Marine Hydrodynamic

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Lecture - 1
Introduction to Marine Hydrodynamics

Good afternoon, today is the first lecture on marine hydrodynamics. And I assume, you have already done some of the basic courses which are pre requisite for the, this course. And basically in the second year itself in the department of ocean engineering naval architecture, you take this course first course in marine hydrodynamics, which would be followed by several other courses. And so a thorough background of this course is very essential, because even if tomorrow you are going to design a shape or any off shore structure or anything, then that will require the knowledge of the specific marine hydrodynamics background. And also you will be coming at the several other courses in hydrodynamics which will be the, which will be followed from this course.

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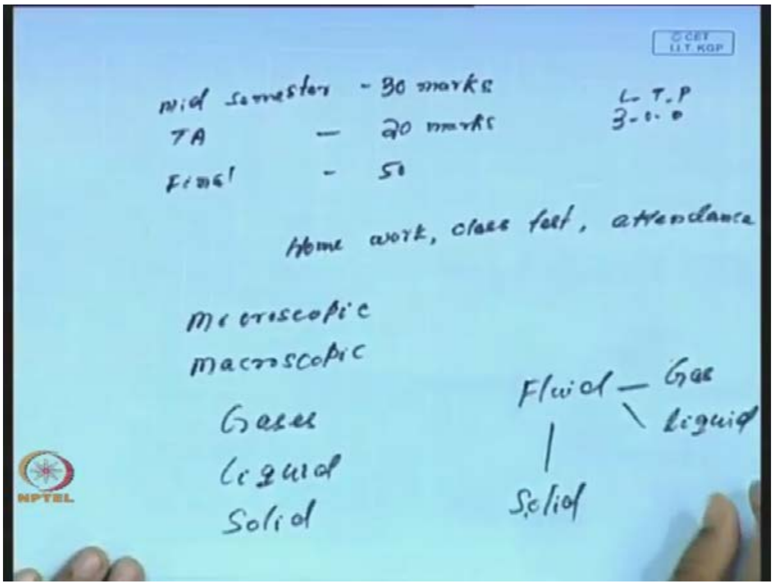

So, as a consequence when it comes to the, the assessment of the, the course this is a 3 credit course, and out of the 3 credit… We have mid semester, we have mid semester exam. Mid semester is 30 marks then your teacher‘s assessment, what we call it T A that is your 20 marks, than you have final terminal examination that is 50 marks. And your total is 3 0 0, this is your L T P, L T P and then it comes to, when it comes to the teacher's assessment, I emphasize mainly on 3 aspect, one is the home assignment, homework. Some of the home work, I gave you need not return, but some of them you have to return then you have a class test. The class test, may be a separate one or sometimes I do tell that the date side domains declare 1 or 2 days before the class. And then also, I give emphasis to the attendance. So, this is the way course will be done.

So, I there have already mentioned that the course is very basic. So, and it one has to know the details about this, so you have to be very careful while attending the class because you should not miss a class in this course. Then why marine hydrodynamics when it comes to the earth ocean surface the total earth, ocean are of one of the, that list explore and about 70 to 75 percent of the earth surface is covered by water. The total area of earths cover is, is 97 percent by water and out of the. So, this is a very high potential to understand this water particularly, those in system. And in the process marine hydrodynamics plays a very crucial role. And this marine hydrodynamics, some of the major, when it comes to ocean some of the major use of the ocean it is a 4 half. And at the mode of transportation, we can use those in surfaces, ocean. And also you can utilize the ocean space for various humanitarian and military activities.

So, if these are the ocean resources than how to use them, one as to understand the dynamics of the ocean water that is that is what we will study here that is marine hydrodynamics. So, when you understand the dynamics of the ocean water then we have to understand the dynamics of protein bodies' dynamics of fixed structure like various coastal structures or may be off shore structure anything comes there. Then we have moving bodies like when you look at transportation in the ocean there are ships and other marine body's, even for carrying our transportation purpose particularly, for export import purpose. We always use the ocean and that is one of the cheapest mode of transportation. But in ocean, one of the most disturbing force is the surface of the ocean which is we call the wave it provides lot of resistance to the. When a bodies moves on this it provides lot of resistance, even if when there is a structure that is in the see there are forces which act on this structure and they are the wave forces and that is again the fluid forces.

So this, so this emphasize that one has to understand the dynamics of the marine water particularly, but I say here the marine hydrodynamics. So, this is very essential to understand the dynamics of the fluid. And to understand this before understanding the dynamics of the marine water let us how at the, since it is today, we are going to the basics. So, we will emphasize that what is a fluid, because water itself is a fluid, so what is your fluid. So, when it comes to a fluid, we say that anything that flows that is called a fluid. So, it can be air, it can be water, because when it comes to air, we breathe air and we drink water for every activities of ours we need air and water. So, under here in fluid mechanics we try to study the dynamics of this air water and other fluids.

Now, there are 2, 2 ways to look into one is the macroscopic, one is the microscopic. Any matter, always we analyze it from the microscopic point of view and then also we do analyze from the macroscopic point of view. In the microscopic point of view, when you look at the microscopic point of view, we always consider matters consist of molecules and there which are in random motion. And there are separator from one another by a distance which is at least comparable at the molecular level molecular size. So, in this context, we have 3 things comes into picture that is we have gases, we call our gases, we have liquid and then we have solid.

