Lighter-Than-Air Systems
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Lecture – 21
Introduction to Buoyancy

Okay, so we start the fourth lecture in which we discuss some concepts regarding static lift. It is important to discuss these concepts because we normally hear and read more about the dynamic lift generation wherein you need a relative velocity between the fluid and the body. But as you know in LTA systems, the static lift is generated even when they are stationary.

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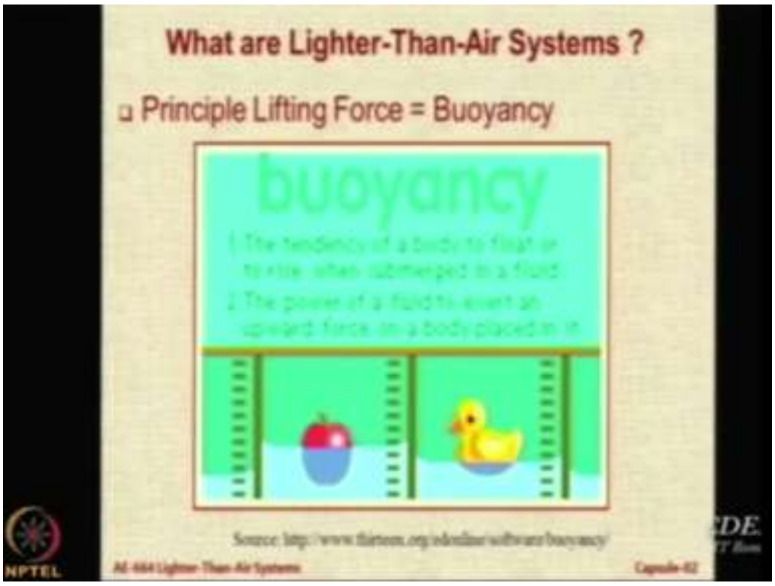

So if I ask this question about how our LTA systems different from normal systems or what are LTA systems, what would either basic quick answer? Yes. So we need to follow a protocol in which you raise hands and then I get to choose, everyone likes choice is not it? You have chosen this course as an elective. So, it is better that you raise your hands when I asked the questions. Okay, so we will start once again.

If somebody ask me a question what are lighter than air systems, what is the first thing that comes to your mind? Anybody would like to answer. The first thing that comes to your mind which are differentiating factor.

"Professor – student conversation starts."

Yes. Lift generation in the character. So what is so different? Buoyancy is lighter than air. Correct.

“Professor – student conversation ends.”
So the principal lifting force in case of LTA systems is buoyancy.

That is the main difference. The heavier than air systems also have some buoyancy, but the magnitude is very small and negligible okay. So you know we have studied in school about buoyancy and these are some pictures. Basically, it is a tendency of a body to float or to rise when submerged in a fluid. And when that happens we know that there is a force that is acting on the body.

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So this particular principle was given to us by Archimedes. So we call him as the genesis of buoyancy. Archimedes was a very famous mathematician. He has done many things other than just buoyancy. He has given many different solutions to us. So one of the questions I want people to answer in Moodle is apart from buoyancy what is the contribution of Archimedes? Okay, I noticed that only a few people are active on Moodle.

I would urge all of you to start using Moodle as an effective tool for interaction. That does not mean that you start logging into Moodle and uploading any junk that comes into your mind. We are not going to look at numbers, we are going to look at quality. So we are going to look at how well you put your points on Moodle. There are some basic guidelines. First of all anything that you put on Moodle, try to ensure that the source of that is also included.

You will notice below every picture below every material that I borrow from somewhere, I always put some source. So that protocol we need to follow even on Moodle page. We are not looking for your opinion or your thoughts on Moodle unless we asked you that specific question. We are looking for information. Second thing is going to Wikipedia and downloading material from there and putting it on Moodle is useful.

