Advanced Hydraulics
Prof. Dr. Suresh A. Kartha
Department of Civil Engineering
Indian Institute of Technology, Guwahati

Module - 1
Open Channel Flow
Lecture - 2
Various Classifications of Open Channel Flows

Very good morning to all of you. So, we will start the lecture two of our course on advanced hydraulics. As we have mentioned in the last class, the topic on advanced hydraulics is applicable to water resources engineering and even in various hydraulic project related engineering's. In the last class we had not mentioned some of the references that we are going to deal in the particular course. Today just illustrate some of the reference, textbooks which we are going to deal.

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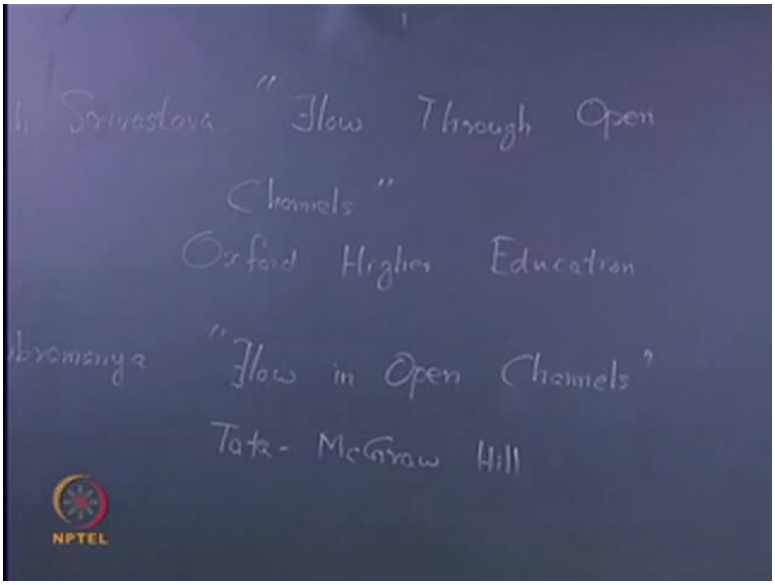

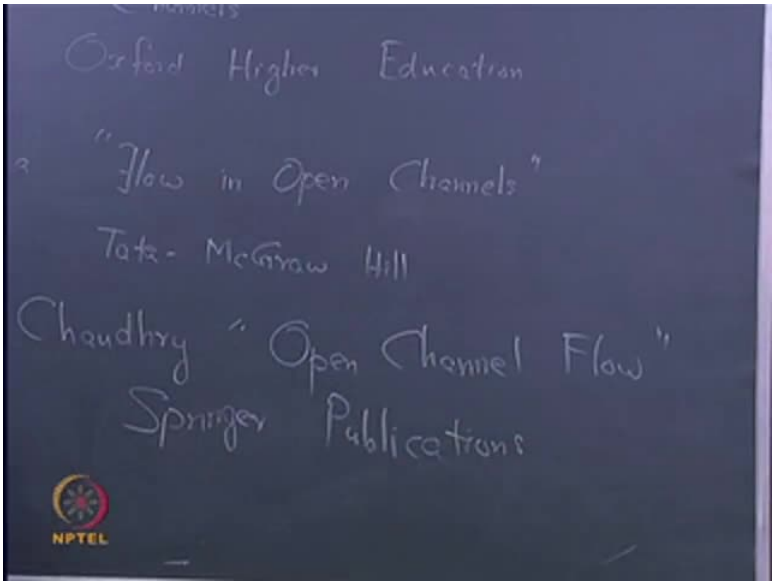

First one is Professor Rajesh Srivastava, Professor Rajesh Srivastava book on flow through open channels. This is published by Oxford higher education, another text book or which we will refer is on professor K Subramanya's book on flow in open channels, this book is published by Tata McGraw hill. Next, we will be following is professor m Hanif Choudhry's book on open channel flow, this book is brought to you by Springer publications.

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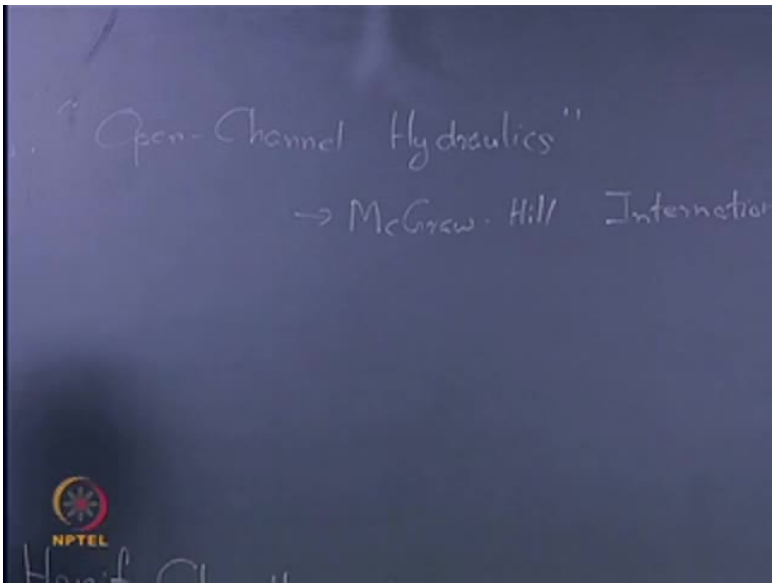

And one more book which we will be going through is professor V T Chow his book on open channel hydraulics published by McGraw Hill international limited. In addition to these books we may also refer some or the other books available already in the market or

even in the websites. We will also try to update with the latest information available in our course related matters. So, as was mentioned in the last class we will be having regular quizzes as a part of evaluation on this course, so the students are advised to be always attentive on the course lectures.

