**Cellular Biophysics**
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**Tutorial 5**
**Fluid Mechanics and Reynolds Number**

Hi, as we were discussing earlier, we have gone over the theory of fluid mechanics and Reynolds numbers and their role in cell movement as well as basic laws that we can perform it.

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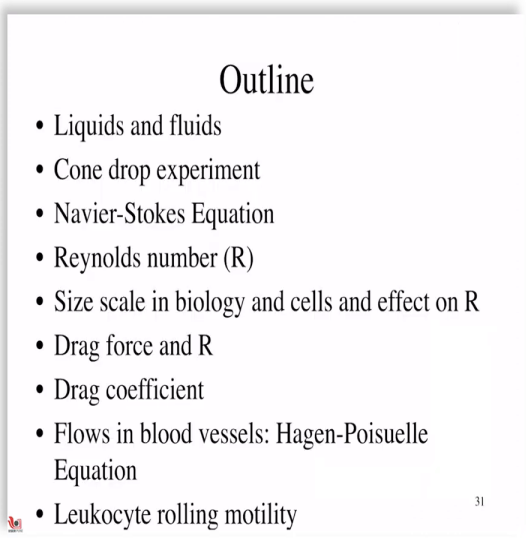


For now, I am going to go over a summary of what we have already spoken about to dive a little bit more into the detail of the distinction between the terms liquid and fluid, so in a way a definition these may seem at the outset similar or even the same and I hope you will see what the distinction is. I will elaborate a little bit more on the cone drop experiment that I have discussed with you as a possible experiment you can do at home, I will move on to the Navier-Stokes equation.

We discussed Reynolds number in the context of size scale in biology, talked a little bit about the original experiment of drag force, going to drag coefficient and finally discuss an interesting problem of flowing blood in blood vessels and the equation of Hagen and Poiseuille that allows us to make very interesting inferences about the cell biophysics of blood flow inflammation and wound repair in terms of Leukocyte, rolling, motility leukocytes as you know white blood cells.

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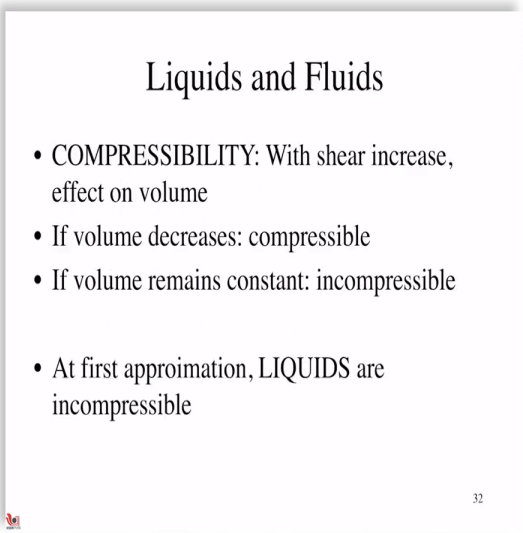


So, let us get, so what is the difference between liquids and fluids? The idea is that compressibility is defined as a change in volume with increasing shear. So, a material whose volume decreases with shear is compressible, elastic solids are an example, if the volume remains constant it is incompressible at a first approximation liquids are incompressible liquids therefore are incompressible.

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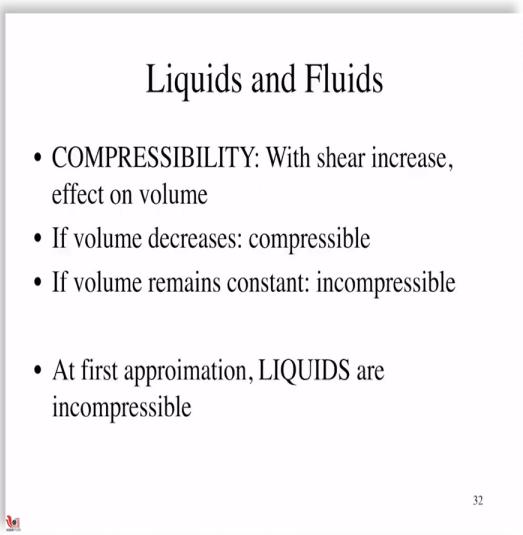

Fluids is a general term and a continuous medium which has the property when in dynamic equilibrium the shear stress must vanish at every point and the pressure function must completely specify the stress tensor pressure function is equal to stress tensor, now the interesting part is that gases and liquids can both be considered fluid like this is why the use of fluid mechanics is also used in atmospheric problems as well as what I spoke about earlier namely the cone drop experiment as much as they are useful for liquids themselves.

