesn't is the one that has air in it, and the one that explodes...

has the water in it, provided that we really filled it to the brim.

Oh, boy, there's still something in there.

[blowing]

Okay.

I did something wrong, but that's okay.

All right, there goes the bullet.

Okay, are we ready for this? So you tell me which can is filled with air and which can is filled with water.

Three, two, one, zero.

[gunshot]

Okay, this one is closed.

It has a nice hole here and a nice hole there.

And this one has a hole here and a hole there, but you saw the top come off.

So we know which one had water in it and by the way, it's still there.

These things are not so intuitive.

I will assume from now on that liquids are completely incompressible.

In other words, I can now use this law that we have there and do a very simple integration.

I have now dP, which I can integrate from some value P1 to P2.

This is y, level P2, level y2, level y1, pressure P1 in the liquid, and that equals now minus rho g dy, integrated from y1 to y2.

So that's now a trivial integral because rho is constant--

rho is not a function of y.

With the atmosphere of the Earth, that's more difficult, because rho is a function of altitude with the atmosphere but not with liquids.

And so we get that P2 minus P1 equals minus rho g times y2 minus y1, and this is called Pascal's law.

I prefer to write it slightly differently, but it's the same thing.

I write a plus sign here, so I switch these around: rho g times y2 minus y1.

So what it means is I see immediately that if y2 minus y1 is positive--

this is higher than this--

that the pressure at P1 is larger than the pressure at P2, but of course they are completely identical, so this is the hydrostatic pressure.

This has quite bizarre consequences.

Suppose I had a vessel that I filled with a liquid.

It had a rather changed shape, like so...

a rather strange shape.

So I would fill it with liquid to this level, and the level here is y2.

And let's take the bottom of this vessel and call this y1.

And so inside here we have pressure P1 and right there, we have pressure P2.

Well, what Pascal is saying now is that the pressure here is everywhere the same because y2 minus y1 is the same for all these points here.

And so you will say, "Well, that is sort of intuitive." You will say, "Look, if I take here a column--

"nicely cylindrical vertical column, which has area A, "and I call this separation h, for simplicity--

"then the weight of that column--

"that's the weight of the liquid--

"would be the area times h--

that's the volume--

times the density of the liquid, rho, times g." And so you would say, "That's a force." The weight... the bottom here has to carry that weight and so the pressure at the bottom is that weight divided by the area, so that is rho hg.

So you would say, "That's very clear." Yeah, maybe, but how about here?
The pressure is the same, it couldn't be any different.

If the pressure were different here, then the liquid would start to flow.

But here you don't have that column h over you.

You only have it here.

And how about here? The consequence of Pascal's law is that if you had a vessel like this and you filled it all the way with liquid, that the pressure here at the bottom would be exactly the same as this vessel, which is filled with liquid all the way to the bottom.

And yet the weight of this is way more than the weight of this.

But yet, according to Pascal's law, the pressure differential is the same.

It is not intuitive.

We live at the bottom of an ocean of air.

So here's the Earth and here's air.

And when we go up in y, then we also expect that the pressure will go down.

It doesn't go down linearly, like liquids do.

Liquids are linear because rho doesn't change.

In the case of air, the density does change with altitude.

But if I can take one square centimeter cylinder all the way to the top of the atmosphere just like I did here, in the liquids...

I take a one square centimeter--

I could have taken area A--

and I weigh all this air, then I would get the right answer for the pressure here, because I do that there and that works, so that should work here.

And what I find, then...

then I find that at the bottom... at sea level, I find roughly one kilogram force, which is ten newtons, per square centimeter.

It means, then, that this whole column...

If I take a one square centimeter tubing all the way to the top of the atmosphere--

a few hundred kilometers--

that that would weigh one kilogram only, all that air.

One kilogram per square centimeter.

If you convert that to newtons per square meter, then you get roughly ten to the fifth pascal.

And that is called, generally, one atmosphere.

It's called the atmospheric pressure.