I also use Wikipedia a lot, but that is only a starting point, that is not the ending point. So go for material which is more detailed, more specific, try to put material which adds to our knowledge, not something that just replicates. So if you start using Moodle just for using sake, then it will be detrimental against you. It is better that you apply your mind, post interesting material, search for photos, videos which are illustrating the concept very well.

Much of the content that you see has come by diligent search by my students. But the beauty of PowerPoint is you can always update it, you can always change it, wo that is why I use PowerPoint. It is easy for me to go to the blackboard and derive the things. I use PowerPoint because it allows me to dynamically alter the contents every year to make it more interesting, to bring in some new concepts, etc.

So help me, when you post material on Moodle, you help me in making the course more interesting. You help in clarifying the concepts to others and also you help in enriching the course. So this is what happened to our friend Archimedes when he was having a shower. During the bath, he realized that when he goes inside the bathtub some water spills out and he figured out that a body will float only if the mass of the fluid displaced will be more than the weight of the body that is floating.

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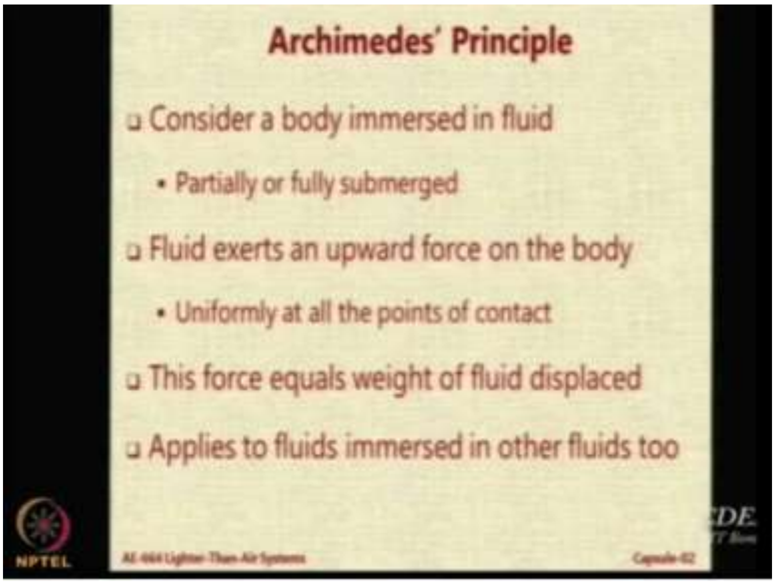

So, he gave us the Archimedes' principle which says let us consider a body which is either in fully submerged condition or in partially submerged condition, it applies to both. The fluid exerts an upward force on the body and this force is distributed roughly uniformly at all the points where the fluid touches the body okay. And this force is equal to the weight of the fluid displaced. And this particular principle applies to not only bodies immersed in fluids, but also fluids immersed in fluids and oil droplets submerged in water or in some other fluids.

So, now I would like to ask you to again use the Moodle page to give us examples of buoyancy in which there is a fluid submerged in a fluid. These examples are not very easy to come by. So, I would like you to go and search fluids within fluids, how does the buoyancy act and if there is any interesting example or application of this particular principle of action of buoyancy of fluids on fluids.

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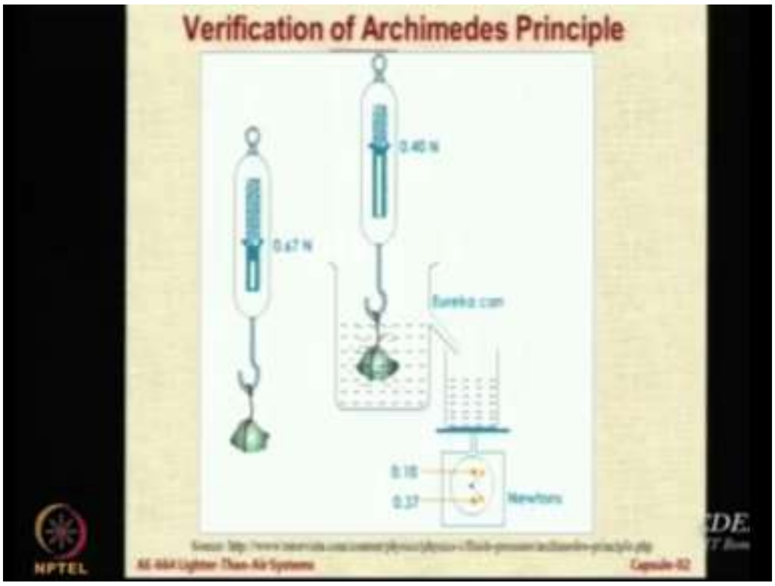

