Fluid Mechanics

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Lecture – 1

Fundamental Concepts of Fluid Flow

Hello, there everybody. In this video course on fluid mechanics the main objectives are introduce fluid mechanics and establish its relevant in civil engineering develop the fundamental principles demonstrates how these are used in engineering, especially in civil engineering field. This video course consist about forty lectures presenting the concepts theory and applications.

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The important topics covered in this course include the fundamental concepts of fluid flow, fluid statics, kinematics of fluid flow, dynamics of fluid flow, laminar and turbulent flows

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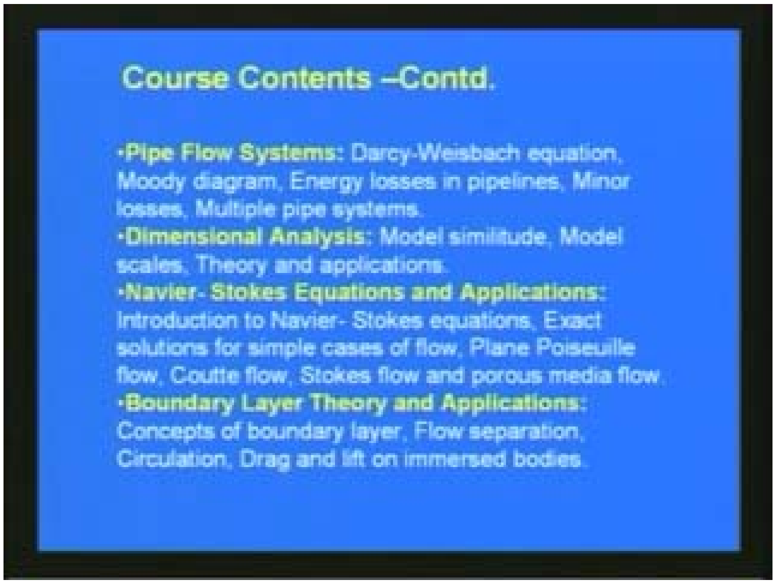

Pipe flow systems, Dimensional analysis, navier stoke equations and applications and boundary layer theory and applications.

So in these forty lectures, all this topics will be covered with various examples with theories and fundamental principles. The important references used in this course include the fundamentals of fluid mechanics by Bruce R Munson and others, the fluid mechanics with engineering applications. Daugherthy and others, fluid mechanics the

Douglas and others, fluid mechanics by Granger, fluid mechanics by streeter and V.L.Wylie and mechanics of fluid by shames.

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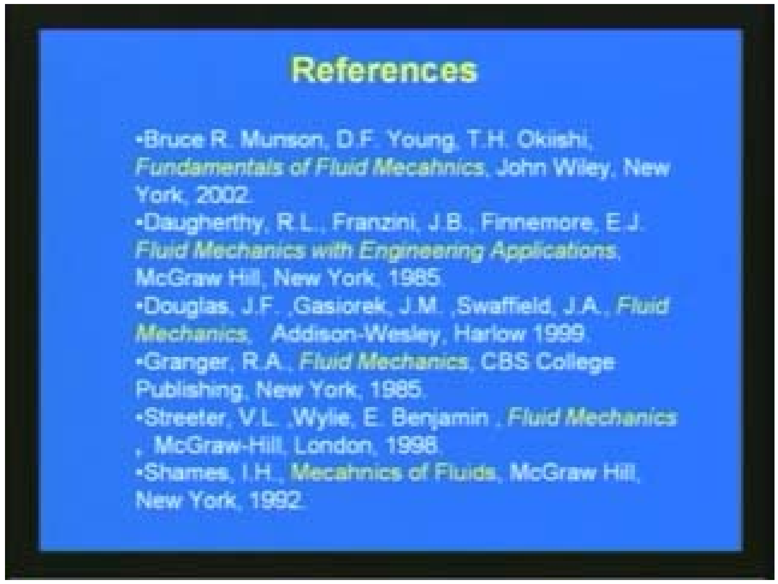

In this introductory lecture today, we will discuss mainly the fundamental concepts and fundamental properties and fundamental definitions of fluid mechanics.

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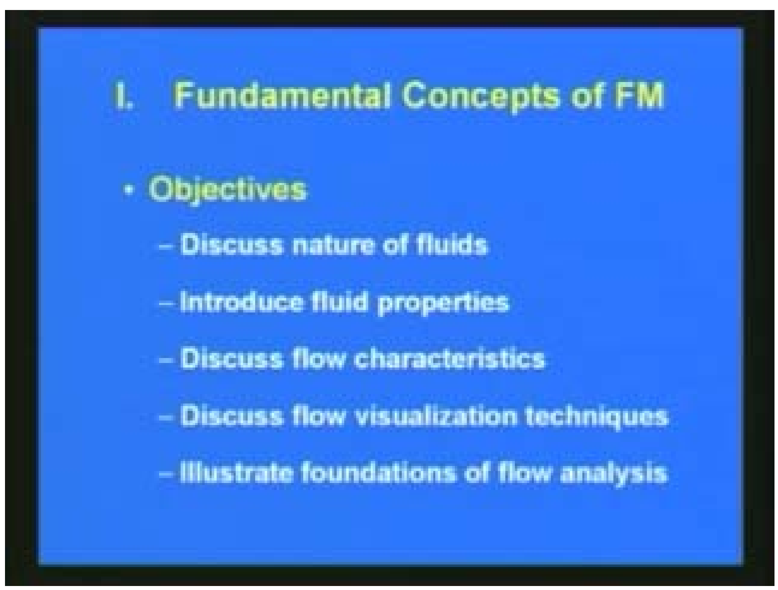

So the main objectives in this lecture are to discuss the nature of fluids to introduce fluid properties; discuss the flow characteristics; discuss the flow visualization techniques and illustrate the foundations of fluid flow analysis.

So, all of you know the importance of fluid mechanics it is the most important subject in all science including physics, chemistry, biology and mathematics.

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And all branches of engineering involving civil engineering, mechanical engineering, chemical, metallurgy and aerospace and all this science branches and engineering branches will be studying fluid mechanics in one way or another way and its related theories and applications.

So, first we will discuss what fluid is and then what are the difference between fluids and solids and how the fluid is behaving and what are the fundamental properties of fluids. So what is a fluid, we can define a fluid as a substance capable of flowing, so it can be gases or liquids, so here you can see a glass of water.

So when we apply some force, some shear force especially it will deform or it will start to flow like you can see in this glass of water or here you can see bottle of water when we apply some shear stress or some shear force it will start to deform are it will start to flow.

So, this fluid is the most vital for all forms of life as you know we will be using fluids as water or liquids we will be drink using for drinking purpose it will be used for say all types of life activities including bathing, taking bath whether drinking water or irrigation purpose or navigation purpose or recreation purpose for all purposes fluid say in liquid form of water is used or in the form of gases the air which we are breathing or all other aspects of life is required this fluids either in liquid form or gases form.

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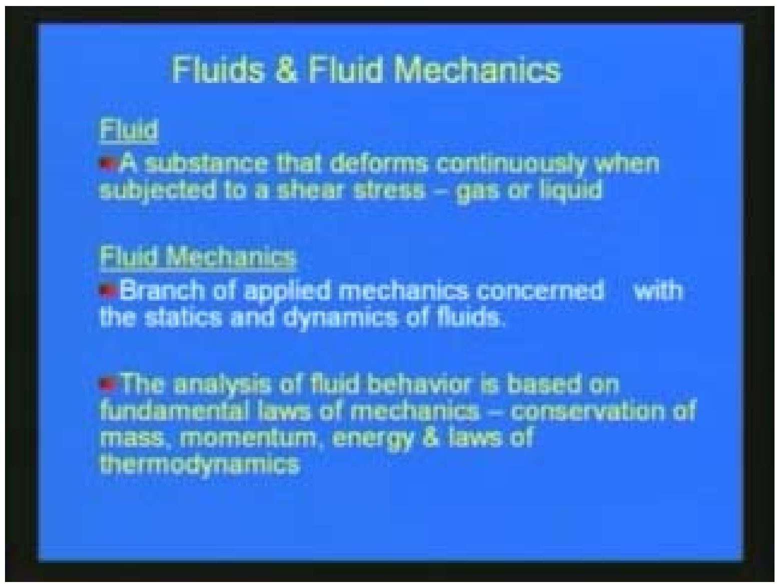

So, as I mentioned fluid always deforms continuously when subjected to a shear stress whether it is gas or liquid. So, fluid mechanics is mainly the study of what is happening when some forces applied on a fluid where it is at rest or it is emotion.

So fluid mechanics can be mainly divided in to statics and dynamics. So, statics will be discussing what is happening, the fluids or liquids especially in the condition of the static that means which is not moving say for example if we consider the water store in a reservoir or in tank, so it is static it is not moving.

So, that branch of fluid mechanics study is called statics and if we consider flowing water say for example in a river flow is concerned over the pipe flow is concerned it is dynamics of fluids are the fluid is moving and hence a study is called dynamics. So, in all this we will be analyzing the fluid behavior based on various fundamental principles.

So, the fundamental principles using mechanics such as consideration of masks, consideration of momentum, consideration of energy and a loss of thermodynamics. All this fundamental principles are very much used in fluid mechanics also. So, let us see what is the major difference between fluids and solids? Here, in this figure.