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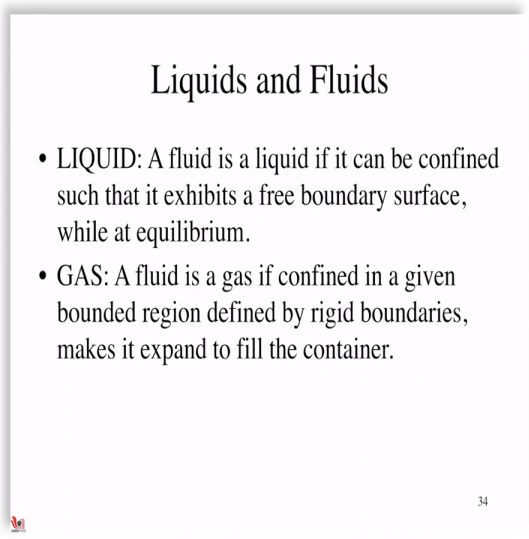


Now, given these properties a liquid there is a fluid that can be confined such that it exhibits a free boundary surface while at equilibrium, while a gas is a fluid if confined it is defined by the rigid boundaries and its volume changes it expands to fill the container pressure changes volume changes liquid is incompressible gas is compressible.

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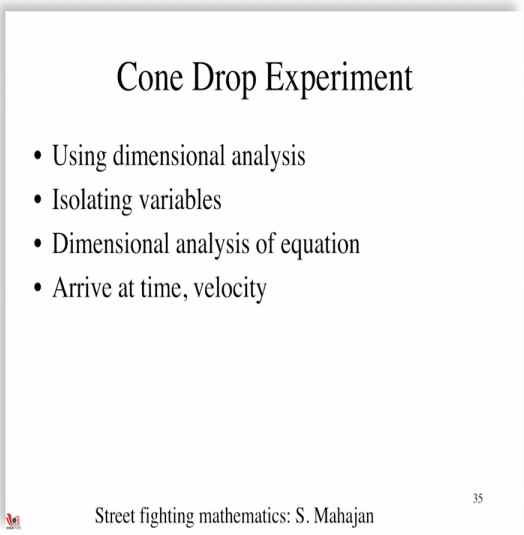


So, coming back to the cone drop experiment there are ways by using what is called a dimensional analysis and I referred you to a beautiful textbook which is online and free available by Sujra Mahajan called street fighting mathematics, isolating variables, dimensional analysis of the equation and arrive at a velocity. So, you remember I said that you need to find the terminal velocity well this is how you can write it the equation for it derive it in other words.

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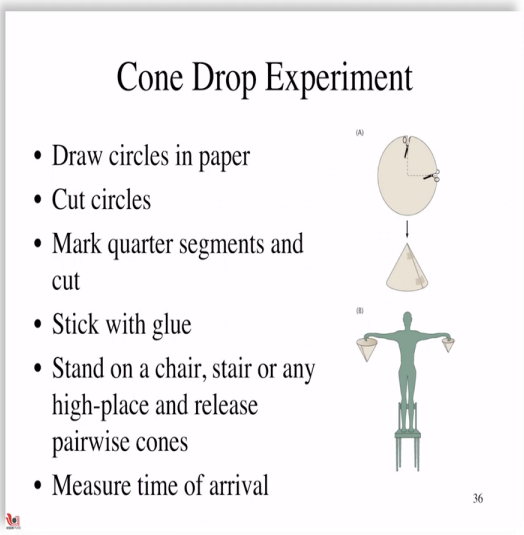

For the experiment you can instead of using a square you can use a circle of paper you can use your compass that you have from school geometry box or ‘katori’, ‘vati’ and cut circles mark quarter segments cut stick with glue stand on a chair release, the point is to measure the time of arrival as you remember.

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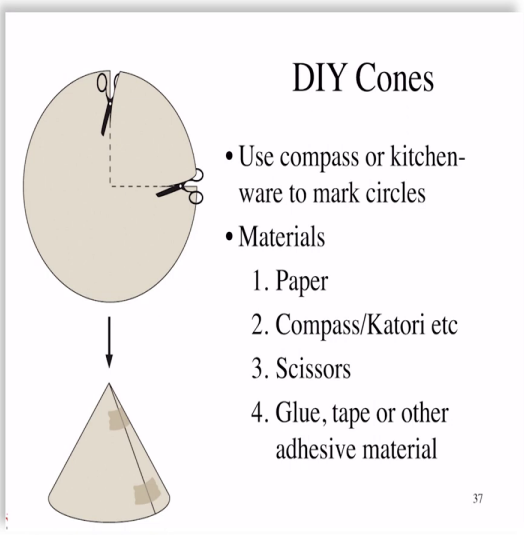


So, the diy cones the do-it-yourself cones use a compass or kitchenware to mark circles kitchenware can include ‘katories’, larger vessels it does not have to be two times as large you want to have a systematic effect you can do this but it just needs to be larger or smaller, obviously you must use the same paper because otherwise the control is not there.