So, in case of a gas, the separation distortion this molecular separation distance is less sorry, it is great. On the other hand, in case of a liquid, it is more than that of a solid and less than that of gases. On the other hand in solid, this molecular separation distance is a least. So, again when it comes to fluid and we talk about fluid as I have mentioned that anything that flows is called a fluid. So, again it is can be, this fluid itself can be called as gas and another we can call it as liquid. Then we can always say that there are 2 branches, one is the solid, one is fluid.

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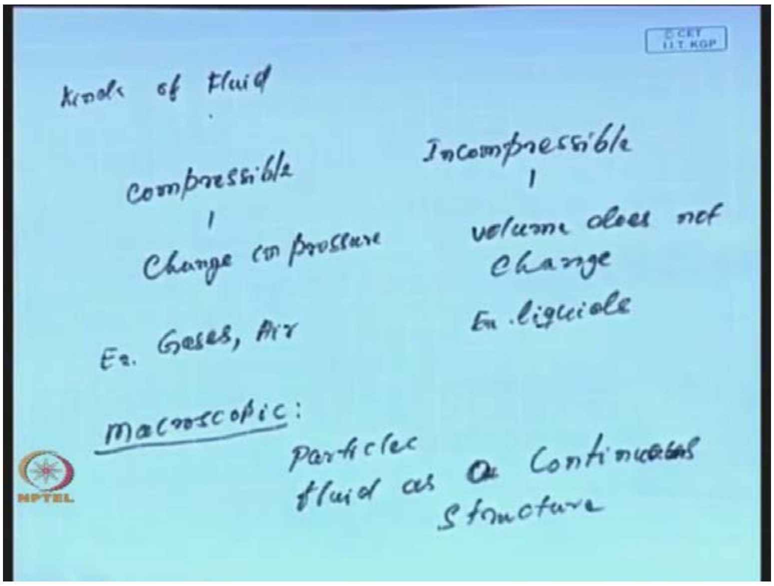

Now, when it comes to then if we want to understand better about the fluids, we have to know some of the characteristics of the fluid, and when it comes to the characteristics of fluid then I will say that what are the kinds of fluid, as we have already know that as, we already know that water is a liquid whereas, air is a in the gaseous state. So, we always say that one is compressible fluid, and the one is in compressive one. So, because gases changes in compressible fluid, the boiling changes with the changes pressure. On the other hand, in this case with change in pressure the volume changes. So, it is compressible, here volume does not change, it does not change with the change in pressure, almost all liquids are here. For example, all liquids and here you can say gases example of gases air etcetera.

Now, this is when we are looking at as, I say that the microscopic level. we consider this. But what happened that is another aspect, what we call is macroscopic, macroscopic level. In the macroscopic level, what we consider, we do not consider. In the macroscopic level, the molecular distance structure particularly is not that important here. We always consider that everything like a practical, we call about particle and we always call the fluid as a, as a continuum; as a continuous structure, we consider this as a continuous structure. So, as, as I result it will have various characteristics, so that like we should velocity this are density etcetera and. So, now with this, now if I will come back to little about a little introduction, I will give about what happen some of the questions, I will raise.

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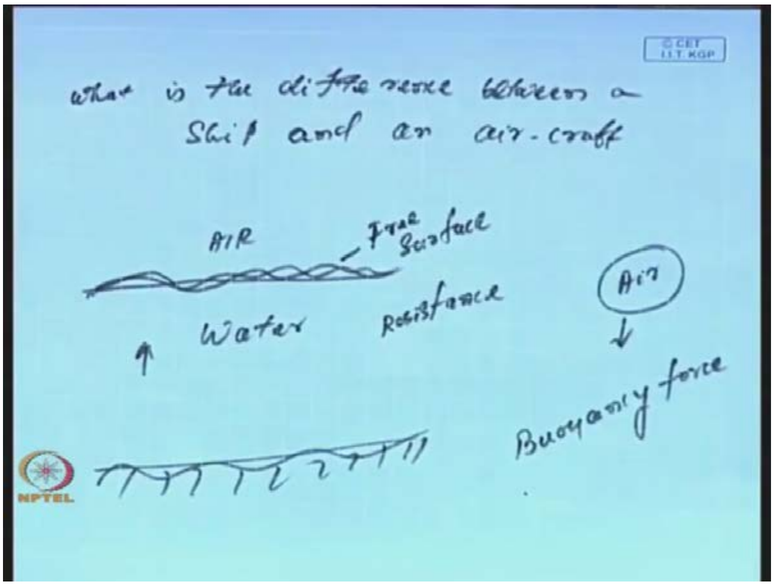

What is the difference between a ship and a, what is a difference between a ship and a air craft ship? And then aircraft particularly, a ship is floats in the water whereas, a aircraft it is always fly in the air medium. But in case of a ship, we have always we need two medium, there is a water surface, there is a air medium that is a water medium. And it always moves at this interface the air water interface and that is where. So, it moves in two medium. On the other hand, when it comes to the, so ship on the other hand, in case of air craft, it only has one medium. And in this two medium, what the water does it provides certain resistance, because the free surface, the air water interface, the water air interface. I call this as the free surface and this free surface provide good amount of resistance to the ship. On the other hand, when I look at a submarine, it is emerged in the submerged in the; in the water. So, it moves in one media whereas, there is a free surface one side, you have the free surface other side, you have the bottom.