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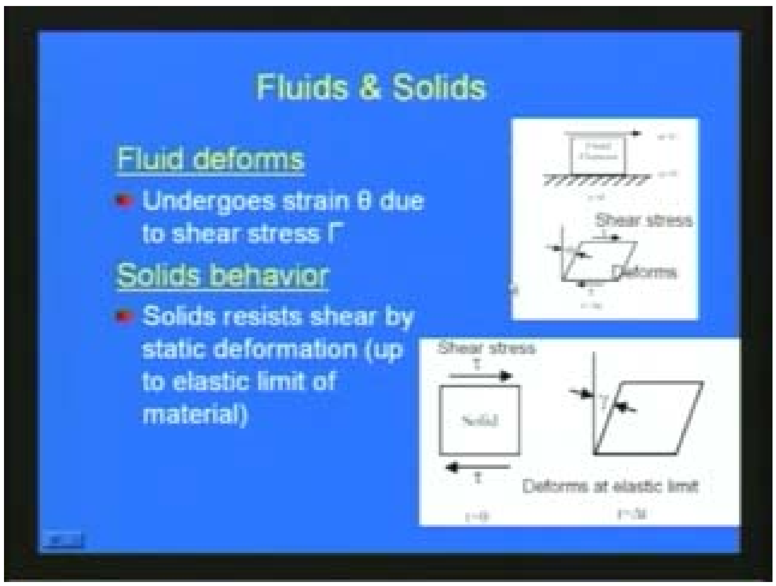

In this slide you can see a fluid element, so when we are applying shear stress it is deforming, say an angle theta like this it deforms and it undergoes strain theta due to the shear stress and if you consider solids and solid discontents say here you can see a small ball.

So here even if you applied some shear stress it will not deform to certain level that means and it reaches its elastic limit it can sustain the shear stress and it will not deform. So as you can see here in this slide, so then a shear stress is applied on a solid element it will not deform to certain extent and say when it reaches the elastic limit it is starting to deform as in this figure.

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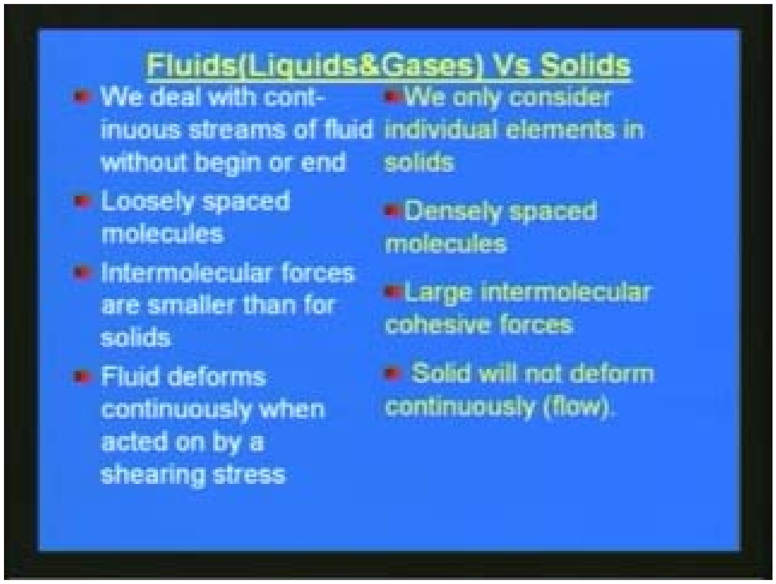

What are the major differences between say fluids including liquids and gases and solids? So in fluids we deal with continuous streams of fluid without begin or end. So for example if we consider the watering this bottle, so you can see it can continuous from one end to another so that we have to analyze by using the continuant concept. But as far as store is concerned, mainly we will be using say include the elements when we are applying a force like this a point force is applied for load is applied here.

So what is happening particular, say include the elements in solids so that is the major difference between solid and fluids and you can see that in say in fluids the molecules are usually place or usually spaced so that it is tatting to flow by just applying some shear force.

But as far as, so it is concerned the molecules are densely packed so that the deformation takes place only after certain limit say elastic limit and as far as full disk concerns intermolecular forces are smaller than for solid that is why the fluid is trying to flow by applying a small shear stress.

But as far as the solid is concerned, here is large intermolecular cohesive forces and hence you have to apply large shear stress large force to make it some deformation and as far as fluid is concerned fluid deforms continuously when acted on by shearing forces but solid will not the deform continuously. So these are the major difference differences between the solids and fluids. So, even though we are using the fundamental principles of mechanics in fluid mechanics, so this differences we have to consider in the development of all theories and when we are applying this theories we have to take here all this differences between the solids and fluids since we will using most of the time the fundamental principles developed in mechanics.

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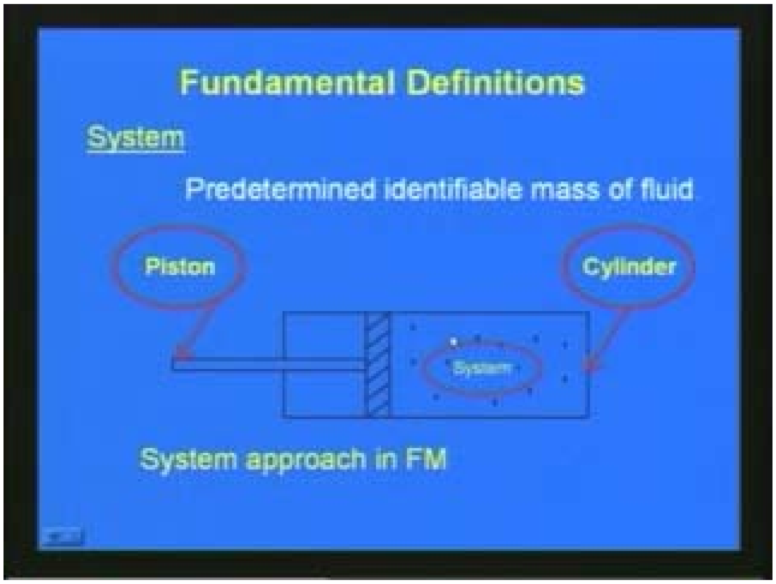

Now we discuss the fundamental definitions in fluid mechanics. So, first we will discuss what we say system. So as you can see in the slide a system is predetermined identifiable mass of fluid say here you can see a cylinder and there is a piston and what is existing the fluid liquid or gases are existing in this system.

Say for example, here if you consider a bottle of water so the system what is existing the volume existing in this say one liter of water including here in this case water and air so this is the system so system approach is very important (12:12) in fluid mechanics since fluid is always trying to deform with respect to shear force or shear stress and trying to flow.

So generally all the analysis will be for a particular system that means the particular say volume in a piston as shown in this slide or are what is shown in this bottle of water say that means with in this space which is predefined space what is happening in between that is will be generally discussing. So this is called a system approach in fluid mechanics then another important definition is the control volume.

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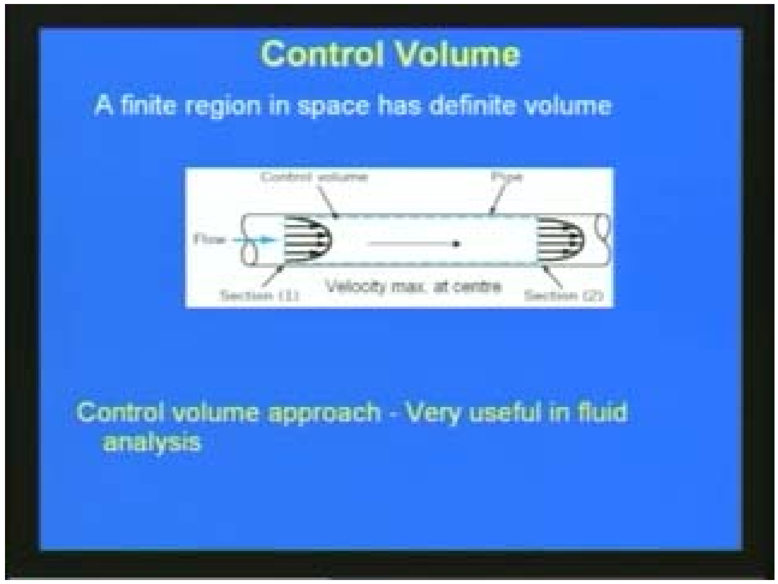

Say control volume as you can see in this slide a control volume is a finite region in space and has definite volume. So here you can see a pipe so here between section 1 and section 2. So, the fluid existing that volume that is control volume, so that we are considering so what is happening in this is the major analysis which will do, so this is the control volume approach used in fluid mechanics. So say here if you consider a pipe like this so when the pipe flow is there between one sections to another, what is happening so that is the control volume approach.

So now as in mechanics and all branches of science and engineering in fluid mechanics also the fundamental quantities like length, the dimension of which is L and unit is m and other dimensions like mass the dimension is M, unit is kilogram and a time say in unit in second and force unit is Newton and temperature unit is degree centigrade in the system international units.

So these are the fundamental quantities used in fluid mechanics and based up on this fundamental quantities we will be deriving the secondary dimensions say for velocity or acceleration or force or other say other type of quantities like viscosity and say the acceleration and all this quantities will be derived based upon the fundamental quantities of mass, length, time and the temperature unit degree centigrade. So generally when we derive this fundamental quantity we will be using continuum concept.

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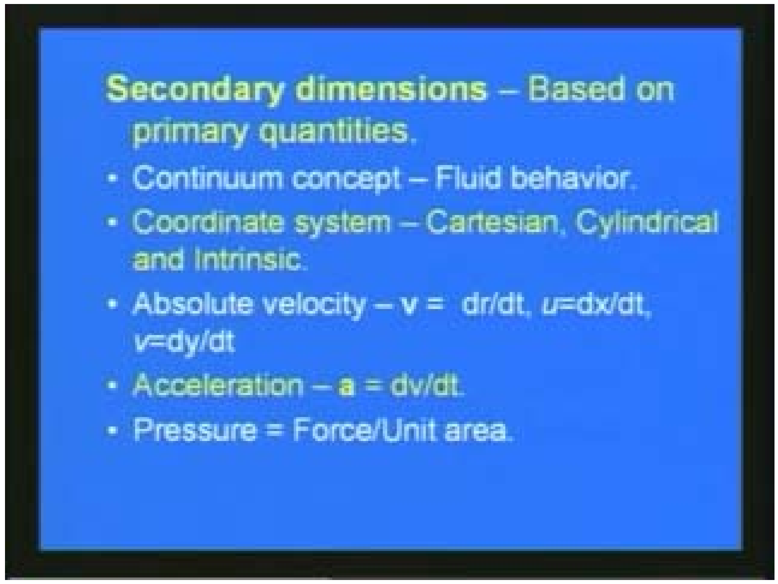

Since the fluid is say as I mention the flow is continuous are the molecules are very much say we detect the continuum approach, so all the fluid behavior is based up on the continuum concepts and theories are derived base upon that and as far as coordinate system is concerned generally in all this lectures we will be using Cartesian or cylindrical and intrinsic coordinate system and then say as I mention the other units will be derived based up on the secondary dimensions will be derived based up on the primary units and in fluid mechanics we will be using two kinds of approaches or two kinds of description.