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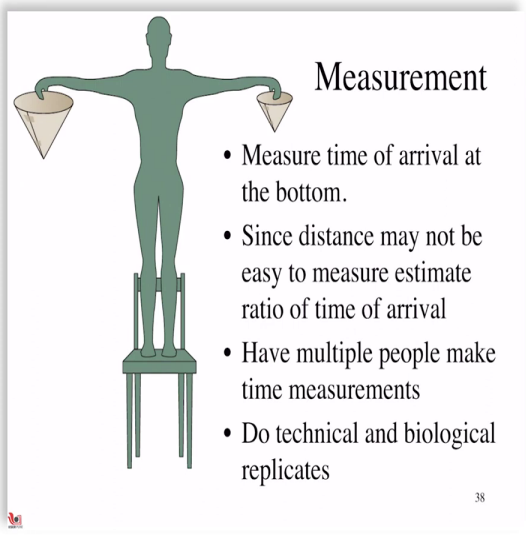


The measurement must be at the time of arrival after release how much how many seconds milliseconds it takes.

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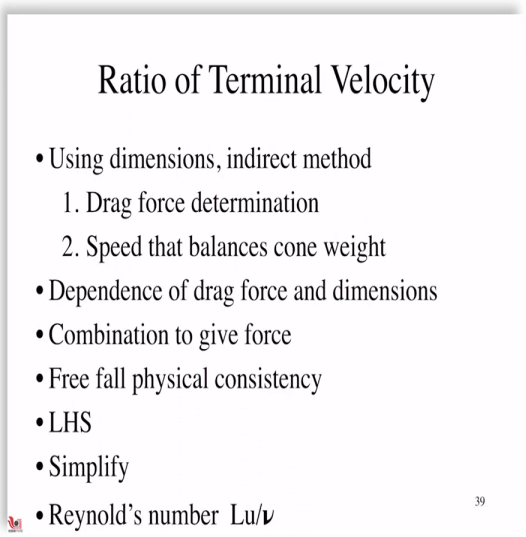


Since the distance may not be easy to estimate, we are only looking at the ratio so therefore we only want the velocities for the derivation for the measurement we take the ratio of times because time ratio is equal to velocity inverse of velocity ratio have multiple people make measurements, so that you have a control meaning because one person did the measurement and their

measurements are biased you can take another person and another person and remember reproducibility.

So, we do technical as well as biological replicates, technical replicates means that we repeat the experiment 3 times, 10 times, biological replicate this is an interesting point means we do it on two different days or a different person does the experiment and we try to see if we get the same answer. This is a fundamental problem in measurement in biology in general which is that it may not always be possible to do many replicates.

So, in physics typically when they say replicates they are talking about 1000, 10,000 measurements of the same thing. In biology if you open a research paper you will find that the replicates may be in the 5s and 10s maybe 30s if you like experimental data. So one of the aims of quantitative biology is to also know how many measurements are reliable from the perspective of error margins.

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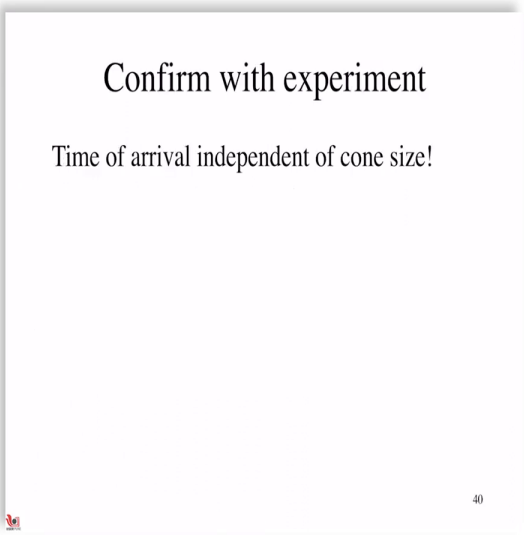


To get the ratio of terminal velocity in theoretical terms, we need to use dimensions indirect method dependence drag force and dimensions combinations to give force, free fall physical consistency left hand side right hand side equivalence and simplify Reynolds number as you remember is a Lu by ν and when we compare with experiment we will find that the time of

arrival is independent of cone size. So, I already gave you the answer now, now you need to check why and whether you can actually find the same thing.