They have to be prepared for the quiz at any time, even during the middle of our lecture or during the beginning of the lecture or during the end of the lecture and it may be taken in a random way. Today we will be conducting the quiz, on the last days lecture in the beginning of this lecture today. It was well advised to you before coming to the class itself that there will be a quiz on yesterday's lecture.

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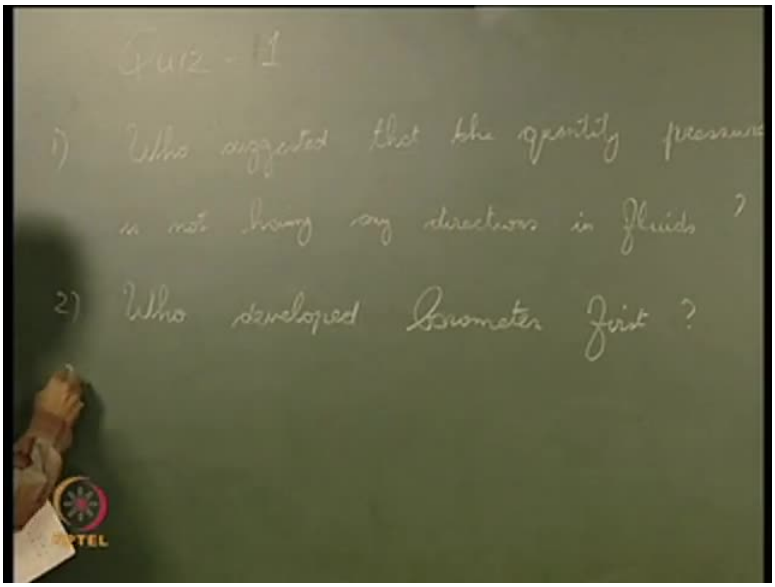

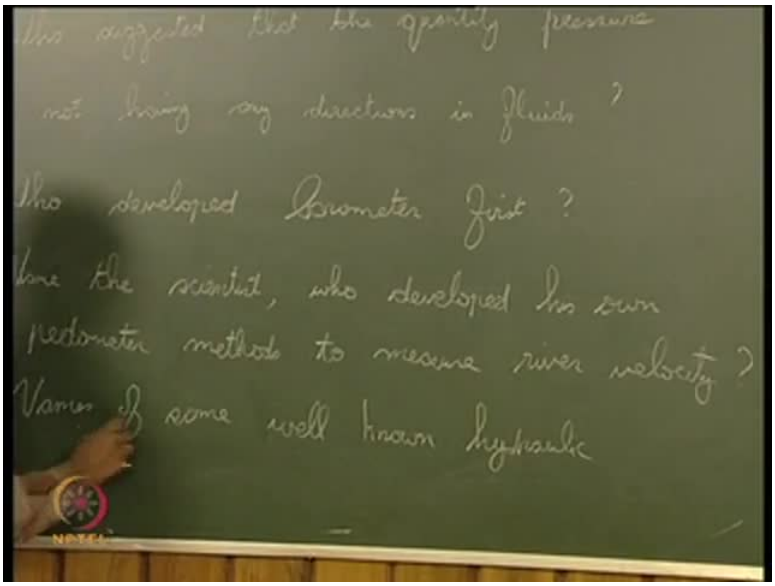

So, today let us just give you a quiz on the following topics first question for quiz one, first question on quiz one is; who suggested that the quantity pressure that the quantity pressure is not having any direction in fluids? You have to name the scientist who has suggested the pressure is not having any direction in fluids. The second question is who developed the barometer? Who was the scientist who developed barometer first? The next question is name the scientist who measured velocity of flow in a river by his own pedometer method? Name the scientist who developed his own pedometer method to measure river velocity? The fourth and final question, fourth and final question give the names of give the names of some well known hydraulic projects in India.

Give five names, give names of give names of five some well known hydraulic projects in India. We will give the solution of these questions after today's lecture. So, as per our course contents we described some modules, some six modules related to the course and the first module is open channel flows.

So, we had discussed some of the contents of the open channel flows in this module. What are all things, we will go through in this particular module. Now, as a beginning let us ask you, what is meant by open channel flow? What is meant by open channel flow? If any of you has some inputs from this question, you are free to discuss on that. So, open channel flow, it means that the flow of liquid which is open to atmosphere the flow of liquid in which it is open to atmosphere that is called open channel flow.

You might have seen the various type of open channel flows in various situations, that is whether it is in rivers, whether it is in canals, whether it is in channels, various type of channels even in large pipes where water is not fully occupying the cross sectional area. In various cases you will see open channel flow, that is in these situations the flow the top surface of the water it is open to atmosphere in rivers canals channels, it is readily which to you however in pipes if there is a circular pipe.