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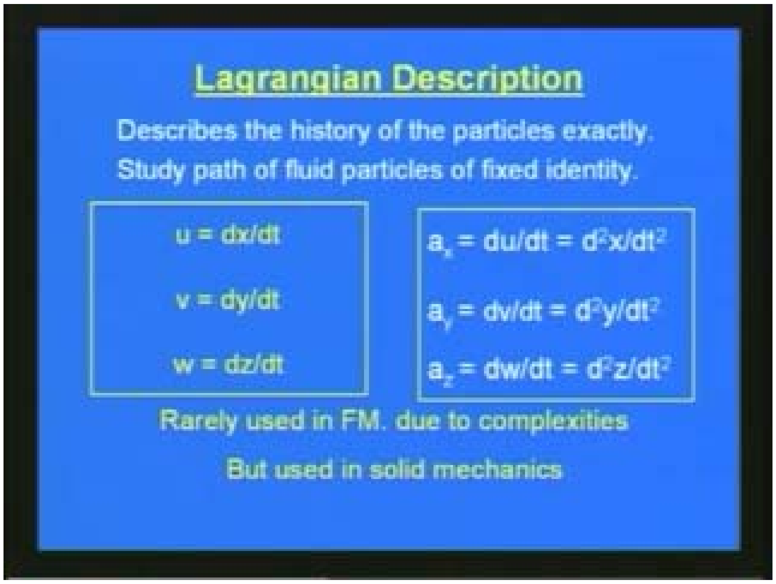

First one is called lagrangian description, so in the lagrangian description we discuss the history of the particles exactly, that means say we study the path of fluid particles of fixed identity so for example if you consider a flow say from one section to another we will be tracking some of the particles and then what will be happening to that particles from time to time.

So that is the approach called lagrangian approach. So, in this approach say the velocity in xyz direction u can be express a dx by dt, v can be expresses as dy by dt and w can be expressed as dz by dt. So similarly the acceleration can be expressed as a_x in x direction a_x is equal to du by dt or that is equal to d square x by dt square and similarly in y and z directions. So here in this velocity and acceleration expressions we can see that it is mainly what is happening with respect to time that is what will be analyzing.

So this concept is rarely used in fluid mechanics due to the various complexities so here you can see the fluid is moving continuously say one section to another section so to track certain particles under then what is happening with respect to time that kind of analysis is very difficult in fluid mechanics, but this lagrangian concept or lagrangian description is mainly used in solid mechanics. Second kind of description is called the eulerian description.

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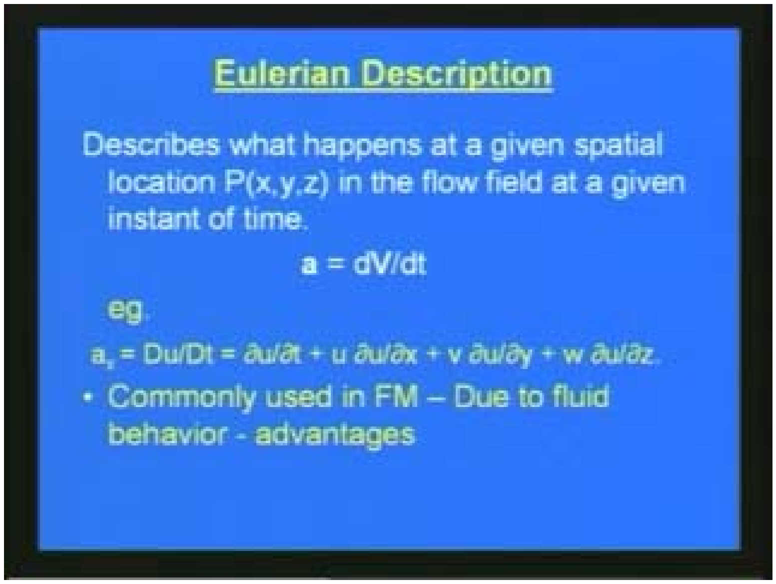

So here what we are doing is we will be analyzing what is happening between two sections at a given spatial locations in the flow field what is happening say for example if we consider a fluid flow in a bottle like this what is happening for the pipe flow what will be happening one section so particular section with respect to xyz dimensions will be considering and then what is happening for various fluid particles at the particular section with respect to time.

So that the acceleration can be written as a is equal to the total derivative dv by dt. So, a_x is the acceleration x direction can be written as du by dt or that is equal to del u by del t plus u into del u by del x plus v into del u by del y plus w into del u by del z, so this concept is very much used in fluid mechanics.

Since this has got number of advantages since fluid is moving continuously so in a pipe flow in a open channel flow so if you consider a particular section and then what is happening with respect to space and time what is happening so that kind of analysis is what will be doing in this eulerian description and that is very much used in fluid mechanics.

Now, at the beginning we are discussed, say a fluid is getting deformed with respect to shearing forces.

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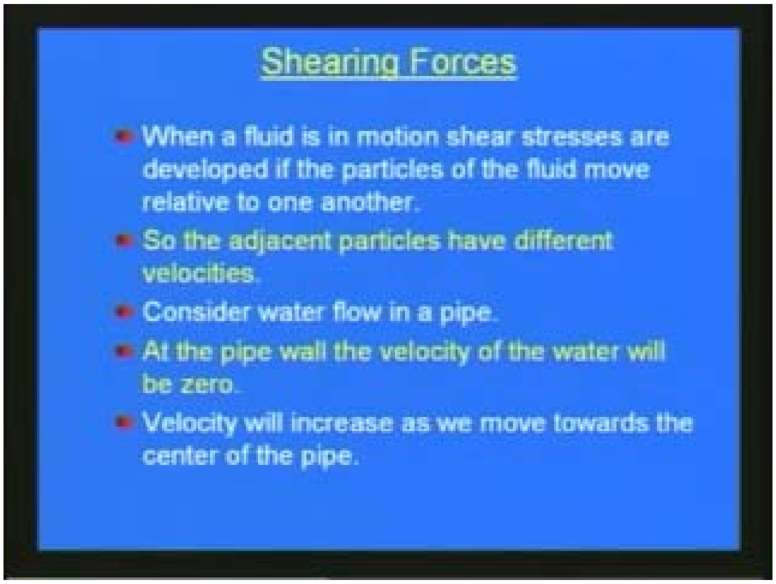

So, shearing forces are very important fluid mechanics, so when a fluid is in motion shear stresses are developed if the particles of the fluid move relative to one another. So since fluid is moving so you can see that say with layer there would be shearing stresses between the fluid say if you consider a section say between the layers there will be the shearing forces shear stress will be there.

So the adjacent particles have different velocities so for example if you consider water flow in the pipe is consisting of more pipes like this say the flow is considered say in a pipe flow so at the pipe wall the velocity will be zero in this say this solid the pipe say it is not moving. So that the velocity will be zero at the pipe wall and then it will be increasing as we move to watch the centre of the pipe.

So here in this slide you can see that.

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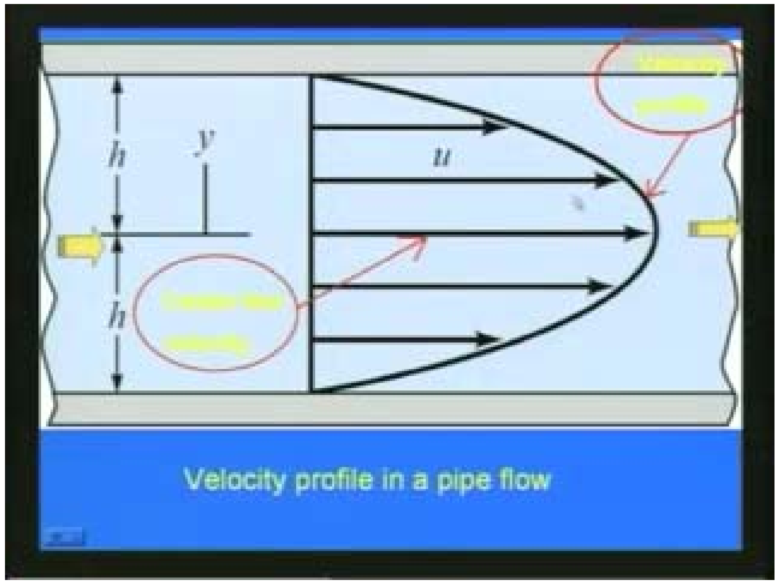

Say here in a pipe flow the water is flow from left to right. So here since this shearing force effect say or the nonstick condition so at the pipe wall here the velocity zero and the other end also the velocity zero and you can see the at the center line the velocity is maximum and you can see there will be a parabolic profile like this as far as pipe flow is concerned..

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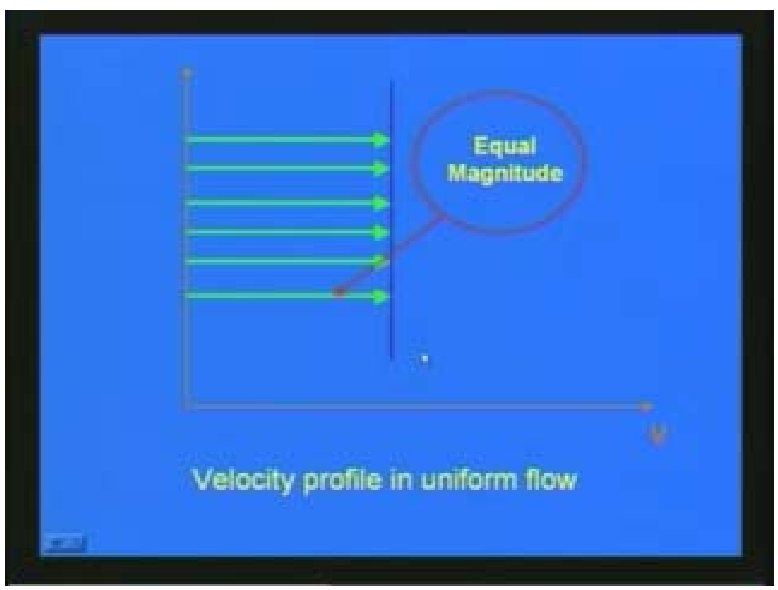

But if you consider say in a uniform flow like this say if there is no solid wall or if do not consider the effect of the solid wall then you can see as in this slide the velocity is equal in magnitude. So that the velocity profile is like this slide and that is called the uniform flow, so some times in open channel flow we consider this kind of uniform flow and now we will discuss some of the important fluid properties, as I mentioned mass is one of the primary quantity which is one of the most important properties of fluid and then another important property called density.