So, often we say that suppose an accident took place, then what happens there? When an accident took place in the air, if accident took place in the air the body will fall and everything will be destroyed. But if an accident takes place, so in the water what happen there is a chance that the body will float after the accident, because water provide there is a of thrust which is provided that is called buoyancy, buoyancy force, here buoyancy is provides of thrust. So, the in case of water the, there is a chance that the body will try to float, because of the buoyancy force, because it provides the out thrust. On the other hand, in case of air gravity buoyancy is negligible. So, in case of air always gravity is since a buoyancy force is negligible the body will fall down and there is a chance that destruction will be more.

Now, another question, I will which, which you can why water butts have waved feat this question, I leave it to you, it can be answered later. We will; we will come to that in some point of time, where you can answer to me in the next classes. Where are the second question, I always, I want to put you, where are the position of the propeller in a ship or aircraft and then why and give me the difference between a submarine and the ship.

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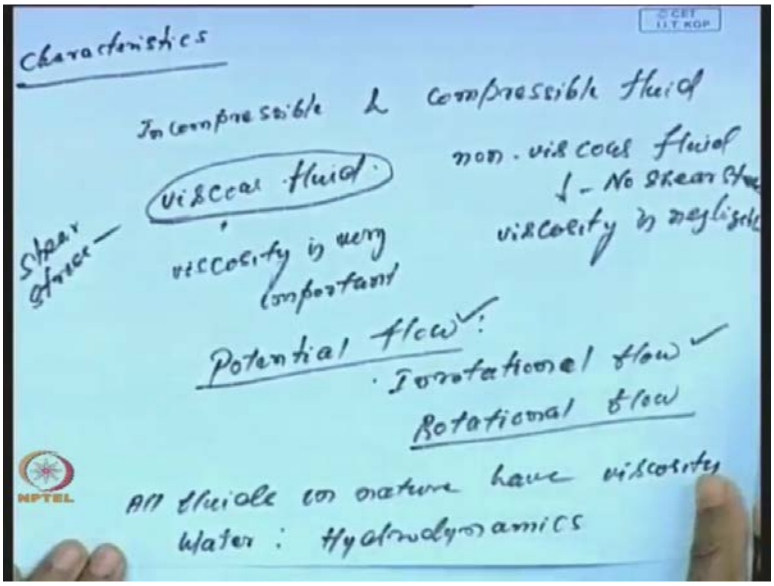

Now with this, if I go to now we will go to that some of the characteristics, as I have already told incompressible, and compressible fluid. Now, fluid is a incompressible and compressible fluid and I have told that air is a compressible whereas, water is incompressible. In case of air, we have a then we have something I will come to that little later viscosity viscous fluid, non-viscous fluid. In case of viscosity viscous fluid, viscosity is important, viscosity is very important. And in this case, in case of a non-viscous fluid, your viscosity is negligible, where viscosity is negligible then we have something called potential flow, talk something called potential flow. That means, when the motion, when the fluid is, when the motion is irrotational then we call the corresponding flow as potential flow, irrotational flow and rotational flow. So, in this case the fluid rotate, here a fluid will not rotate and in this case we call the flow as potential flow.

Now, in case of a viscous fluid, in this case, in case of a viscous fluid fluidexert pressure that is normal to the boundary and it exerts some shear stress. On the other hand, in case of here presents of shear stress. On the other hand, in case of non-viscous fluid shear force no shear stress, no stress is available. In general, I will say that all fluids in nature have viscosity. So, water when it comes to water, we say basically we deal with hydrodynamics, we deal with hydrodynamics.

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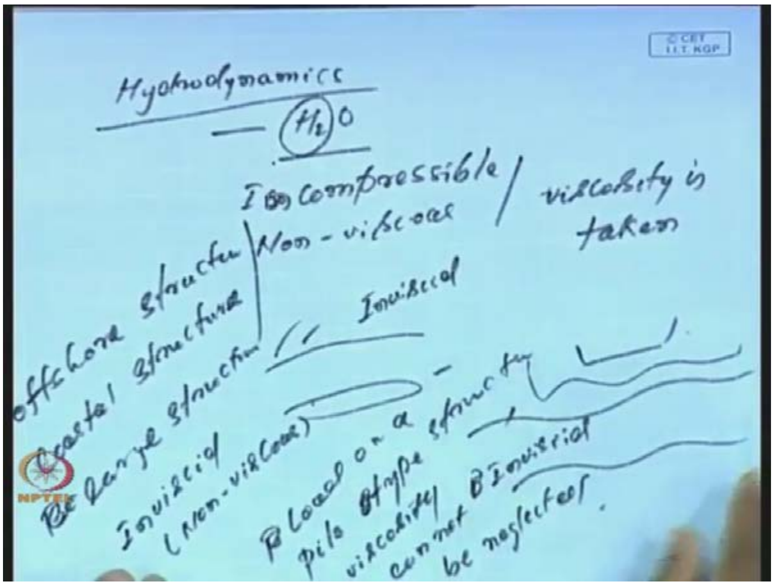

The word hydrodynamics comes from the H 2 O. This is hydro, from this the word hydrodynamics because always we will we always, because hydrogen is the dominating term. So, always we will look in to the dynamics of the hydrogen basically of the water that is why you call it hydrodynamics. Here, I assume here, we always say that the fluid is in compressible and we emphasize in hydrodynamics, major hydrodynamics study, we assume fluid is non-viscous. Of course, there are some branches, where so there are some parts of hydrodynamics, where we emphasize that the fluid viscosity, viscosity is taken. Particularly, I will give you example, where the fluid viscosity is important whereas, in a major cases like, on the like. In case of a aircraft, on the boundary near the; near the boundary of the structure give viscous. Viscous forces are important and you have a boundary layer beyond the boundary layer; beyond the boundary layer, certain layer then this fluid can be considered as inviscid.