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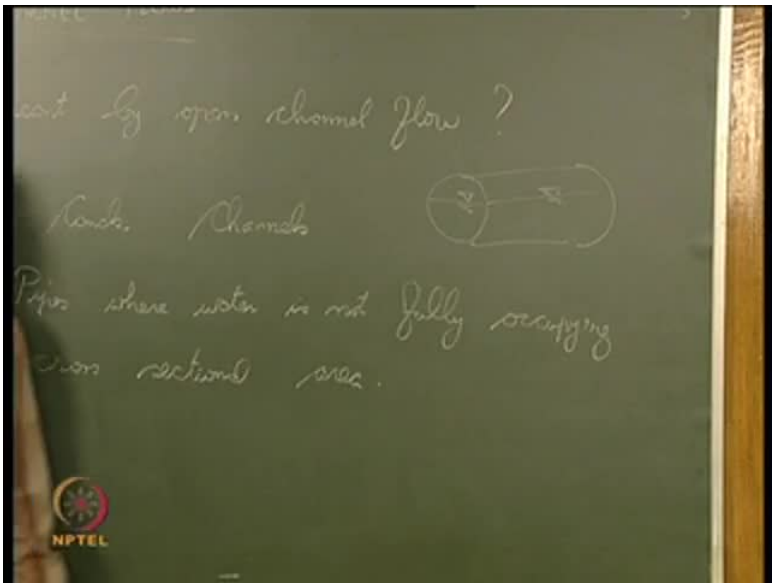

And if the level of water is only this much and it is open to atmosphere, if the top surface of water, if it is open to atmosphere even in these closed pipes the flow is called open channel flow. It does not matter if it is an enclosed conduit and all if, is if the top surface of water is open to atmosphere it is considered as open channel flow. Why do you study open channel flow? What are the various proposes? Why do you want to study open channel flows?

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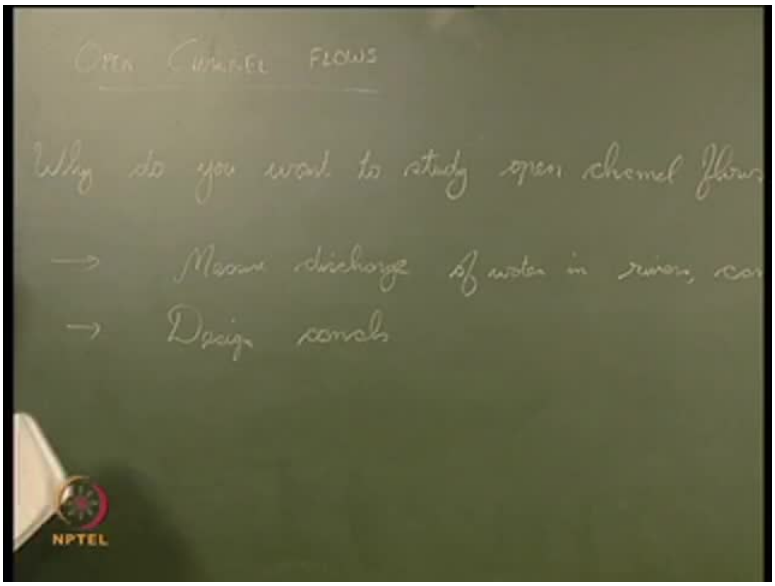

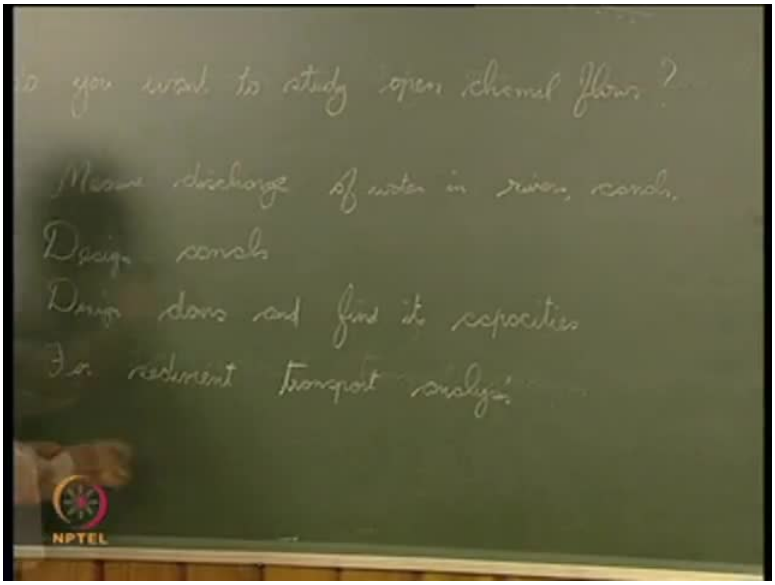

There are several reasons you can enumerate them, this will able you if you study open channel slow. It will help you to measure discharge of water in river is canals etcetera, it will help you to design canals for irrigation for navigation for various purposes, it will help you to design dams and find its capacities. It will also help you to understand say if any flood way if you take a particular channel water is there and if if this is the bed of the channel flow is occurring in this direction, if all of a sudden if some wave flood waves appear how the flood wave. See if it is there or certain flood wave it may propagate in this direction. How the movement of this flood wave occurs? And how it affects the entire channel hydraulics that can be studied using your open channel flow methods?

You can also study open means by studying open channel flow, it will be useful for sediment transport analysis. Well this is an another course sediment transport by studying the same course you will be able to find.