So the air pushes down on us--

that gives us the atmospheric pressure--

not unlike the way that liquid pushes down because of its weight and increased pressure as you go down.

This atmospheric pressure is also often called barometric pressure.

The idea of a barometer.

Here's my hand, and my hand has an area of roughly 150 square centimeters.

Force is always perpendicular to the surface.

I discussed that several times.

For each square centimeter, there is an equivalent weight of one kilogram due to the air above me.

That means 150 kilograms is pushing down on my hand.

Why is my hand not going down? Well, because there's also 150 kilogram pushing up.

And so, I feel very comfortable.

I don't even notice it that there is this huge force in this direction and this huge force in that direction.

So how can I measure this atmospheric pressure if I can't feel it?
The way that you can measure it is by the following experiment.

You take liquid, and you put a hose in the liquid, as I will do very shortly.

This is cranberry juice, and this is the hose.

And we're going to immerse the hose completely into that liquid so that it's completely filled with the liquid.

And then we lift it out, and as we lift it out, we will see that the liquid will stay there.

It's the barometric pressure that's pushing it in.

And I pull it out and pull it out and pull it out and pull it out and there comes a time that it will not stay in there anymore.

So it's way down there now, the vessel, and then it lets go.

And this is now empty, and here is the liquid.

And this is a way that we can measure the barometric pressure and I will show you shortly how that works.

But let me first convince you that if I let all this cranberry juice inside the tubing that I have...

I put my finger on top of the tubing and I lift it out.

Notice that the cranberry juice stays there.

It's not running down.

It's only when I take my finger off the top--

[whooshes]

then it goes down.

But as long as I hold my finger on the top, it isn't going down.

If my hose were long enough--

and we will know shortly how long--

it turns out to be more than ten meters--

then we would see the cranberry break loose from the top.

And this is a way that you can measure the atmospheric pressure and I will now be more quantitative about that.

I will leave this equation because I like that equation.

So imagine that we have this experiment--

which in the old days wasn't done with plastic hoses, which was done with glass tubes--

and suppose I end up here with liquid and here with such a tube and that the liquid had broken, so it's empty here...

and here is the liquid.

This is y1, this is y2, this is the pressure P1 and right inside here is the pressure P2 which is zero, because it's empty, there is nothing.

A little bit of vapor pressure, but that's very small.

And so this distance here...

let that be h.

And so now what is the pressure here at P1 which, of course, is the barometric pressure? It's just exposed to the atmosphere.

Well, P1 minus P2 equals rho of the liquid times g, times y2 minus y1, which is h.

But P2 is zero, so P1 equals rho gh and that is the barometric pressure.

So all I have to do is take a liquid, know the density of the liquid, measure how far I have to pull that hose up before the liquid breaks loose, and then I know what the barometric pressure is.

Now, this was done in the early days,

in the 17th century by Torricelli.

He used mercury and he found that...

Mercury, by the way, has a density of 13.6 times ten to the third kilograms per cubic meter.

So this is mercury.

He found that h is about 76 centimeters--

0.76 meters.

This is a fact.

It changes a little bit from day to day.

It could change by a few centimeters--

a little down, a little up.

If it's up, the barometric pressure is higher than when it's down.

And so the barometric pressure, P1, is then 13.6 times ten to the third times g--

for which I will take ten--

and the height is 0.76, and that is 1.03 times ten to the fifth pascal...

which comes very close to the one-kilogram force per square centimeter that I mentioned to you earlier.

One atmosphere's pressure is defined in a very special way in a very precise way--

namely, that it is exactly the pressure when the column here is 760 millimeters of mercury.

Then we call the pressure here--

that's the definition--

one atmosphere.

Now you can do the same experiment with water, whereas we tried to do it with cranberry juice.

The density of water is 13.6 times lower than that of mercury, so the column has to be 13.6 times higher than 76 centimeters, which is about ten meters.

So you would have to raise this thing up to ten meters before you would see the break.

But you would have...

then you've built yourself a water barometer.