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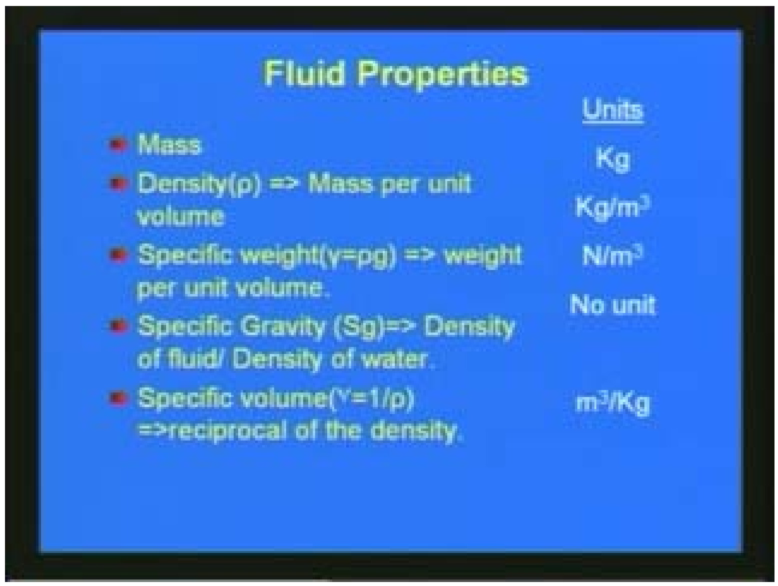

So density it is the mass per unit volume and it is expressed as kilogram per meter cube and another important unit is called the specific weight which is the weight per unit volume and that is generally expressed as gamma is equal to row into g, where row is the density, g is the acceleration due to gravity and its unit is Newton per meter cube. Another important property which will be using called is specific gravity and it is the ratio of density of fluid to density of water and then another property is the specific volume, it is the reciprocal of the density and its unit is meter cube per kilogram.

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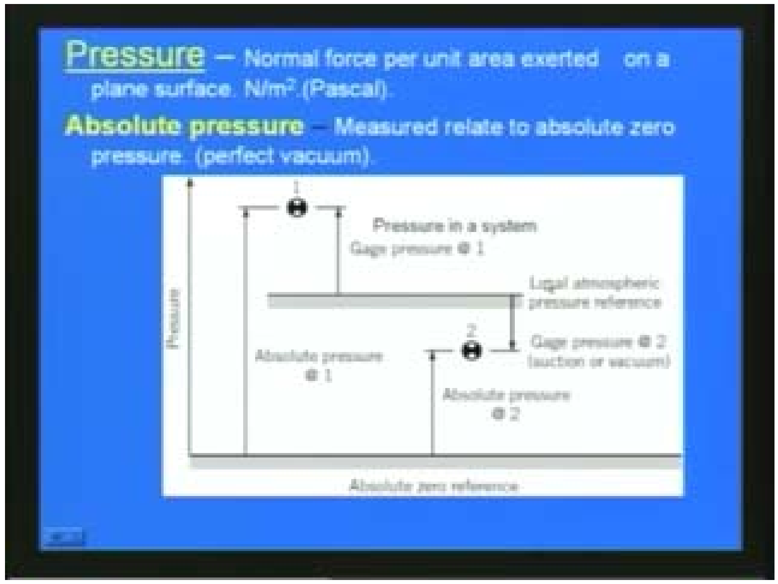

Another important property is called the pressure the pressure is the normal force per unit area exerted on a plane surface. So if you consider say a plain surface like this when we are applying normal force the force per unit area is the pressure and its unit is Newton per meter square and expressed as Pascal. This pressure can be expressed say like absolute pressure when we are measuring with respect to certain edge for local atmosphere pressure reference is put then we can express as gage pressure absolute pressure and also vacuum pressure as differentiated in this slide.

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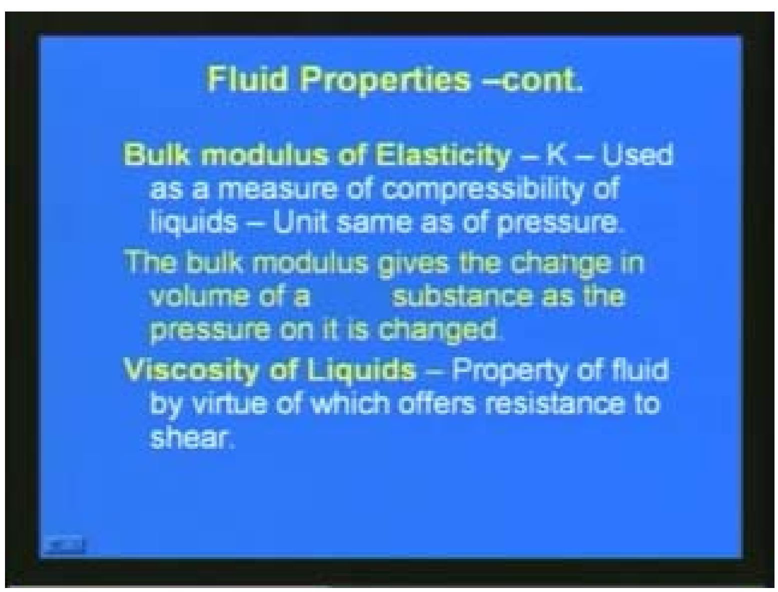

And then another important property is the bulk modulus of velocity expressed as K, it is the measure of compressibility of liquids and unit is same as of pressure. So especially we are dealing with gases so the compressibility is very important and also the compressible fluid compressible liquids this by modulus of velocity is very important.

The bulk modulus is the change in volume of a substance as the pressure on it is changed. Generally these expressions with respect to this solids and also with respect to liquids also we can express and another important fluid property is the viscosity of liquids.

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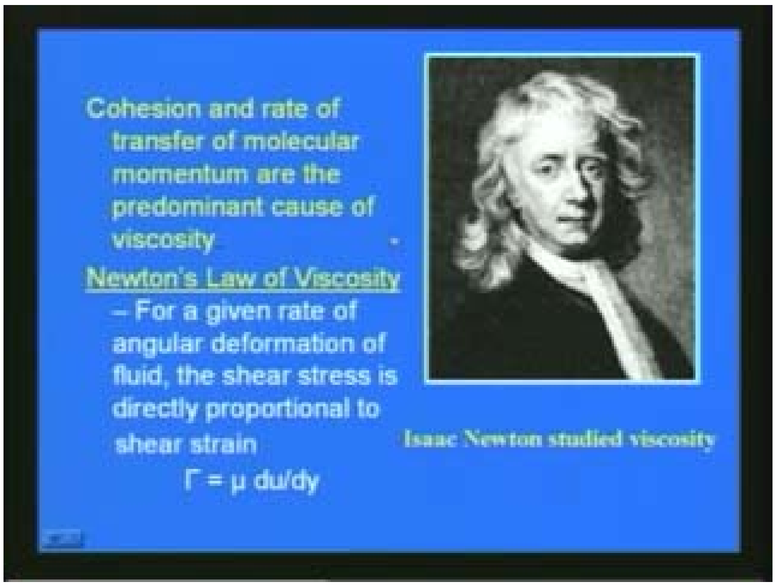

So this property of fluid by virtue of which offers resistance to shear so this viscosity has been observed by famous scientist Isaac Newton and he was answered the cohesion rate of transfer of molecular momentum are the predominant cause of viscosity and he was derived the Newton's law of viscosity. So here you can see that if you consider water so it has got one type of viscosity and if you consider say other kinds of viscous liquid say for example here have some honey.

So if you just try to power this honey on a plate like this you can see that since it is highly viscous the movement itself is very slow and then that of shear stress is there between the layers. So that is the difference between say viscous fluid and say when the viscosity is varying just like in a water and honey.

So Newton with after studying this property, he derived the fundamentality equation of Newton law of viscosity which can be expressed as or he observe that the shear stress is proportionally to the shear strain the du by dy and he derived the equation tow is equal to mu in to du by dy where mu is the coefficient of viscosity. So here the shear stress is proportional to the shear strain.

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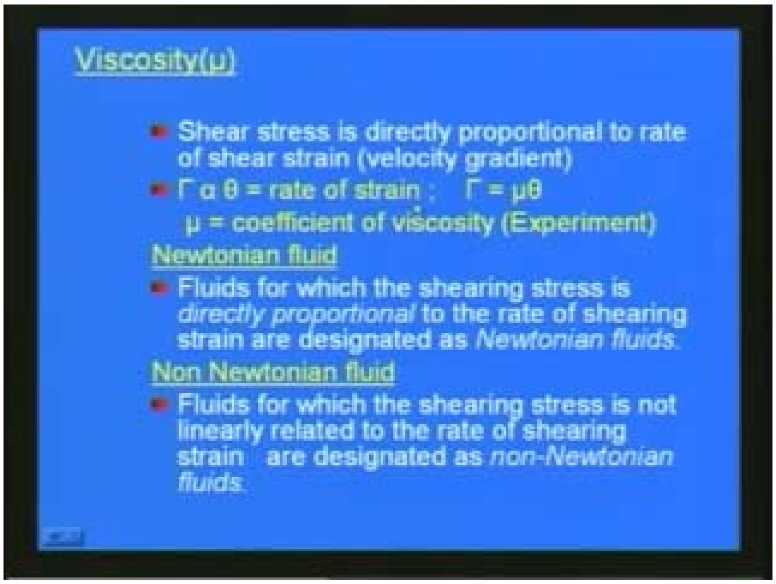

And when he expressed tow is equal to mu into du by dy tow is equal to mu theta where mu is the coefficient of viscosity, so it was already seen here the viscosity coefficient with respect to honey or with respect to water, the viscosity is changing and then the fluid property is also will be changing.