Similarly, when we look at the motion of a ship, when we look at the just around the ship; just around the ship; around the ship near the, the viscous forces plays a certain role. But beyond, that beyond certain limit your viscous forces will then the fluid can be assumed inviscid. Again while dealing with a off shore structures, other marine structures like offshore structures or coastal structures used for various activities. If the structures are large basically for large structure, large structures, we assume fluid is inviscid non-viscous. However, if you look at a pile structure, you calculate the load on a pile structure, piled type structure. If you calculate load on a pile type structure then your viscosity plays a role viscosity cannot be neglected. Now, this in background, there are other aspect, one of the major part of water is that there are current in ocean, we have current in the ocean.

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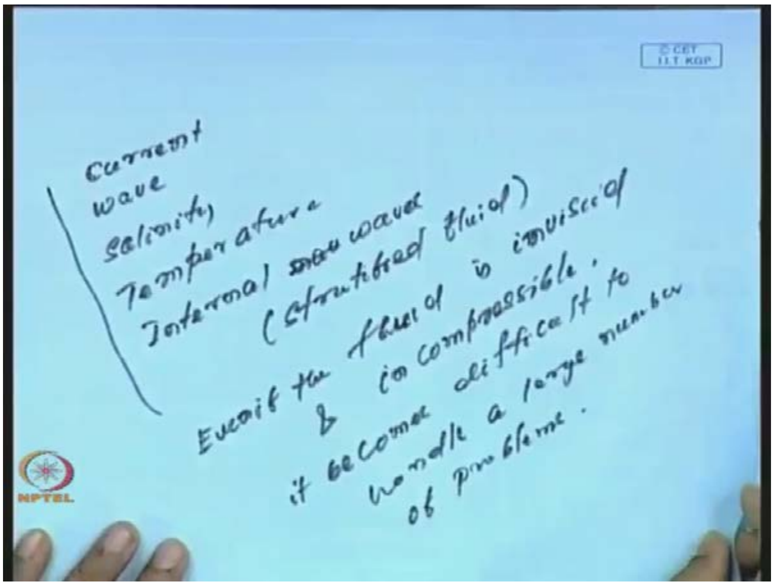

We have wave in the ocean, we have salinity, ocean salinity, we have temperature. Something, we have like, we have sometimes we see that in the ocean, we have internal waves particularly, in a stratified fluid, when there is a change the fluid density. So, then then all these things comes in to picture, the problem becomes more complex. And in that situation understanding of the even if the fluid is even, if the fluid inviscid and the fluid is inviscid is inviscid and incompressible. It becomes difficult to handle problems to handle a large number of problem. Now, another aspect comes that keeping this in mind. So, what I am going to talk about, now that here, what are the various aspect once we understand the basics, basics of the marine hydrodynamics. Then there are other similar courses which one you have to come across that is hydrostatic stability.

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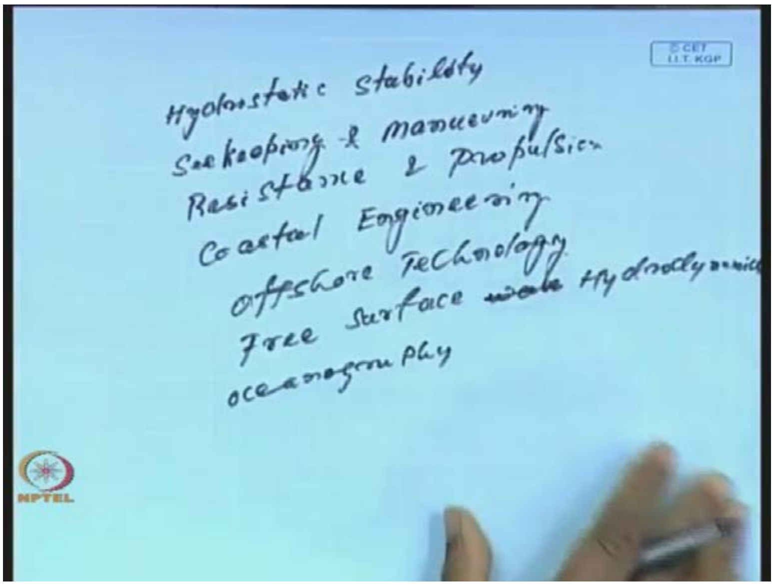

You have hydrostatic stability that is a course already you might have taken in the previous semester. Then you have other courses like, you have sea keeping and maneuvering and sea keeping and maneuvering. And you have resistance on propulsions; you have like courses like, coastal engineering, which mainly major part on wave mechanics what we have to understand the coastal hydrodynamics part. Then you have courses like offshore technology where you need to know you will understand the how to calculate nodes, wave node on various kinds of offshore structures. Then similar courses are there free surface hydrodynamics, where you try to understand a various with dynamics sea surface wave dynamics, free surface hydrodynamics. And then you have a course; you have courses on oceanography, where you will understand the ocean wave modeling ocean circulation and etcetera.