If you do it with mercury, you have a mercury barometer.

You would see this level go down.

And if the pressure is high, the weather is good; and if the pressure is low, the weather is not so good.

So you could build yourself a water barometer--

has to be ten meters long.

The story has it that Pascal, who was French, did the whole thing with red wine.

So he had a red wine barometer.

It's very good to remember that ten meters of water produces a hydrostatic pressure of one atmosphere.

So if you go down into the oceans by 100 meters, then the hydrostatic pressure increases by ten atmosphere.

So every ten meters is one atmosphere.

Cornelis Van Drebbel--

and I know how to pronounce that name because I'm Dutch; he was a Dutch inventor--

is usually credited with building the first submarine in the very early 17th century, around 1622.

And he successfully operated this submarine at a depth of about five meters.

Imagine, five meters.

The hydrostatic pressure there is half an atmosphere.

Ten meters, one atmosphere--

five meters, half an atmosphere.

Nowadays, submarines go...

It's a little secret how far they go, but they have gone up to 3,000 feet, which is 900 meters, where the hydrostatic pressure is 90 atmospheres.

On every square meter of that submarine, if it is at 900 meters, there is a force of 900 tons--

900,000 kilograms.

Now, Van Drebbel's submarine was an enormous accomplishment for the 17th century, because how are you going to seal a vessel whereby the inside of the vessel is one atmosphere--

that's the air that he was breathing--

is five meters below the level, and so the outside pressure is one and a half atmosphere? Namely, one atmosphere barometric pressure and half an atmosphere from the hydrostatic pressure.

So there's an overpressure on the vessel of half an atmosphere.

So that means on every square centimeter, there is a force pointing inwards of half a kilogram--

the equivalent of half a kilogram weight.

Force is always perpendicular to the surface, and if you would take two square meters of his submarine, that would be a force of 10,000 kilograms.

It's amazing that he managed to do that and that he could actually operate his submarine successfully.

I can show you here in 26.100 what kinds of forces Van Drebbel was dealing with.

You see there in front of you a paint can.

And I'm going to evaporate the...

not evaporate, I'm going to evacuate the paint can.

I'm going to pump the air out.

And so here is the paint can, about 25 centimeters by 15.

And so it has equilibrium--

there's one atmosphere outside, one atmosphere inside.

Paint can is happy.

I'm going to suck the air out, so I get an underpressure here.

In other words, the pressure outside is higher than inside--

exactly the problem that Van Drebbel had.

The pressure outside is higher than inside.

You get an implosion.

He managed to counter that, to build it strong enough.

When we take out the air here, you can argue, well, then, the overpressure is really one atmosphere and he only dealt with half an atmosphere.

Well, before we reach this to be a vacuum, believe me, it already implodes.

So the forces that we're dealing with are very comparable to what Van Drebbel was dealing with when he built his submarine.

And so this can will start to crumble when we take the air out, and that's another way of really seeing the atmospheric pressure.

So I take the pressure out of the inside and the can will literally be squeezed because of the ocean of air that is hanging on us and is pushing down on us.

Okay.

It has to be properly sealed, which is always a bit of a problem.

And so I have here a vacuum pump, and let's pump on it.

[can buckling]

You can already hear the crushing.

The force on the front cover alone...

this is 375 square centimeters.

If the pressure inside were zero, that would be a force of 375 kilograms.

But look--

it's not very happy, that can.

And these are the kind of forces very comparable to what Van Drebbel was dealing with in the 17th century, and he was able to even operate his submarine under these forces, without collapse.

Okay, I think we...

you want to take this as a souvenir? Oh, no, I can't give that to you.

We have to first take this off, but you can pick it up later.

That... that mouthpiece is quite precious for us, because we have to use that again, of course.

So you see what tremendous forces are at stake when you deal with barometric pressure.

If you go scuba diving, you go to a depth of ten meters--

could you stick a tube in your mouth, which could go all the way to the surface, and could you breathe? Well, there's no way.