So Newton’s observe say if the change in shear stress with respect to the shear strain is linear then that kind of fluid is called as Newtonian fluid so fluids for which shear stress is directly proportional to the rate of shearing strain are designated as Newtonian fluids and in the case fluid for which the shearing stress is not linearly related to the rate of shearing strain are designated as non Newtonian fluids.

So according to the viscosity, Newton’s classified mainly the fluids into Newtonian fluid and non Newtonian fluids. So now in this slide you can see.

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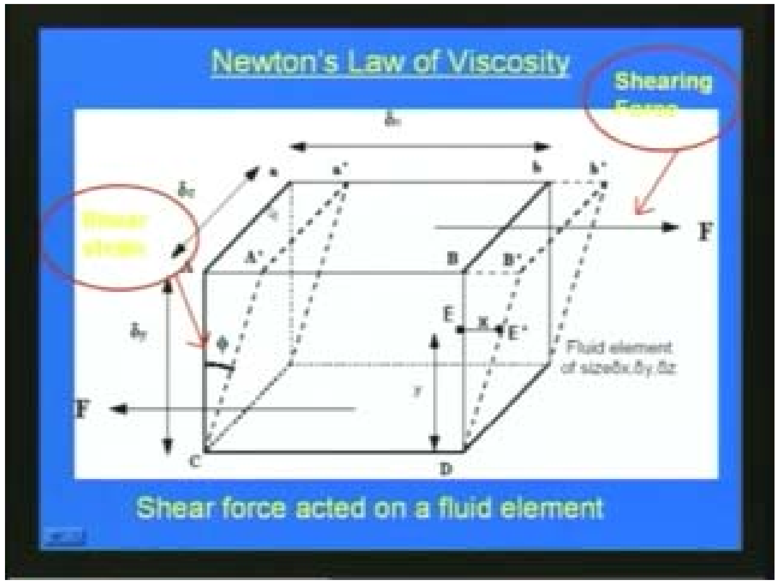

A fluid element like this, so now a shear stress are shear force is applied here applied so here we are considering a fluid element of say delta x size delta x delta y and delta z and shear force is applied for f in this direction and the top and a bottom in the other direction and now if you study with respect to the shear force the shear strain we would be considering phi here. So the shear force is acted on a fluid element.

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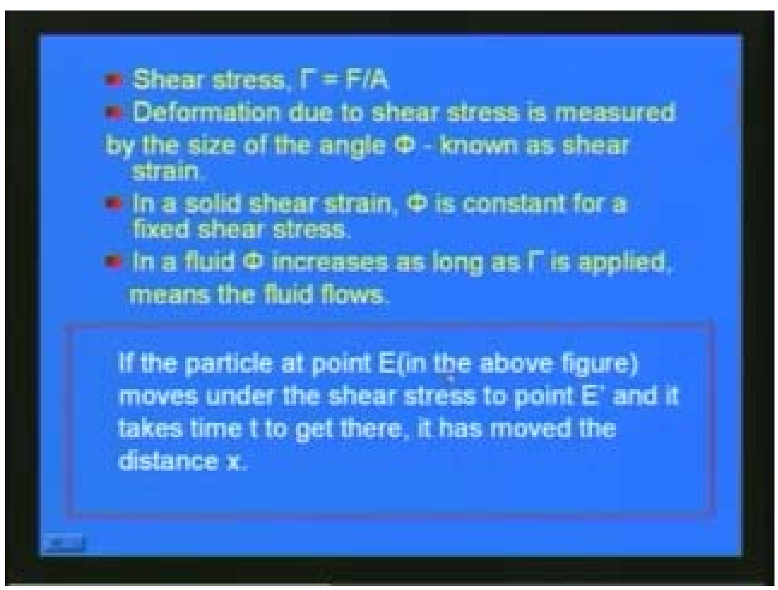

Now, shear stress can be written as tow is equal to shears force divided by area A and deformation due to shear stress is measured by the size of the angle phi know as the shear strain.

So if we consider solid, phi is constant for a fixed shear stress but in fluid phi increases as the shear stress is applied means the fluid is flowing. So since the fluid is flowing this phi increasing and this depends up on whether it will the variation depends up on the type of fluid. So if the particle at a point E in the previous slide moves under the shear stress to point E and it takes time t to get there it has moved the distance x.

So we can express shear strain phi is equal to x by y and write of shear strain can be written as phi by t which is equal to u by y and the velocity of particle at E is equal to x by t is equal to u so that finally we can write shear stress is equal to constant multiplied by the shear strain u by y. So here u by y is the change in velocity with y so that we can finally here the Newton's law of viscosity is expressed as tow is equal to mu in to du by dy.

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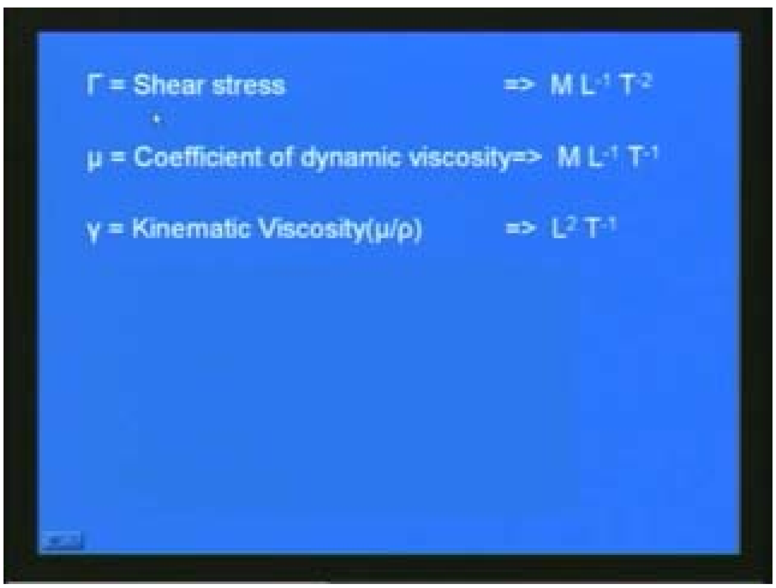

The shear stress unit is say here M L to the power minus 1 T to the power minus 2 and the unit of coefficient of dynamic viscosity M L to the power minus 1 T to the power minus 1 and it is expressed as say in poise in system intention unit and another quantity equal to kinematic viscosity when we divide the coefficient of dynamic viscosity mu by the density row, that quantity is called kinematic viscosity or mu is equal to kinematic viscosity mu by row and its unit is L square T to the power minus 1. So for various liquids like water, air, the coefficient dynamic viscosity varies and the shear stress also varies.

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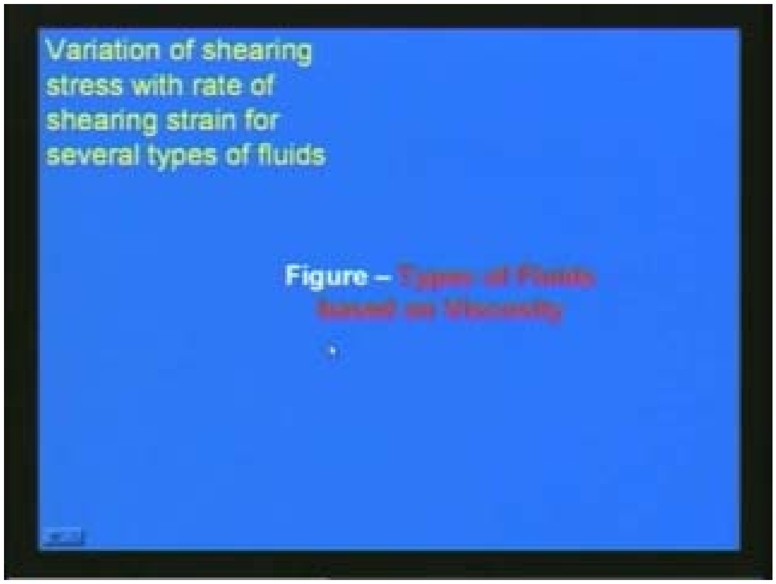

Now, with respect to this variation of shearing stress with the rate of shearing strain we can classify the fluids in to various categories so here I show a figure so this figure you can see here.

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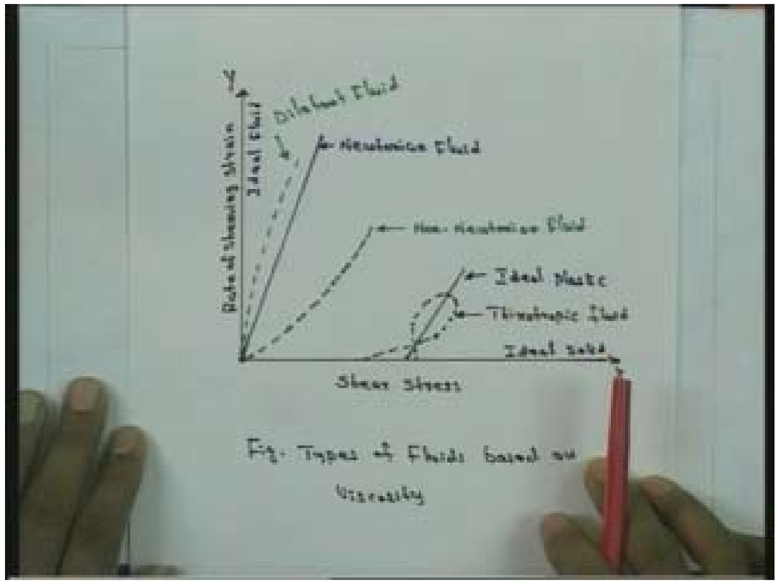

The shear stress is plotted here on the x axis and the right of shear shearing strain is plotted on the y axis. So in this plot if the shear stress is varying linearly with respect to your shearing strain then we get a straight line like this that there is linear variation. So, that kind of fluid is called Newtonian fluid say for example water is Newtonian fluid and if this variation is not linear. So here this line can see the various is not linear so those kind of fluid is called non Newtonian fluid and then if say the strain, the right of shearing starts after application of the efficient quantity of shear stress like here is up to this point there is no deformation.