Let us see how we can verify this principle through a small school experiment. So, you can take a spring balance and on that spring balance you can load a small object such as a stone shown in this figure. And you can see the readings. For instance, the reading in this case is 0.67 Newtons. So that means the weight of the stone is 0.67 Newtons. Now you take a beaker, fill it with water in such a way that the level of the fluid is just below the spill point or below the spilling nozzle.

Such a can is called as a Eureka can probably to commemorate Archimedes and his Eureka moment, I do not know, but it is called a Eureka can, right. So, that means what will happen is the moment fluid is displaced, all the fluid will come out of this nozzle and fall below. So what you do is you take our stone and now submerge this stone inside this particular can, obviously some fluid will spill and there will be a reading on the spring balance.

So the reading of 0.67 now shows 0.40. Assuming no other forces acting on the stone, can we assume that the vertical buoyancy acting on it or the buoyancy force acting on it is different between the two okay. Now to verify that you take a beaker on a weighing balance, take the reading of the empty beaker and take the reading of the beaker with the spilled water or the displaced water. So the reading was 0.1, it becomes 0.37.

So it shows that if the beaker weight is point 0.1, 0.37 means the difference is 0.27 and that matches exactly with. So this experiment we have done in school, I remember. Incidentally, I went to my school day before yesterday. I was just traveling and I just went to my school, I met the principal. And I remembered, actually I remember this experiment done in the science laboratory. So then I thought let me recreate the experiment here in the classroom through a small animated sequence.

We all studied this in school, so we know. But what can you learn more about this? So what is this 0.27? Is this the weight of the stone?

"Professor – student conversation starts."

Yes. Loss in weight also. So what can we learn about the stone from this experiment? Volume. Volume of stone. How much is the volume of stone? The volume that we got in the Eureka beaker. But that is true if the density of the stone and the fluid is same.

The volumes will match if the density matches. Sir volume of the stone is equal to the volume of the water in the, correct. So you are right. The volume of the stone is equal to the volume of the water displaced. So if you want to calculate the stone volume, you can work out from this. What about the weight of the stone? We already know because you have taken reading okay, fine.

"Professor – student conversation ends."

So I am just trying to see if you are attentive because it is early in the morning from IIT students at 11, right.

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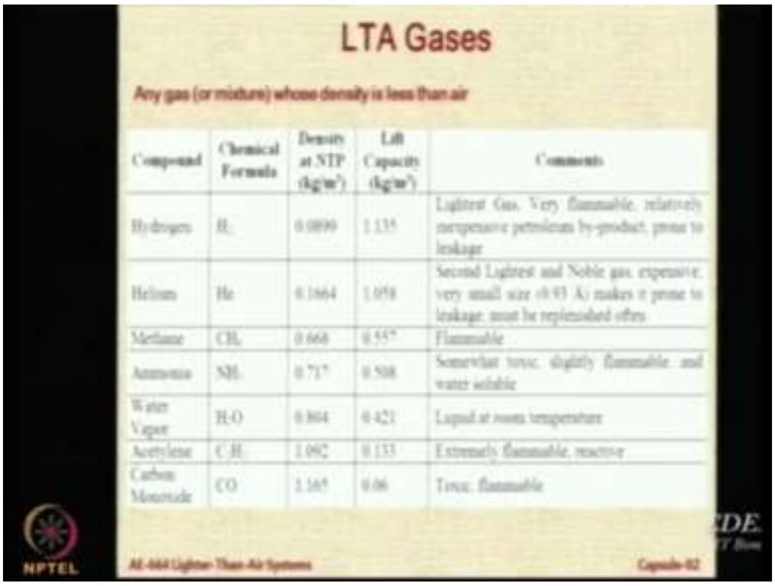