If you were here and you have a tube...

here's the water level...

and if this is ten meters, then the overpressure here between your lungs and the water is one atmosphere, overpressure.

So here is one atmosphere barometric pressure.

Here is one atmosphere hydrostatic pressure plus the barometric pressure, so here you have two atmospheres.

So there is a huge force on your chest.

Inside your lungs is one atmosphere, outside is two atmospheres and there is no way that you could breathe.

If the area of my chest is some 30 by 30 centimeters--

which is a thousand square centimeters--

it would be like having a hundred-kilogram weight on my chest, and also on my back, of course, because it's in both directions--

it pushes like this and it pushes like this and like this and like this.

So you're really being squeezed to death.

So what do you do when you go scuba diving? You need pressured air with you in the tank and that you breathe, and so now, with the pressured air, you can obviously counter the hydrostatic pressure from the water.

Now suppose we go snorkeling.

That's different.

Then we do have a little tube in our mouth, and we snorkel.

How deep do you think we could snorkel--

that our lungs could easily accommodate the hydrostatic pressure? Any idea? Do you think we could snorkel maybe three meters? Who thinks we could easily do three meters? Okay, who thinks maybe only one meter? Who thinks way less than one meter? Well, we know it's not way less, because snorkels are this long, you know, so you know you can at least do 30 centimeters, so it can't be all that much less.

Well, we can measure how deep we could snorkel and we can measure what the capacity...

the capabilities of our lungs are in order to counter the hydrostatic pressure.

If I'm underwater, there is pressure on my chest, and so to let the air out is easy.

You just...

I'm squeezed in, right? That goes out.

But in order to inhale, to suck in the air...

[inhales]

I would have to push out my chest with a force that counters the force due to the water.

And so the question is, what kind of pressure could I generate with my lungs to overcome the hydrostatic pressure? And we are going to measure that today with an instrument that we call a manometer.

A manometer is a simple tube--

it could be made of anything, but a plastic tube will do fine.

And we have liquid in here.

It's open here and it's open here.

I put my mouth here, and I'm going to see how much overpressure I can produce in my lungs by pushing, by blowing.

And so I'm going to blow in here and then this level will go down and this level will go up.

And this height difference--

let's call that h--

and the density of this fluid is rho.

We will use water for that, colored water.

So the pressure here at y1 equals P1--

that's here--

and the pressure here at y2 equals P2.

And so P1 minus P2 equals rho times h.

I apply the law that we still have here--

P1 minus P2, rho times h times g.

I know that the P2 level is one atmosphere, that's correct.

This is one atmosphere--

that's open to the world.

So P1 equals one atmosphere plus rho hg.

And so what my manometer indicates is how much pressure I can generate over and above the one atmosphere, and we call that overpressure.

We often work with overpressure gauges.

When you go to the gas station and you have your tire pressures measured--

the pressure in your tires--

there's also a gauge which measures the overpressure.

And so right there...

we have such a manometer.

I'm going to blow in here, and that's going to tell us immediately how deep I can snorkel.

If I was able to make this height difference ten meters, then I could snorkel at a depth of ten meters in the water, because it means that I could generate an overpressure of one atmosphere.

If this would only be five meters, then I could only snorkel down to five meters.

If this is only a sad one meter, then I could really only comfortably breathe one meter below the surface.

And that's what you see here and I want you to...

Already you know it's not going to be so fantastically high.

Otherwise, these hoses would be longer.

This is the level that we have now.

On this side is atmospheric pressure, that's open there, and on this side is also atmospheric pressure, it's open.

That's why the levels are the same.

This mark is 50 centimeters above here and this is 50 below.

So if I can generate an overpressure in my lungs of one-tenth of an atmosphere, then this one would come up 50 centimeters and this one would go down 50 centimeters.

That's one meter of water.

One meter of water is equivalent to a tenth of an atmosphere, remember? Ten meters of water is one atmosphere hydrostatic pressure.