So that kind of fluid is called ideal plastic and that is after reaching the particular point it is the variation is linear and then if the variation is non linear like this then it is called thixotropic fluid and then again if the strain is say increasing like this in this figure say this kind of fluid is called dilatant fluid and if say the fluid is such that the shear stress there is not shear strain only shear stress say if you plot like this that kind of fluid is called ideal solids and ideal fluid is totally shearing with respect to that there is infinite quantity of strain with respect to shear stress that kind of fluid is called ideal fluid.

So these definitions will be discussing further in the coming slides so with respect to the viscosity we can classified the fluids.

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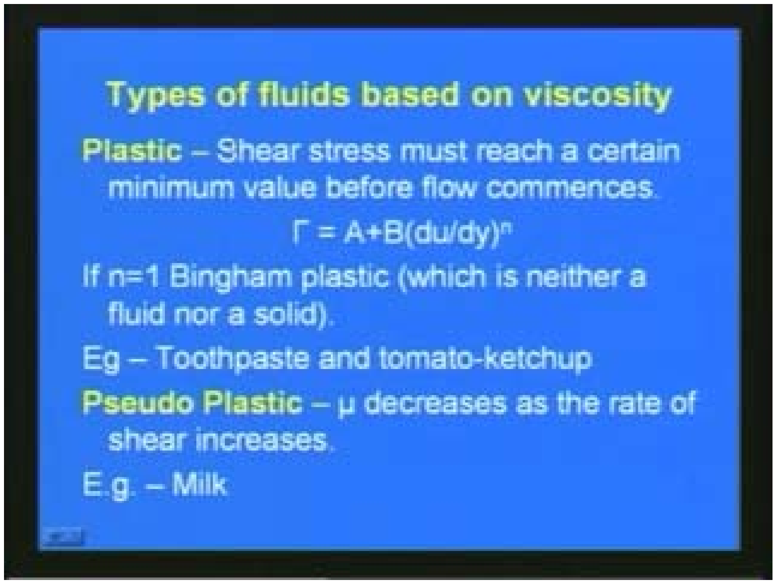

As we already seen in this figure now say if we classify various liquids say a plastic fluid in the case of plastic fluid say the shear stress must reach a certain minimum value before flow commences. So that we can write a shear stress tow is equal to A plus B in to du by dy with power n where A B and n are some constant and a plastic fluid is set to be bingham plastic which is neither a fluid nor a solid when n is equal to 1 in this relationship say for example

Say toothpaste and tomato ketchup have some example so this kind of say plastic or bingham plastic fluid so here you can see when it is taking this say the toothpaste you can see how it is behavior. So this kind of fluid is called bingham plastic fluids and in the case of as we have seen in the previous figure the coefficient of viscosity is decreasing with respect to when the shear is increasing that kind of fluid is called pseudo plastic say for example milk and if the mu increases as the right of shear increases that kind of fluid is called the dilatants fluid.

For example, paint or the printers ink and in the case of fluids in which mu decreases with time for which the shearing are applied that kind of fluid is called thixotropic fluid say for example mud gels used in drilling can be classified as thixotropic fluid and in the case mu increases with the time for which shearing forces are applied that kind of fluid is called rheological fluid and similar to Newtonian fluids then the time variant condition but if shear stress changes suddenly and behave as elastic that kind of fluid is called viscous elastic.

So as we have seen in this figure with respect to viscosity the shear stress variation and shear strain variation, if we plot then as we have seen say the variations whether it is linear non linear for whether it is increasing with respect to shear stress the shear is strain is increasing or say it is decreasing. So accordingly we can classify the fluids and we have seen the definition of these types of fluid with the examples.

Now we will further discuss some other important fluid properties, so as I mentioned in the beginning temperature is of course another important property so with respect to temperature.

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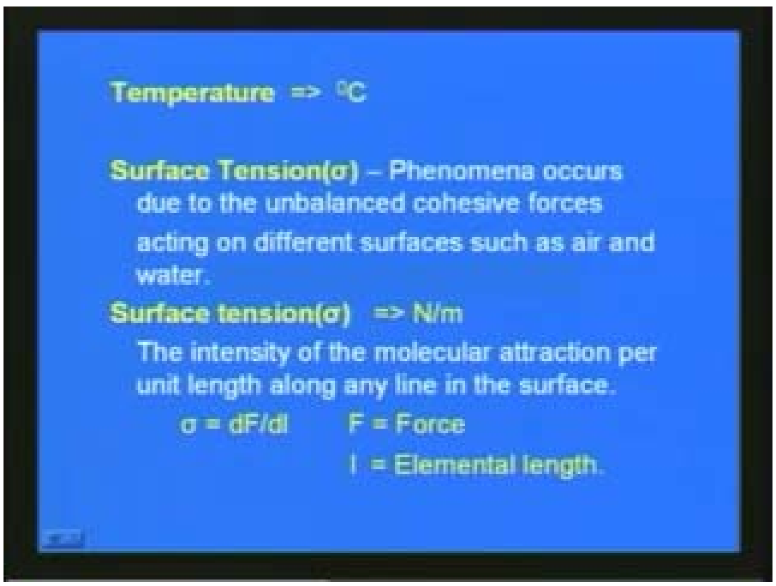

The fluid properties like say viscosity may change, density may change, so temperature is also another important fluid property and then another important property is the surface tension. So the surface tension is the phenomena occur due to the unbalanced cohesive forces acting on different surfaces such as air and water.

So surface tension it occurs due to the unbalanced cohesive forces acting on different surfaces such as air and water. So it is generally expressed as sigma and then its unit is Newton per meter. So the intensity of molecular attraction per unit length along any line of the surface is the surface tension sigma indicates.

So sigma can be expressed as DF by Dl, where F is the force and l is the element length. So due to the surface tension and other properties there is another important properties in fluid mechanics called capillary rise.

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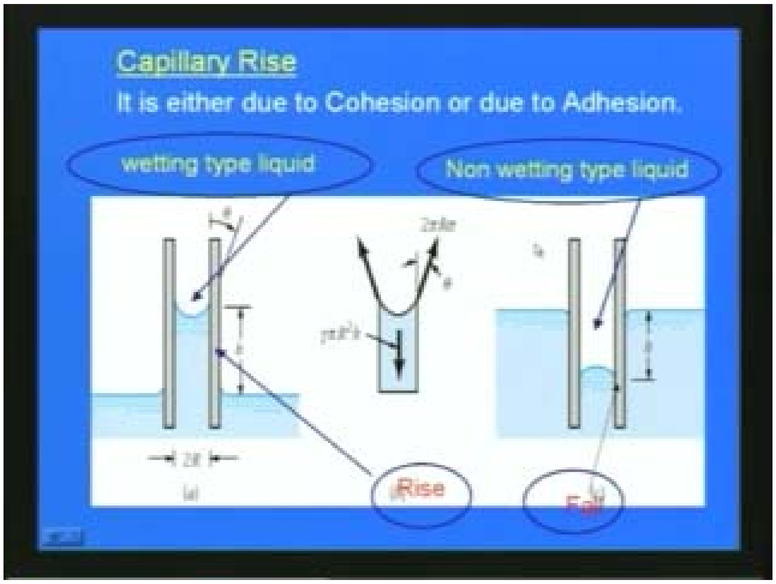

So this capillary rise occurs as you can see in the slide, it is due to either cohesion or due to adhesion. So when we place a small tube say like a small tube is placed like this say in water so here it is not observes, no color here.

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So but you can see in this slide if the liquid is wetting type we can see that there will be a small rise like this so that is called capillary rise so this the liquid is you can see that both surface it is wetting for that is why due to the cohesion it is a rising is taking place and that is what is called capillary rise.

But in the case of non wetting fluids like say for example mercury so if you take mercury if you put mercury in a say bottle like this and then put a small troop then you can see that it is decrease it is falling down. So these takes place adhesion of the non wetting type liquid it will be going down so that is the capillary falling so there can be capillary rise or capillary fall based upon say depending upon the type of liquid due to cohesion or due to adhesion.

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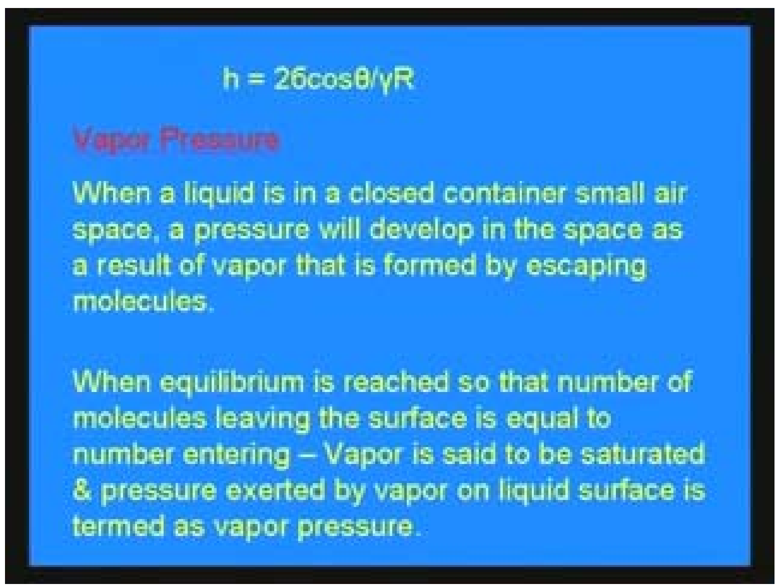

So this capillary rise or fall we can derive as h is equal to 2 sigma cos theta by gamma into R, where gamma is the specific wait and R is the radius of the two which we have seen in the previous slide and then another important property is called vapor pressure. So the vapor pressure takes place when a liquid in a closed container say if there is some space smaller space is there the pressure will develop in the space and as a result of vapor that is formed by escaping molecules.