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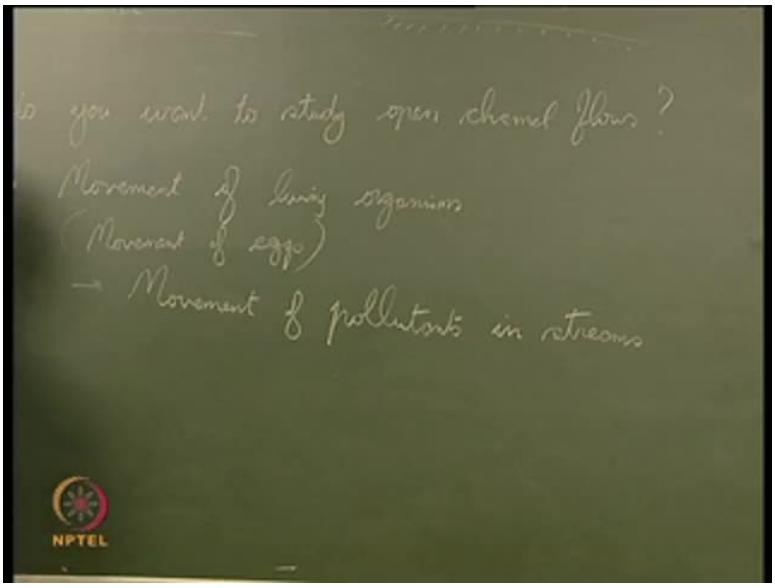

Say you will be able to find the movement of biological organism, living organisms in river especially say if some fishes lay eggs in large quantities. How the movement of eggs occur in the channel? How they can affect or how some of the human intervention can affect the movement of these living organisms that can also be studied using open channel flow. You can also study the movement of pollutants in streams. So there are various reasons for which you can study open channel flow so on open channel flows now you need to identify what are the different classifications of open channels.

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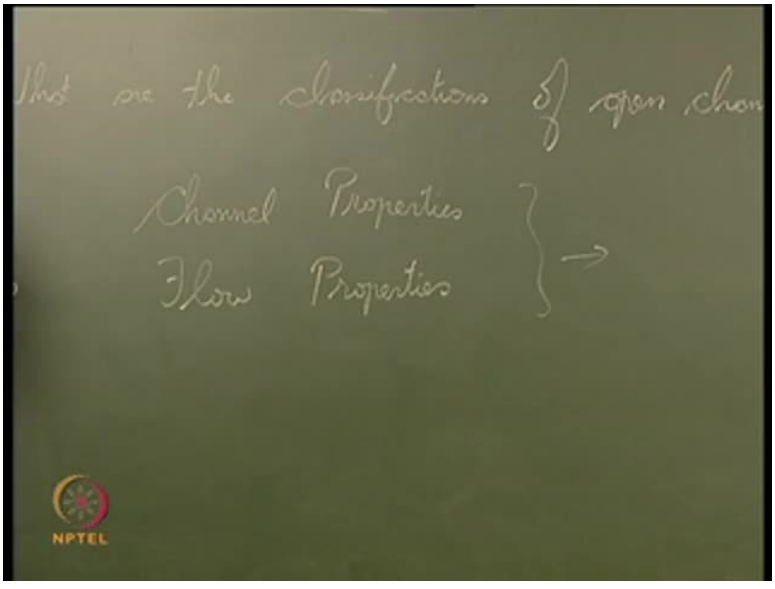

What are the classifications of open channels? It can be analysed in any way, you can classify open channels by any methods that it is an individualistic property as it is mentioned. Say one can classify open channel based on some parameters, one can classify open channels based on some of the locations, one can classify open channel based on other variables non physical variables physical variables, whether it may be anything you it is an individual property. However, let this suggest in our course that we can classify open channels basically with respect to two main parameters.

That is you are going to classify the open channels basically with respect to the channel properties as well as the flow properties. So, one can classify open channels based on channel properties and flow properties. How can you classify them? What is meant by channel properties? What is meant by flow properties? So, these again it is as mentioned some of the individualistic perceptions, but there are some common theories behind this thing and we will see some of the common definitions that are used for channel classifications. First we will go through the channel properties to classify the open channels in short form. For Open channel flows I may write it OCF and for open channel I may write in short form as OC.

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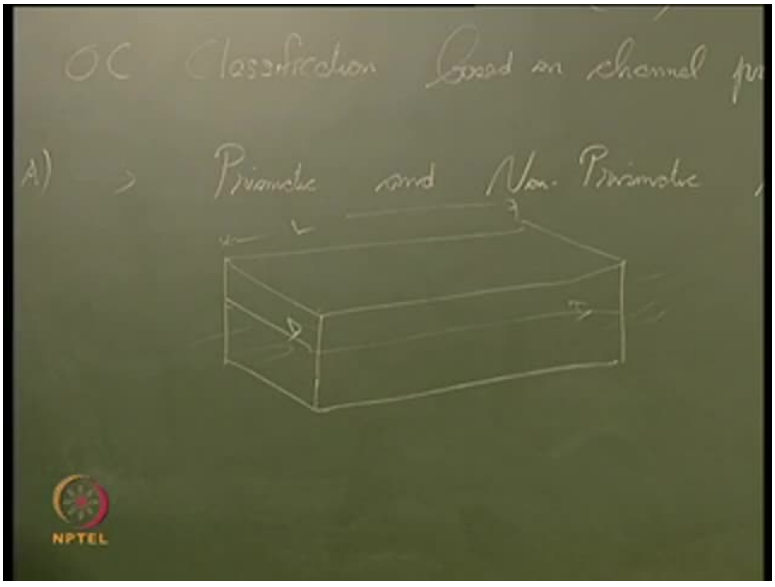