So if I can manage that, then I can generate an overpressure in my lungs of a tenth of an atmosphere and I could snorkel, then, at a depth of one meter.

Let me try it.

[inhaling deeply]

[exhaling]

[inhaling]

[exhaling noisily]

A meter is impossible.

You can have it maybe for a few seconds, but not for very long.

This is very disappointing.

So you cannot even snorkel at one meter.

If someone else wants to try, I will cut this off, so it's very hygienic.

Maybe some of you can do better.

You are the strong guy, remember?
Now, when you blow, don't make the liquid oscillate, because then you can squirt it out.

You should really try to take a deep breath and then push as hard as you can.

STUDENT: Okay.

LEWIN: Go ahead.

Strong man! You were about one meter and 20 centimeters.

This is great, terrific.

[class applauds]

How about sucking air? How much underpressure could I generate in my lungs? Well, we can measure it with this instrument.

[inhales]

I can go like this and, of course, the liquid will go the other way around.

Maybe I can do much better in terms of underpressure than in overpressure.

Let's try.

[class laughs]

About the same, a lousy one meter.

When you're underwater, it's never a problem to let air out, because due to the hydrostatic pressure, there is a force on your chest.

So letting the air out is easy.

The problem is to expand your lungs again to raise your chest.

That means the problem is that you can't...

[inhales deeply]

suck in the air, and so it's really the second experiment that I did that determines how deep you can snorkel underwater, and we found that it's about one meter.

So it's not the blowing out, but it is the...

[inhales deeply]

sucking in.

And so, this weekend--

and this is a true story--

I said to myself, "Gee, suppose I see someone...

"From the second floor, "I look down on someone on the first floor "having a great glass of juice or wine or whatever, beer...

and I would like to steal that by sucking it up with a straw."

[class laughs]

Could I do that? And the idea would then being...

I would be standing here.

The person being unaware of this glass down here with some great stuff in it...

This would be my straw, and I would just suck it up.

And I decided over the weekend that the straw could not be much longer, then, than about that one meter that you just saw--

that's the underpressure.

In fact, when you go to supermarkets and you buy yourself this stuff for kids, you know that this can be done.

You can suck up at least...

this is maybe 40, 50 centimeters.

That you should be able to do;
otherwise they wouldn't sell them.

But I didn't think that I could do much more than a meter.

And so I went to the supermarket and I bought myself a hose and I bought the hose to be two meters and I stood on the...

in the kitchen, like this.

And I had a glass there and I managed to do it.

And it surprised me.

So I went back to the super...

to the hardware store, got myself a three-meter hose... tube.

I knew for sure that there was no way I was going to do it, so I went to the second floor of my home--

I can look down on the first floor;
that's the way the house is built.

And I can't believe it, I can't believe it--

why I can suck so well.

It looks like it's almost a violation of what I showed you, and so I need some help from someone.

And I'm going to demonstrate how good I am in stealing someone's drink.

Could you assist me with that? Because you have to hold my straw in that juice, you see, because I will go very high.

And so you...

well, just stand here, and I will throw you the hose in a minute.

Stand a little bit on the side, so that the class can see you.

I'll see you shortly.

Hello.

[class laughs]

Okay, here's my straw.

Can you put it in there? Now, as I'm going to try to get this liquid up to me, I want you to think about why I can do that whereas there I could only do one meter.

There is something very special.

There's no way that in my lungs--

this is five meter almost--

there's no way that I could have half an atmosphere underpressure in my lungs; that is not possible.

So somehow I don't do it with my lungs, and maybe I won't even make it in the first place.

I can't talk when I do it.

I cannot talk.

There we go.

[class laughs]

LEWIN: Mmm.

Mmm.

[class laughs]

Okay, I drank cranberry juice, believe it or not.

Think about all this and try it at home, it's fun.

Buy yourself a hose that is even longer.

Now watch it...

watch it, hold it.

If I take my finger off, what do you think will happen with the cranberry juice? It will run down, there it goes.

Okay, thank you.

See you Wednesday.