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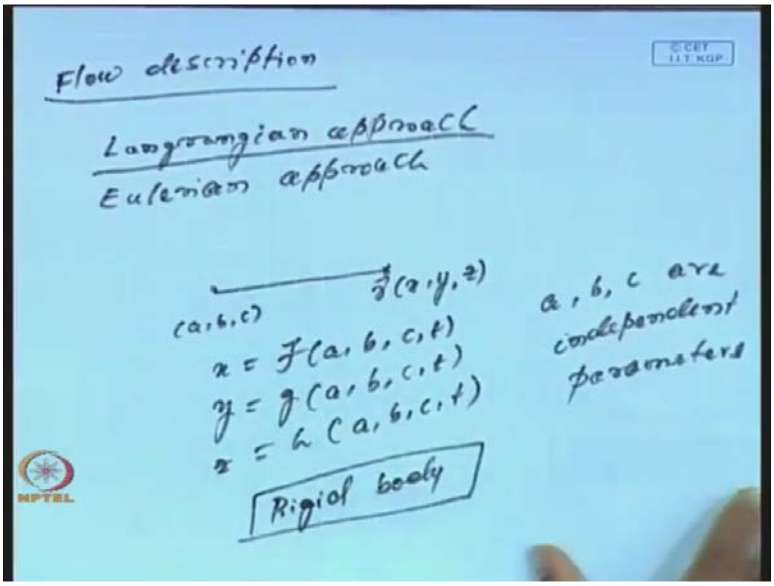

So, with this, now if this background I will go to tell you what is how to go to the, I will talk about the flow description, when I come to flow description, there are in general, there are 2 ways by which we can always describe. The flow one is the Eulerian approach and another is the Lagrangian approach. There are flow descriptions a fluid flow, you can always describe by what I say the Lagrangian approach, the other one is Eulerian approach. In the Lagrangian approach, you fix a point first, you focus on a single point and then this is particle and then you follows its path suppose, a b c is the position of the practical. And after some time this position is becomes r is a function of x y z r bar, this is another point. So, x becomes a function of a b c and time y is also a function of a b c and t z is also a function of c and t. So, this a b c are independent parameters, they are independent parameters. And this kind of Lagrangian motion, this is suitable this approach is more suitable, when you have rigid body; rigid body analysis particularly.

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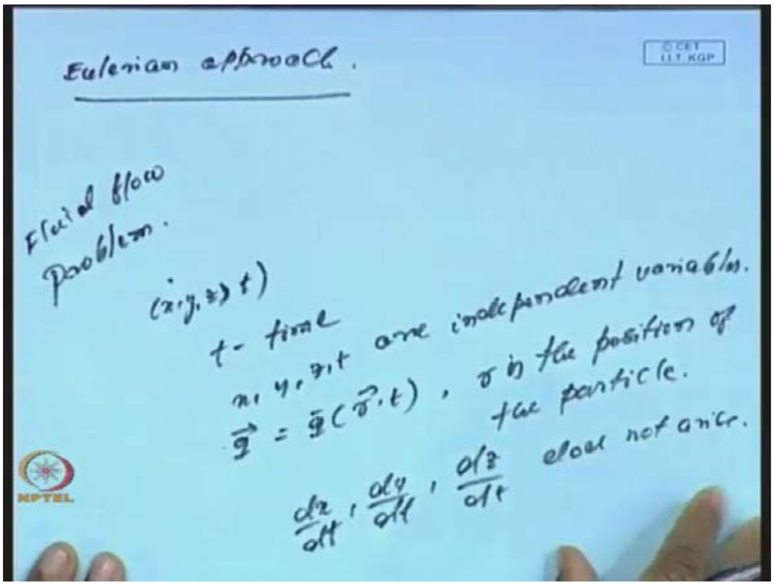

But in case of a fluid; in case of a fluid; in case of a fluid when it comes to a fluid more appropriate, we have the, we go for the Eulerian approach, here any point in a space, we denote it by a point in the space we denote it by x y z and x y z comma t. So, that; so that t is the time; t is the time x y z are the space variable. In this, this x y z and t are independent variables they are independent variables. So, so the position at n n at any point, we always call this if q is the velocity at any point. So, q bar always, we call it t q bar r bar t the r is the position of. So, q is a, this is r t, so r is the position of the particle. In this discussion the concept of d x by d t d y by d t d z by d t, it has not arise, this as they are independent variables. On the other hand and this Eulerian approach is more suitable for most of the fluid flow problem. Now, I come to the let us we have look at the velocity by fluid particle at a point.