So this presser is called the vapor pressure and then when equilibrium is reached, so that the number of molecules leaving the surface is equal to the number entering vapor is said to be saturated pressure exerted on liquid surface. So this vapor pressure is say especially the fluid contains in say both deals are in pipes.

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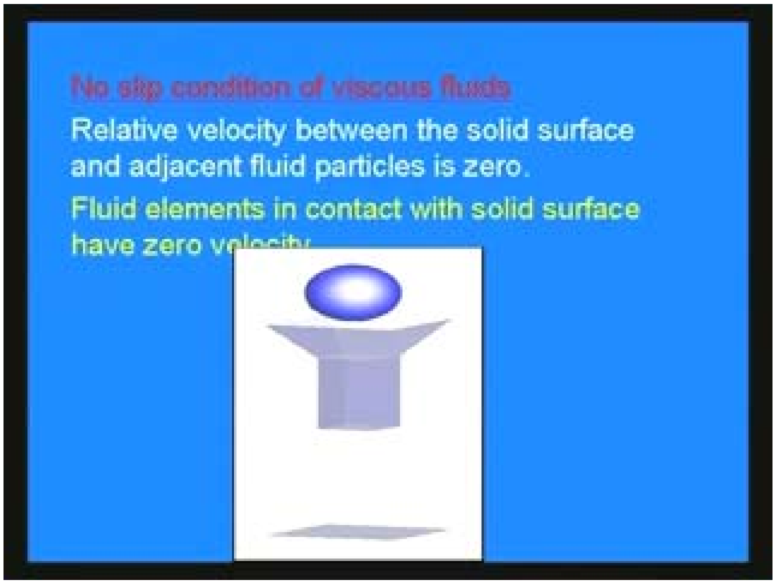

This vapor pressure is also very important. This is some of the important fluid properties and definitions which will be used in this course. So we have seen some of the important properties of fluids and then say some definition are we have seen now as I mentioned earlier say due to the fluid property like viscosity and then other important property say no slip condition of viscous fluid is an important property is especially boundary conditions which will be using.

So you can see that when fluid is flowing say in a pipe like this or in a open channel flow say the solid is say it is not moving that means on the container on which the fluid is say this pipe or the channel where the fluid is contained so the solid is not moving but only the fluid is moving.

At the solid surface where the fluid is moving so at the bottom we have seen the case of pipe flow at the bottom and at the top prefer of the pipe the velocity is zero that since the pipe is not moving. So the velocity the pipe material which is zero and then the velocity of the fluid at that point there is the contact between the solid and fluid. So that velocity due to the viscous effects that will be tending to 0, so this no slip condition occurs due to the relative velocity between the solid surface and the adjacent fluid particles is 0.

So, fluid element in the solid surface has zero viscosity. So here you can see in this slide when the fluid is trying to move as you can see in this say animation.

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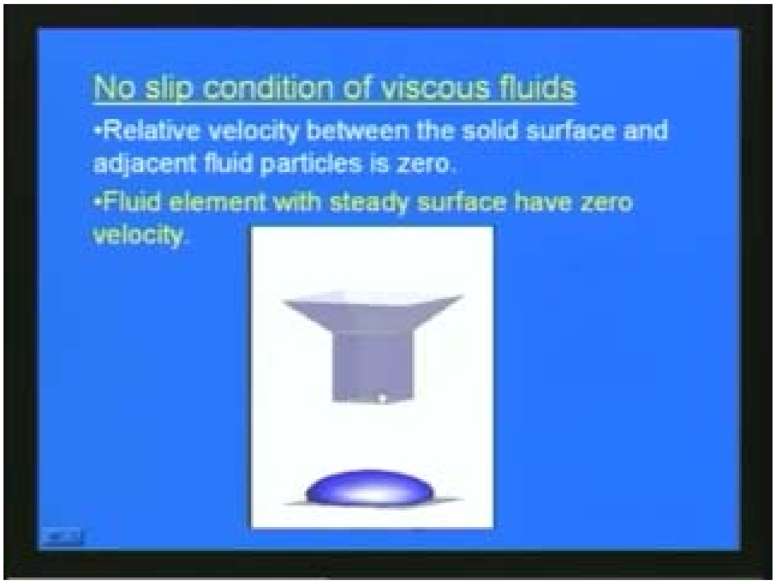

So it is trying to when it is moving say when it is touching this solid surface it is say there is the velocity zero and then say this no slip conditions takes place. Now, based upon this various fundamental properties, now we will discuss the basic flow analysis techniques.

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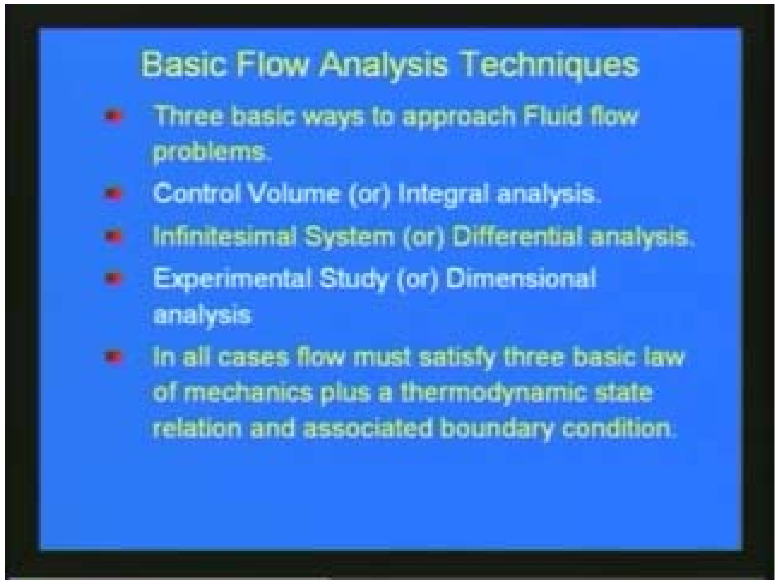

So as I mentioned most of the fundamental principles or theories used in mechanics are also very much valid in fluid mechanics only with certain changes as I mention a fluid is deforming or the variations with respect to solids. So that variations we have to consider so some of the important analysis techniques we will discuss now three basic ways to approach fluid flow problems are as I mentioned first one is the control volume or integral analysis.

So that means what is happening in a volume, we comes a particular volume and what is happening between or between two sections in that container or in the volume so that is called the control volume approach or the integral analysis. So this approach is very much used in fluid mechanics and then second approach is called differential analysis or infinitesimal system analysis.

So here in this analysis what we are doing is say with respect to say particular point say what is the fluid property is important fluid property is like pressure velocity how it is varying with respect to say xyz or that means particular point is concerned. So that kind of analysis called differential analysis say del u by del x, del u by del y or del u by del z so like that what it is happening.

So that is called differential analysis and the third important approach of fluid analysis is called the experimental study or the dimensional analysis. So in the experimental study what we are doing is we are trying to replicate the real problem in the laboratory and then we are trying in a smaller scale and we are trying to observe what is happening and the will be making with respect to dimensional analysis or various other analysis we will be trying to solve the problem. So that is the experimental analysis so this are the three important analysis techniques used in fluid mechanics first one is the integral analysis; second one is the differential analysis and the third one is the dimensional analysis or the experimental studies.

So in all this cases say we have to see that the flow satisfy three basic laws of mechanics and the thermodynamic state relationship and the associated boundary conditions. The three basic law mechanics are the equations or the theories derived based up on the consideration of mass; consideration of momentum; consideration of energy.

So, these are the three basic laws of mechanics based upon which master theories or the fundamental principles derived and then of course we using the thermodynamics theories or thermodynamics equations will also used and then of course the associated boundary conditions also will be used in most of the fluid mechanics analysis. Now we will be discussing the foundations of flow analysis so as I mentioned.

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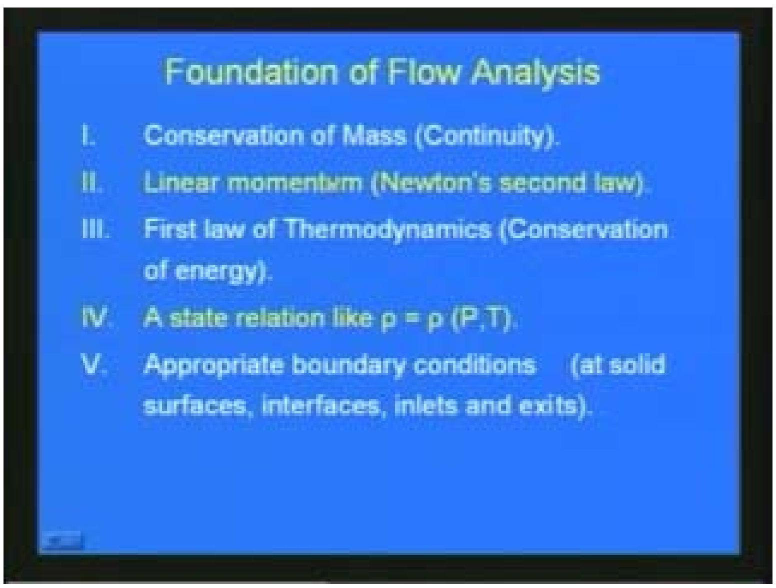

The important theories of mechanics will be using for the flow analysis, so five important foundations of flow analysis are the conservation of mass based upon which generally in fluid mechanics we will be derived the continuity equation and second one is the linear momentum or the based up on the Newton's second law we can derived the momentum equations.

And then third one is the conservation of energy are from the first law of thermodynamics we can derived the energy equations and then we can use this state relationship between say various fluid properties like a pressure temperature and density and lastly the appropriate boundary conditions or say at solid surface interfaces, inlets and exits. So, based up on the boundary conditions we will the deriving the fundamental equations.