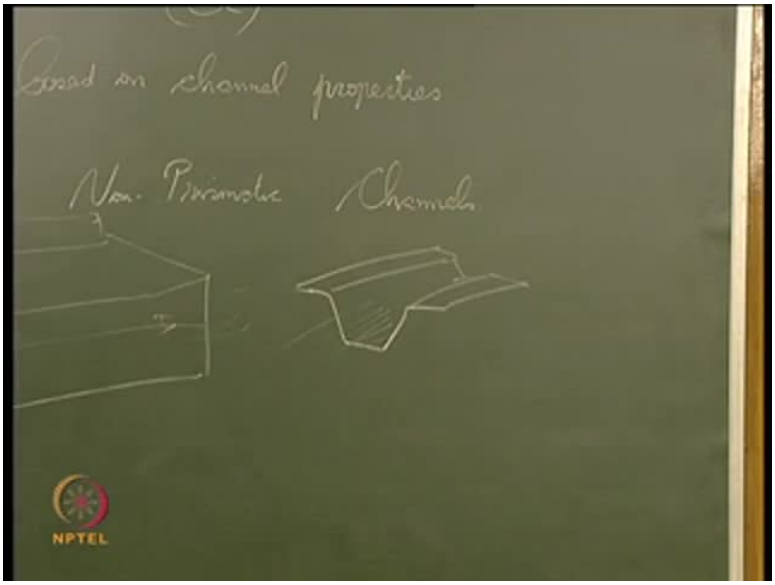

So, in the classification of open channel. The open channel classifications based on channel properties, based on channel properties you can define it, say a prismatic and non prismatic channels. What is meant by prismatic and non prismatic channels? As the word suggest, prismatic it is something representing a prismoid form. If the cross section area if the cross section area of a channel, if it does not vary for a considerable stretch, if it is a uniform cross section throughout the reach of the channel then such type of channels are called prismatic channels. If the cross sectional area varies with distance or with as you proceed in the length, if it varies considerably those channels are called non prismatic channels.

If I just draw say for example, if you observe a laboratory flume I hope you know what is meant by laboratory flume? Students who have studied fluid mechanics and all some of you might have already done some experiments in laboratory flumes and all a laboratory flume is a channel established in lab with the uniform cross section, that is used for studying various flow phenomenon. So, if a channel cross section, if this is a channel artificially created channel it is established in laboratory and all here it has a rectangular cross section and the rectangular cross section is maintained throughout the length of the flume flow. You can analyse flow coming in and say water going out, from this flume all this phenomenon can be studied in such laboratory flume.

A laboratory flume is a classical example of prismatic channel. You might have also seen prismatic channels where say trapezoidal area is used for constructing a trapezoidal cross-sectional area is used to construct irrigation channels and mostly in most of the

irrigation channels in India is of this particular cross section, such type of channels they are also called prismatic channels because it is cross sectional area, it is uniform throughout the length of the stream. The next one is non prismatic channel and as the name mention the cross sectional area varies with respect to a distance, so it may have some a non prismatic channel.

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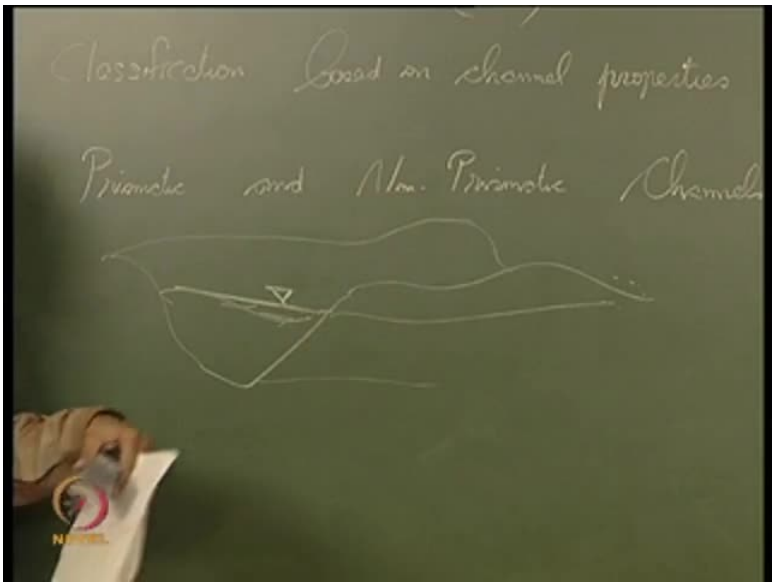

For example, a river cross section, a natural drain cross section and all they are the cross sectional area the width of the channel depth of the channel. They are all vary with distance, so they are called classified as non prismatic channels. Our next classification based on channel properties they are natural and artificial channels.

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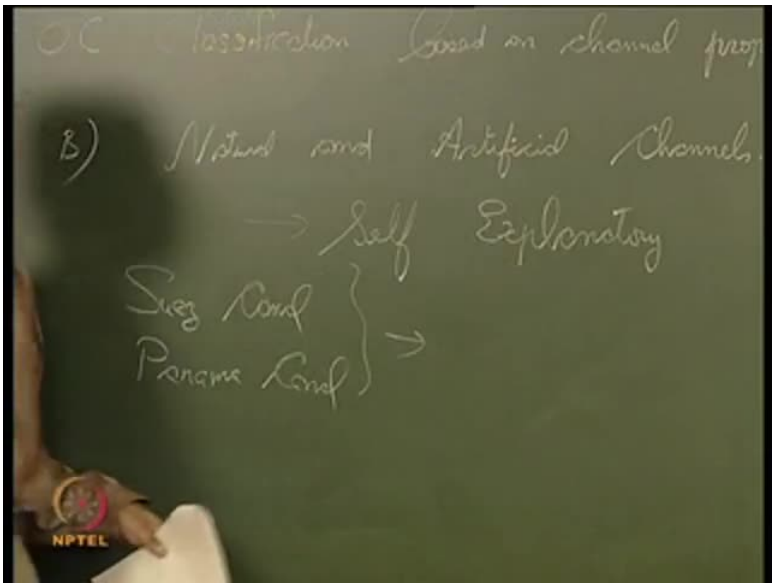