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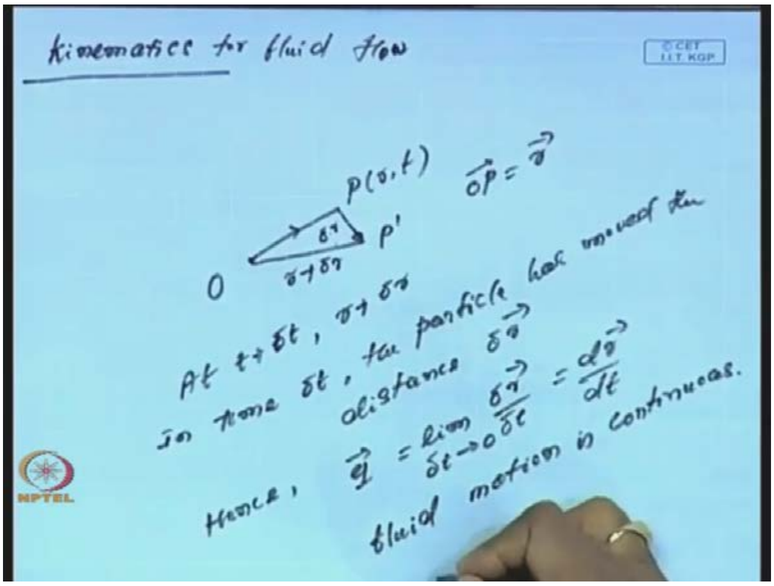

Then I will go the kinematics of the kinematics for fluid flow. Let me say that as if I will follow the Eulerian approach, I will follow the Eulerian approach. In this let a time t that o is a point this is r in o then let me say that suppose p is any point p is a function of r t. Now, now let a time t r is the position. So, we have o p bar is r bar then at time t plus del t, at the particle the fluid particle suppose it is at a point p prime. So, this distance is called del r, call it r plus del r then this distance in this, is this then I call this, if this is del then this is r plus del r. Now, because in time del t time del t the particle has moved no distance del r bar. Hence, we can say the velocity that is q bar is limit del t tends to 0 del r bar by del t and that gives us d r bar by d t. This gives us the velocity of the, so assume under z the assumption that this limit this limit exist. Of course, here we are assuming this motion is continuous fluid motion is continuous, continuous in Cartesian coordinate system.

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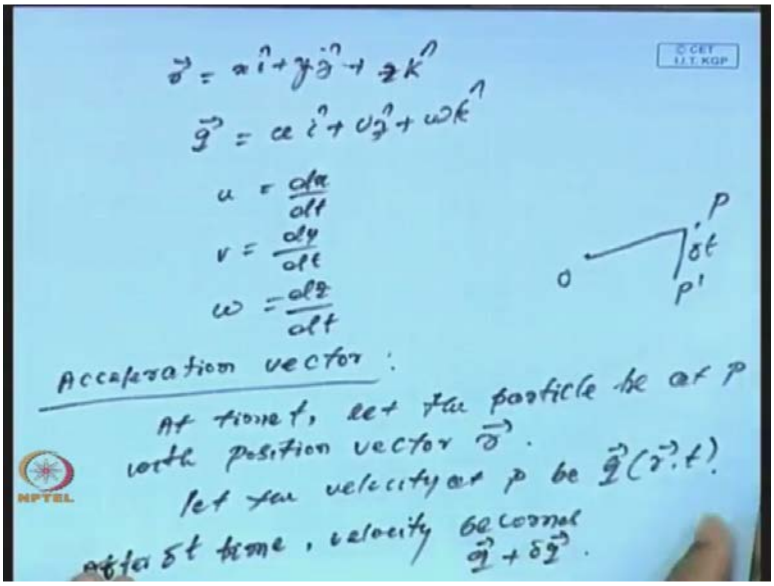

If you put r bar as x i hat plus y j hat plus z k hat then we have q bar is equal to, we call it u i hat plus b j hat plus w k hat. Then we have; we have u is equal to, we can always say u is equal to d x by d t then v is equal to d y by d t and w is equal to d z by d t. So, this is a connection between the Eulerian and Lagrangian system. Now in the same way, if we will go for to the acceleration vector, if I assume that at time t. That the fluid particle; that the fluid particle be at p with position vector r bar. Hence, let the velocity at p be q bar which is a function of r bar and t. Suppose after a interval of time del t a factor an interval of time the particle, if p is the point, sorry initially p h p is here, you have o here. This is o p and after point del t, it moves to point p bar then you have then after, after del t time, the velocity vector becomes becomes q plus del q. And in this case q plus del q becomes q.

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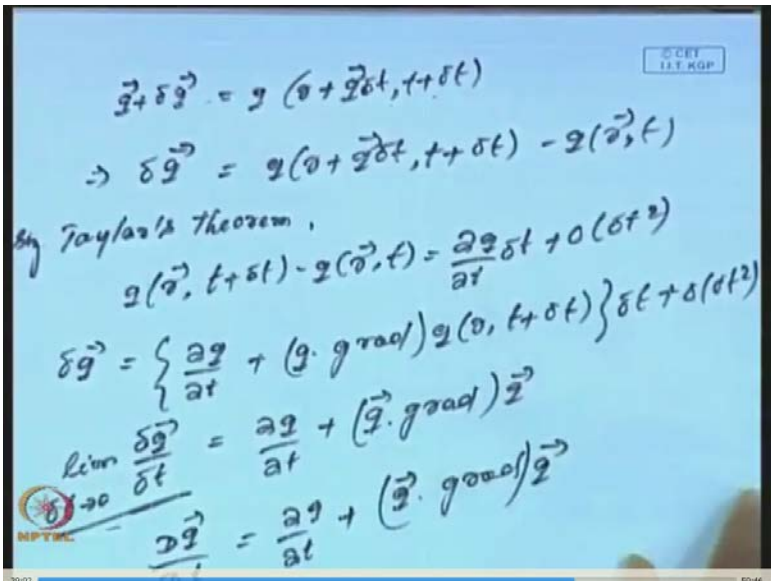