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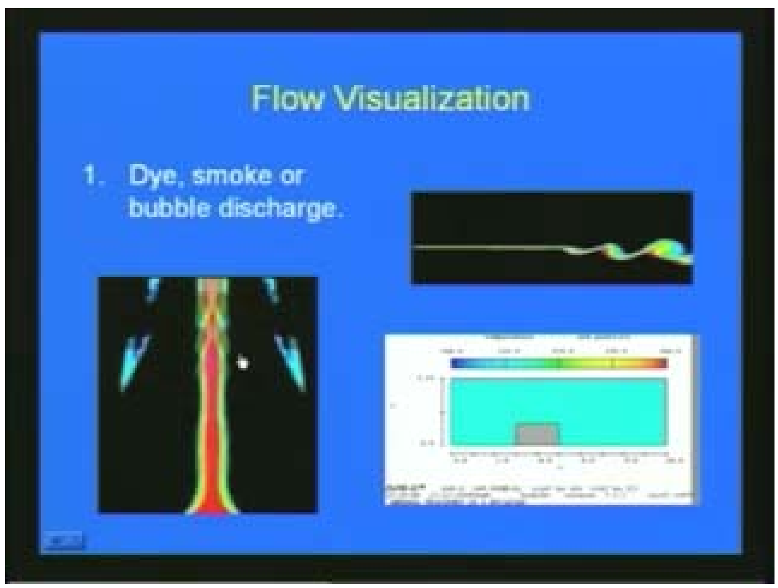

In this introductory lecture now we will be discussing other important aspects that means as I mentioned fluid is always trying to flow or the deformation takes place. so flow visualization is very important in fluid mechanics. So there are various techniques are used for flow visualization just like dye smoke or bubble discharge. So here you can see how we can visualize flow taking place so here this animation shows how the flow visualization can be taken place with respect to dye or smoke and in then another animation here you can see say with respect to say here it is a gas burning.

So how it is behaving with respect to say flow visualization how we can deprecate over so here in this animation you can see there is a cubby place and then over say an abstract is spaced in name flow field and then with respect to that how it is behaving so here you can see the flow behave how it is taking place.

So this say using a dye or a smoke or bubble we can easily visualize what is happening so that is one of the important techniques used in fluid mechanics.

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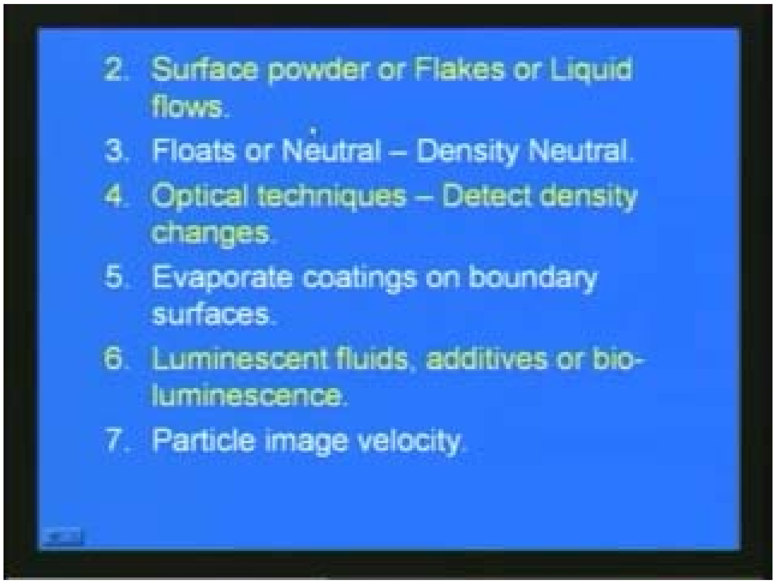

And then we can use surface powder or flakes or liquid flows so here you can see that say in this container or if there is in a open channel the flow is flowing then you can use some say flakes or some floating material and then we can see how it is moving.

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So that is the way which we can observe how the fluid movement that is either using surface or powder or flakes or liquid flows and then another technique is called floats. As we have already seen here or neutral or density neutral floats can be used for the flow visualization and then also we can use optical techniques like detect density variations in the particular say fluids say whether density is varying from say whether it is constant or it is varying from one to another one say and then another technique is called evaporate. Cuttings are bounded surfaces say how it is behaving so this is also commonly used in flow visualization and then another techniques is give me some fluids it is very easy to get the flow visualization by additives are bioluminescence and then another technique is one of the modern technique called particle image velocity.

We can use some special equipments we can observe the particle image velocity and then we can visualize the flow takes place. So we have seen various flow visualization techniques so when we are doing theoretical investigations or sometimes experimentally investigations, the flow patterns we have to identify the flow patterns.

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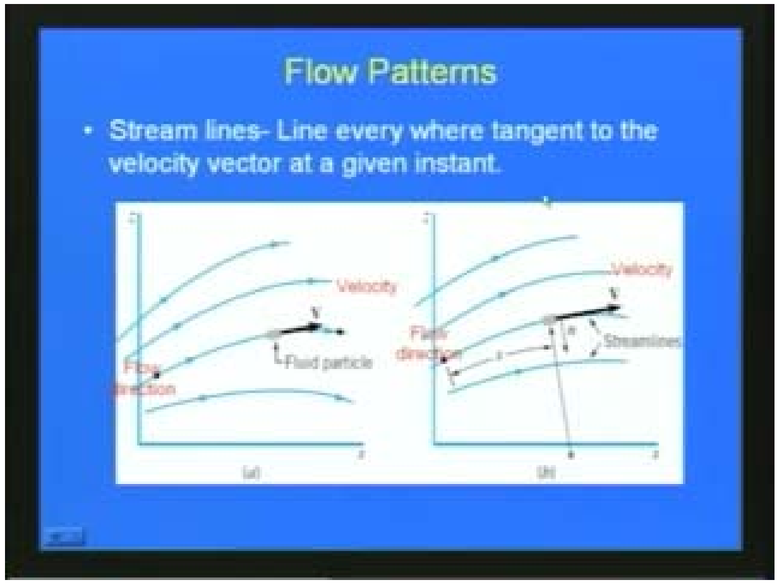

So we will be using some general definitions so we will now discuss some of the general definitions first one is the stream line So stream line we can define as a line everywhere tangent to the velocity vector at a given instant. So here in this slide you can see that flow direction is this way and then say this is the stream line so the fluid particle the velocity is here.

So if you draw a line like this so this are called the stream lines so stream line as such there are no lines but this concept can be used for say to identify how the fluid flow is taking place and then say especially in theoretical analysis we can use this stream lines for the say flow analysis over flow observation.

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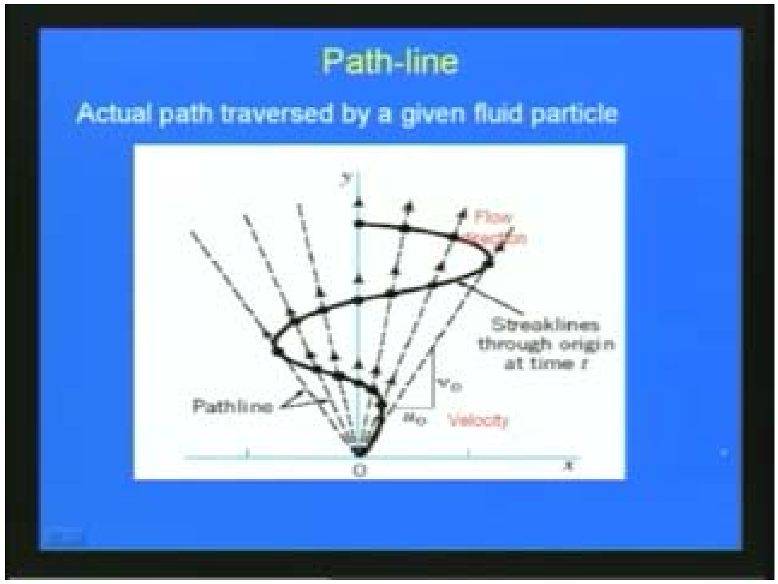

And then another important definition of line is called path line. So it is actually the path traversed by a given fluid particle say with respect to time so here you can see initially the particle position is here and then with respect to say time say how it is traversing so here you can see it is traversing like this. So the flow direction this particular case is like this but the fluid particle how it is traversing. So the path line is also used in fluid mechanics very much.

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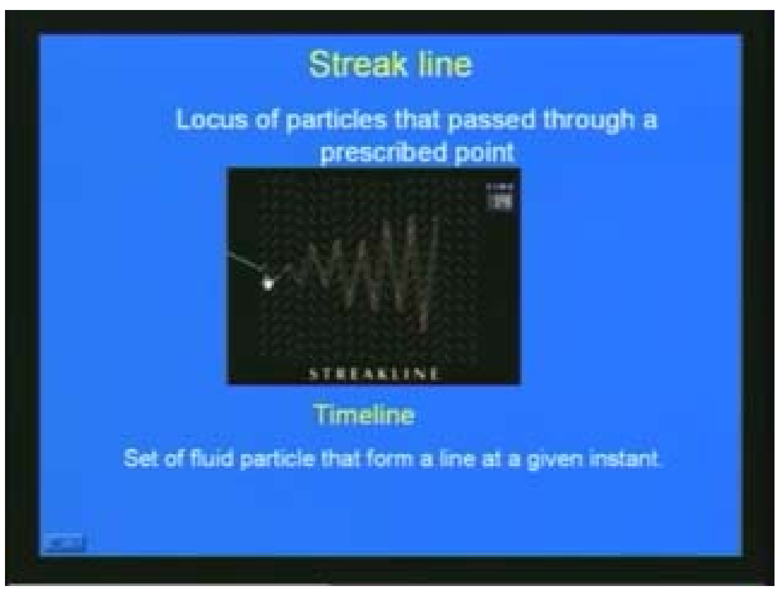

And then another important line which is the definition which is called streak line So streak line is the locus of particles that pass through a prescribed point So, here you can see in this animation say it is the streak line is shown here.

So it is the locus of particle that pass through a prescribed points so here you can see how it is obvious streak line is defined in this animation and then another definition is another line is in fluid mechanics time line it is a set of fluid that forms a line at a given instance.