The next classification you can give it as natural and artificial channels, that is naturally formed channels on earth. Artificially, manmade channels you can give several explanations these are these are all self explanatory. So, natural channels you will see them in rivers, natural drains and all artificial channels. There are many artificial channels that are of utmost importance. You have already seen the case of laboratory flume which is a small structure, you have, you may see various artificial channels that carry large amount of water for example, if man would not have created artificially Suez canal or if he would not have created Panama canal, how much difficult it would have been or how much the human life had been made easier by construction of these artificial channels?

So, artificial channels are also quite prominent and it is need not be that always it should be the natural thing that has to be given predominance, and all man has endured in the engineering science, in such a way he has tried to merge the natural things with the man made things and all so it is quite amazing.

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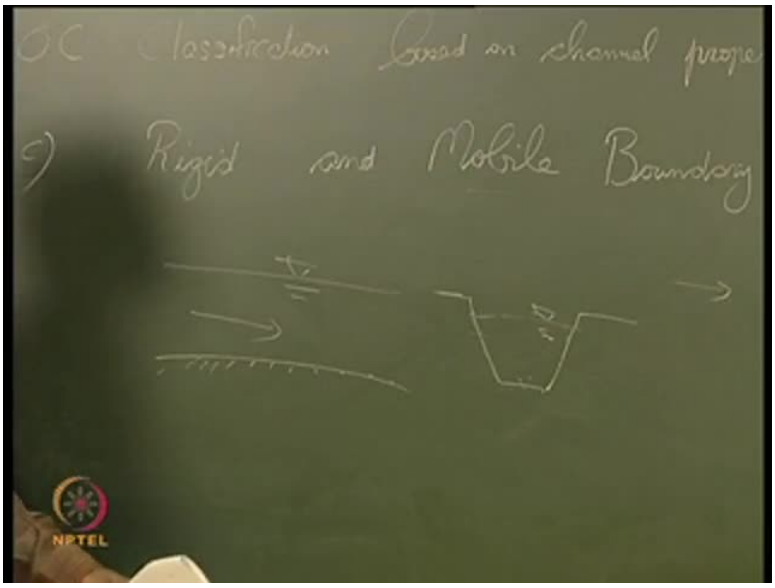

Next, classification we can give based on the channel properties rigid and mobile boundary channels. What do you mean by mobile boundary channel? What do you mean by rigid boundary channel? Any guess? You know the, in the channel flow if there is a bed water is flowing, it has a cross section say may be trapezoid, let us assume that trapezoid. So, the channel boundaries include the channel bottom, the channel sides all these things are coming into picture. So, there are lot of interaction of water with the channel boundaries bed sides and all if due to this interactions if these boundaries, if they are not stable in the, they also start if the particles in that if they also starts moving whether it be in bed, whether it be in the sides such type of channels are called mobile boundary channels.

And the reverse of that that is if even despite of enormous amount of flow in that channel if these boundaries remain firm such boundaries are called rigid boundary channels. If one go through the mobile boundary channels and all you may see that erosion and all occurs along the boundaries, these erosions will lead to the sediment deposit. In some other location the sediment deposits, sediment transport especially the sediment transportation and all it is a much researched topic, now a days for especially for very large rivers or for any hydraulic project related issues and all sediment transport is that is sediment transport is quite large research topic.

Well we are not going into details of sediment transport, this is an another level post post graduate level course. You may be able to do research after undergoing this course and all if you are interested you can specialise on sediment transport and all that will be much much acclaimed. So, till now we have classified channels based on this channel properties, now we can classify channels based on flow properties. We can classify channels based on flow properties, how can you classify based on flow properties? Any guess from anyone? We have seen in the last class that is in the first class in our first lecture, we have seen that any fluid property or any flow properties they can be classified or sorry they can be described using the following parameters.

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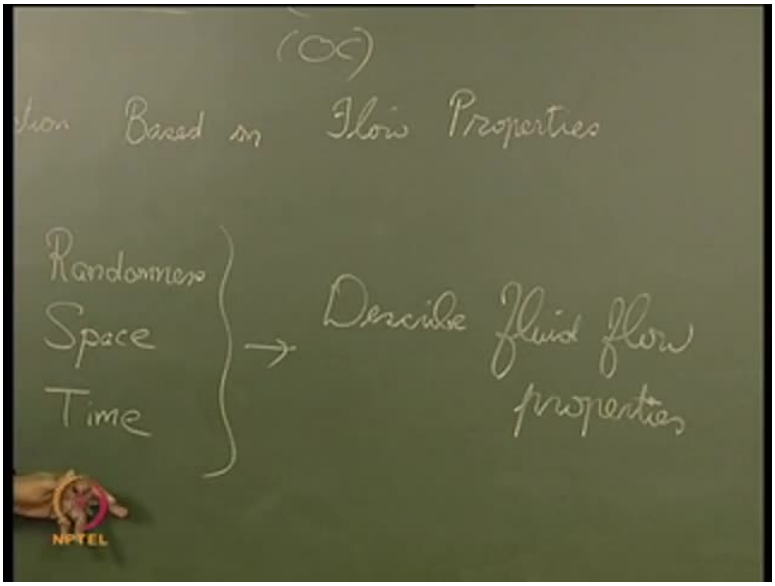

Randomness space time using these following using these three fundamental parameters you can describe any fluid flow properties. So, if you want to classify any flow properties, you have to classify according to the descriptions on these fundamental parameters fine. So, let us see how these fundamental parameters on the variations of these fundamental parameters, how the flow is classified first let us take randomness.