It becomes as usual q r plus q bar del t, t plus del t. So, it implies delta q bar equal to q r plus q r del t, t plus delt t minus q r bar t, if you expand it by Taylor's theorem. By using Taylor's theorem; using Taylor's theorem; using Taylor's theorem; using Taylor's theorem, we can also right q of r bar t plus del t minus q r t is equal to del q by del t into del t is order of del t square. So, in the hence using this noise proceeding in a similar manner, you can get del q bar. Because in this case, we have 2 terms, one is a t plus native one is q plus del q. So, here if you take del q bar, we can easily write as del q by del t plus q into gradient of grad q grad q of r t plus del t del t plus order of del t square. If you do that then if in the limiting sense, if we take the limit del q bar by del t then that will be del t tend to 0 that will give us del q by del t plus q dot grad q bar. And then which can be written from which this becomes this gives us d by d q bar by d t this is del by del t del q by del t plus q bar grad of q bar, so this d by d t.

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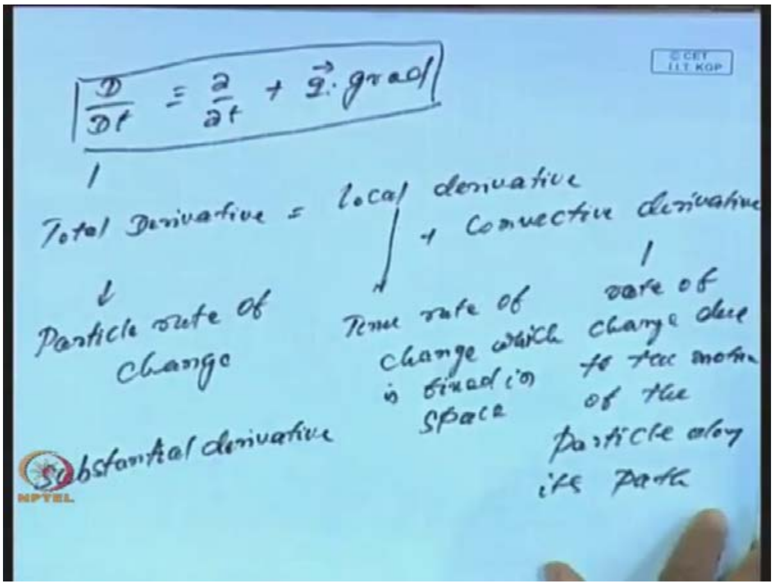

Thus we have got d by d t is identical del by del t plus q bar dot grad. So, this one is called the, we call this as the total derivative, call this as the total derivative, this is called to local derivative plus convective derivative. So, this is called the practical rate of change, this total derivatives sometimes, we call it particle rate of change. This is the local derivative time rate of change this term refers to time rate of change which is fixed; which is fixed in space, basically the point particle is fixed in space here. On the other hand, we have convective derivative this gives the rate of change of due to the motion of the of the particle along it is of the particle along its path. So, in fact in fluid mechanics often, we use this derivative sometimes, we call this as substantial derivative. Let me call this as the substantial derivative, the same also we can also go for this in the same way, so in the fully, this d by d t in the Cartesian coordinate.

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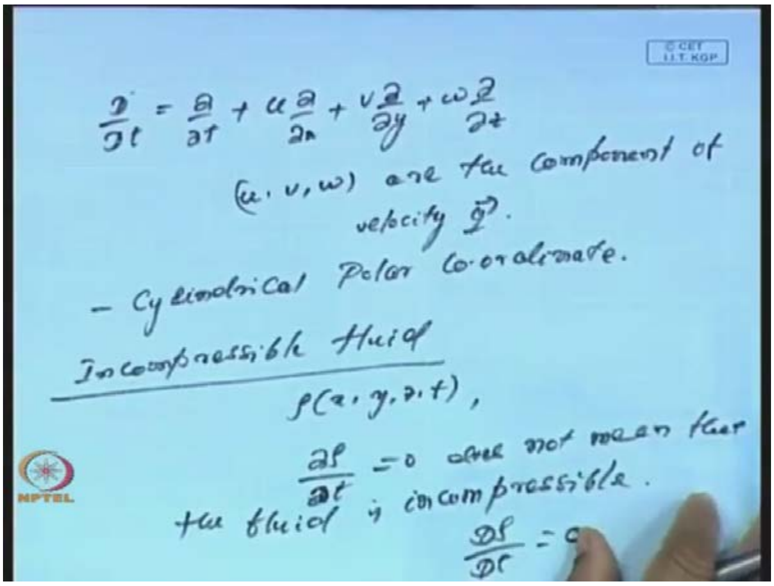

The d by d t can be written as the del by del t plus u del by del x plus v del by del y plus w del by del z where u v w at the component of velocity q bar. The, the same can be easily derived, in case of a cylindrical; in cylindrical polar coordinate. Now, I will come to one thing, when it is coming, we have talked about in compressible fluid, I talked about incompressible fluid. In case of incompressible fluid, we have here, we say we come across, when you have a fluid; you come across the density which is a function of x y z. And t it is not necessary for incompressible fluid, it is del row by del t equal to 0 does not mean; does not mean that the fluid is incompressible.