LTA Gases

Any gas (or mixture) whose density is less than air

Compound	Chemical Formula	Density at NTP (kg/m³)	Lift Capacity (kg/m³)	Comments
Hydrogen	H_2	0.0899	1.135	Lightest Gas. Very flammable, relatively inexpensive petroleum by-product, prone to leakage
Helium	He	0.1664	1.058	Second Lightest and Noble gas, expensive, very small size (0.93 Å) makes it prone to leakage, must be replenished often
Methane	CH_4	0.668	0.557	Flammable
Ammonia	NH_3	0.717	0.508	Somewhat toxic, slightly flammable and water soluble
Water Vapor	H_2O	0.804	0.421	Liquid at room temperature
Acetylene	C_2H_2	1.092	0.133	Extremely flammable, reactive
Carbon Monoxide	CO	1.165	0.06	Toxic, flammable

Now gases which are lighter than air, they are all candidates for the LTA systems. And this table tries to summarize important data regarding these gases. So, top of the list is hydrogen, the most preferred LTA gas if you can live with its highly combustible and explosive nature. So, this particular gas as we can see under the NTP conditions it has a lifting capacity of around 1.135 kilograms per meter cube.

Which means if you take a device or a balloon or any other container you put 1 meter cube of hydrogen in that the vertical force acting on it will be 1.135 kg. This lifting capacity reduces as we go below, for helium it becomes approximately 1 kg per meter cube. So, the ballpark in your mind should be that the lifting capacity of helium is approximately 1 kg per meter cube. Down the list you go you get gases like methane, ammonia, water vapor, acetylene, carbon monoxide.

So, carbon monoxide which is present in the exhaust of most automobiles is also an LTA gas, a candidate LTA gas, but the lifting capacity is so, so small that for it to be of any actual use is very limited. I mean it can hardly be of any use to anybody okay. What about hot air? So let us at demonstration. Let us have a look at the demonstration of the power of hot air. So what we have done is we have tried to set up an experiment using the items available.

(Video Starts: 12:10)

So, this is the standard test that is present and this is a standard bin bag. So what we have done is we have just kept this bin bag over a toaster and we have switched it on. Very soon hot air currents because there is no bread inside, so hot air currents will start flowing and start filling the envelope okay. And the air inside because it is heavier than the gas than the hot air is, I can feel it, automatically coming out.

So it is displacing the cold air by the hot air generated okay and then a time will come when the amount of hot air will be sufficient to generate the lifting force enough to lift this particular balloon. So, we need to wait, it takes time. Remember this room is air conditioned. So, the same experiment if you do in some other room you will find there is a difference in the timing. Now observe very carefully because you are going to do an assignment of the same type very soon.

So it is important that you pay attention and look what is happening. So I think the envelope is getting filled up because you can see it is slowly acquiring the inflated shape. It was in a folded condition when it was put. Now it is acquiring inflated shape. So we need to see. So it is designed to switch off when there is no bread inside of for a long time, so that is why it is generating hot currents but switching off subsequently.

So what he is doing is he is trying to test the buoyancy level because by experimentation he knows at under what condition there is enough buoyancy for it to hit the ceiling. Our target is as possible we want to hit the ceiling of this room. It is not easy, you can try it. It is not very easy to generate so much buoyancy using just hot air to travel this distance because as soon as it goes up hot air will start coming in.

And that will change the temperature of the gas inside and hence its buoyancy. There you go. See it starts turning and it starts falling okay.

(Video Ends: 15:25)

So round of applause for our friends for a nice demonstration about buoyancy.