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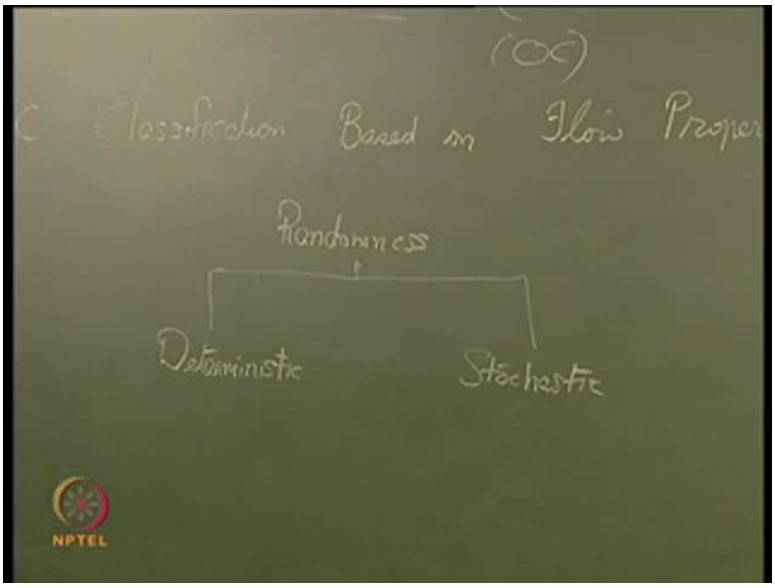

Randomness is such a property that is attributed to a variable, who is having random nature it is attributed to a variable having a random nature. So, a variable can accessed in a probabilistic way or it can accessed in a deterministic way, so any fluid property that can be suggested as say if there is no randomness for that fluid property then that fluid property is called deterministic fluid property. If there is no, if there are randomness appearing in the fluid properties such things are called stochastic properties. So or probabilistic sometimes in some of the things you may see probabilistic variable or probabilistic property.

So, you can based on these phenomenon you may identify the properties appropriately any fluid flow properties appropriately in our lecture. However, we are not going to deal on randomness, we will be dealing only with the deterministic nature of the fluid flow. The higher stochastic or probabilistic nature of the fluid flow and all we will be dealt in higher level courses, which as mentioned earlier. If you are interested you can specialise them.

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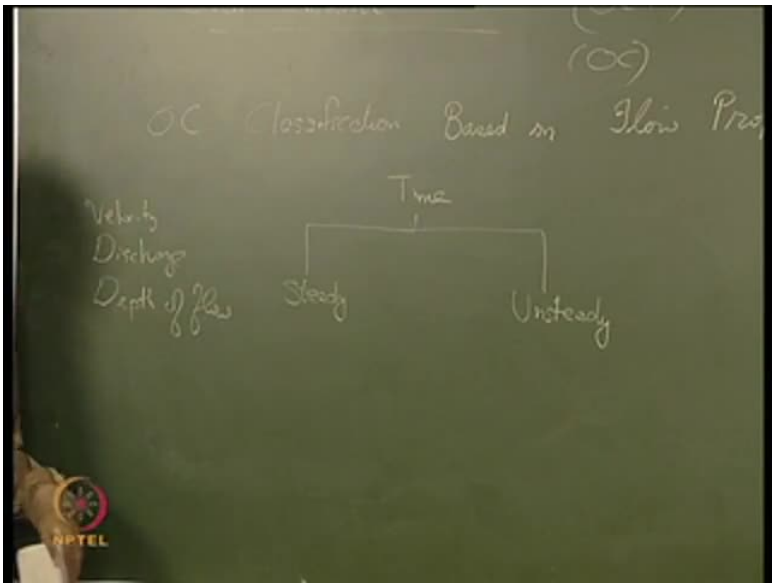

Next based on time any fluid property, if it does not vary with respect to time then that fluid property is called steady and if it varies with respect to time it is called unsteady. There is not require much say any fluid property, if you can say velocity discharge depth of flow say if in a channel if these properties at a location, if it is not varying with respect to time then that flow is called steady flow. So, in channels we can suggest that such type of channels are called steady flow channels or in the channel flows those flows are steady flows. Similarly, if these properties vary with respect to time, they are unsteady open channel flows our next parameter is space.