On the other hand, we will say that is the fluid is incompressible; we have d rho by d t e 0. So, now with this, I think, I will come to with this background, because we have already done the basic motion of the, the basic equations, particularly the velocity and acceleration. So, next time, we can easily come to the law of conservation of mass. And before that, I will just let me highlight here some of the other things, which I will be discussing in this. Because in the law of conservation of mass when you come to that. So, basically it is often called the continuity equation. I will come to that in my next lecture and then before that here we need to before, I have to understand the law of continuity at the, sorry law of conservation of mass or equation of continuity. We need to know some of the basic results on the strokes.

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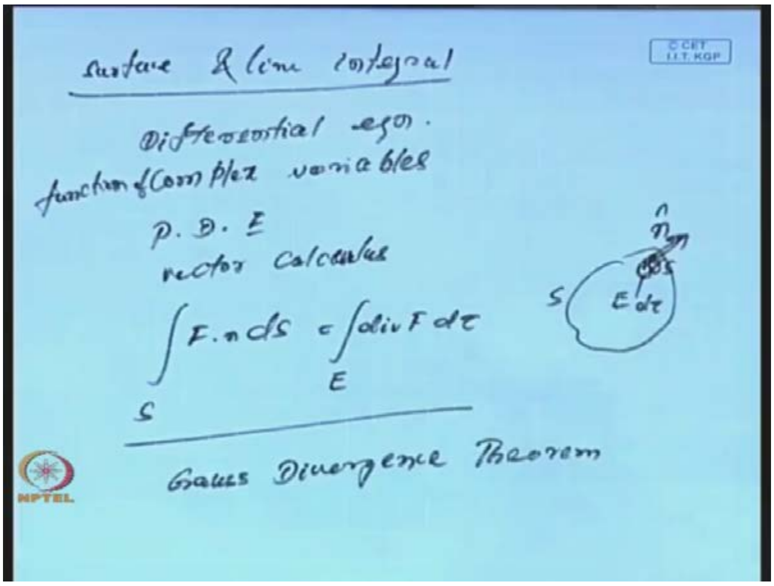

Between surface and the line integral surface and since this course; this course needs a basically, we need to have a background of basic differential equation a good background of differential equation complex analysis, complex variables function of complex variable. And then we have partial differential equation p d then we need basic background of vector calculus background of vector calculus. So, if this backgrounds are there then we will not have much of the difficulty in going through this course. So, since I have a little time, I will just say that let us say, what is the connection between the surface and line integral? Let me talk about the surface and the line integral, if f is a continuously differentiable function vector function. Let me consider a region a and let del s be an elementary surface then and n is a how to I have done normal n hat, if the outer drawn at this point then and s is the surface e is a the region e is bounded by the surface s. Then we have f dot n integral over s f dot n d s is equal to integral over e divergent of f d v d tau where d tau is the elementary volume over the surface area of this surface.

So, d tau is the elementary volume over here. So, this is what and n as I have mentioned n is the outer drawn normal the normal is drawn in the outer direction. So, this, this result is very because this is converts a volume integral to a surface integral. And this is often we call it gauss divergence theorem. So, this result will be very important, because I will be following the vector method. When I will come into the derive, when I will be deriving this continuity equation. And here I will be following some of the books, I will be following is theoretical hydrodynamics by Milne Thomson.

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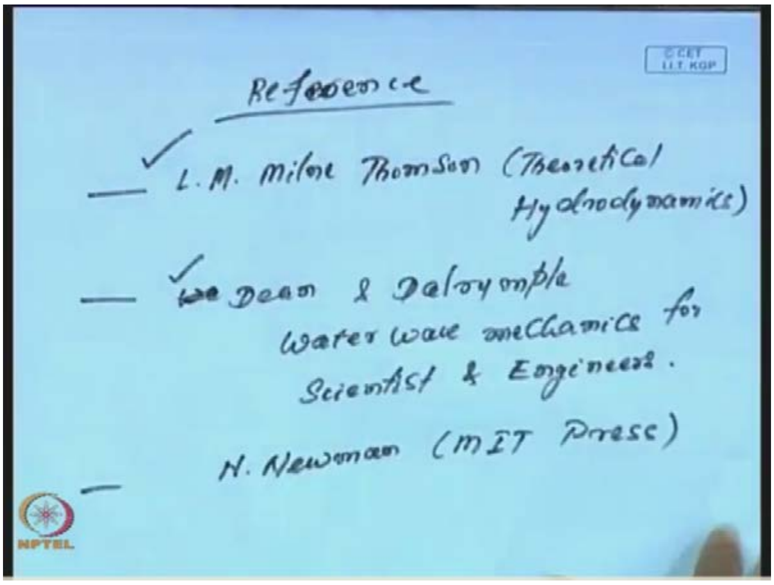

L M Milne Thomson, this is a theoretical hydrodynamics, basically I will be following this book or another book. When it comes to waves, I will be following the book of water wave mechanics, Dean and Dalrymple basically, Dean and Dalrymple that is a water wave mechanics for scientist and water wave mechanics for scientist and engineers. This basically, this 2 books and also, some of the book of N Newman, Nick Newman book of Nick Newman of M I T press. But a major part of the course, I will be following this book, but for the wave part, I will be following this book; this book I will follow in between this is the reference this is the reference. So, with this I will come to an end to the lecture today. And next time, we will again meet in the second lecture will talk about continuity equation, which is basically the law of conservation of mass.

Thank you.