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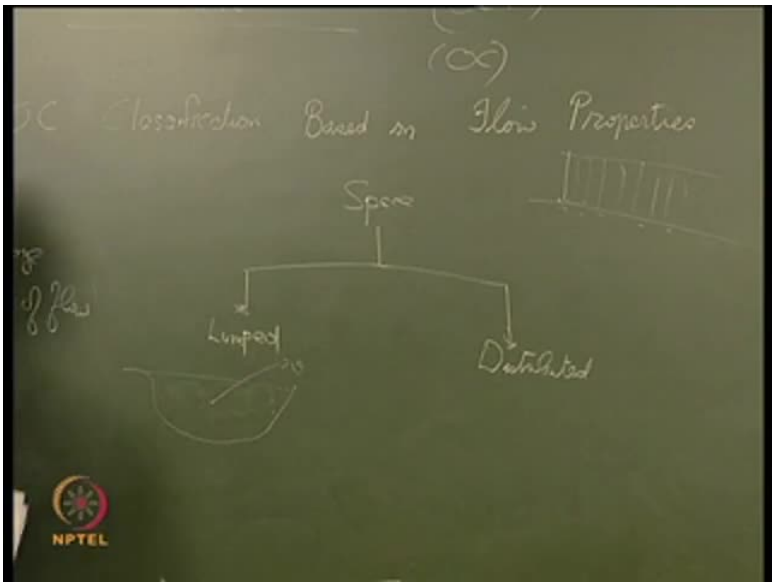

Here again we can classify say if any fluid property, if you are not varying with respect to space considerably, if you are suggesting that for a considerable large location if that fluid property if it is clubbed together at some particular value, then that is called lumped flow property and if the properties if it varies with respect to space channel location at each small small location each distance from the origin, if the fluid properties varies and if you are measuring them such things are called distributed flow properties. Usually lumped flow properties and all you may see if you take the cross sectional area for the entire cross sectional area of the river, if you are clubbing together to obtain a single discharge or if you are clubbing together the velocity if the entire cross section.

If there section the river section may be quite large and all still if you are using a common velocity term for the entire section without measuring at various location, then that velocity is lumped with respect to space there you are not averaging them. So, such things are called lumped properties and the other things are distributed properties. So, let us see using these fundamental three parameters and all how the fluid flow properties are named especially with respect to space.

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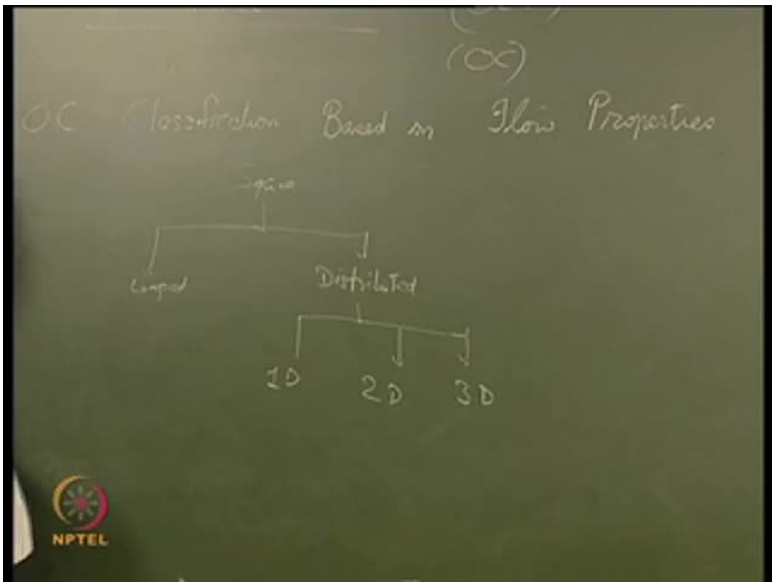

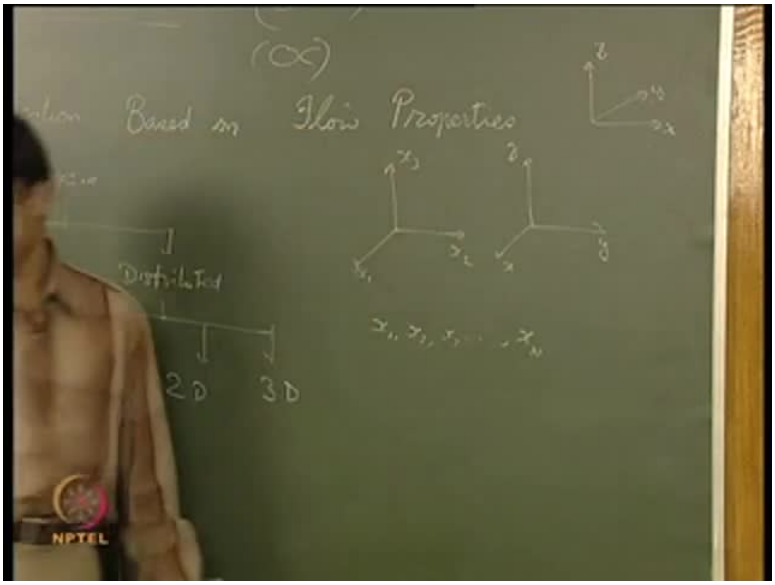

As you have mentioned lumped and distributed as you have mentioned the lumped and distributed in the distributed thing based on your coordinate system, you can have one dimensional fluid flow properties, you can have two dimensional fluid flow properties you can have three dimensional fluid flow properties. If you are following a Cartesian coordinate system say x 1, x 2, x 3 as the three basic directions. In a Cartesian coordinate system or you can may be, you have you may be more familiar with such notation x y z the same coordinate system.

If y is given in the other direction x y z the Cartesian coordinate system can be represented in any form, we may use any of this Cartesian coordinate system. You may see in higher order mathematical analysis and all it is quite common to use the suffixes x 1, x 2, x 3 etcetera. If there is n dimensional plane and all n dimensional representation they find it quite easier to represent x 1, x 2, x 3, etcetera, x n as the n dimensional problem in our three dimensional Cartesian coordinate system. For our simplicity we may use, we can use the following x, y, z Cartesian coordinate system.

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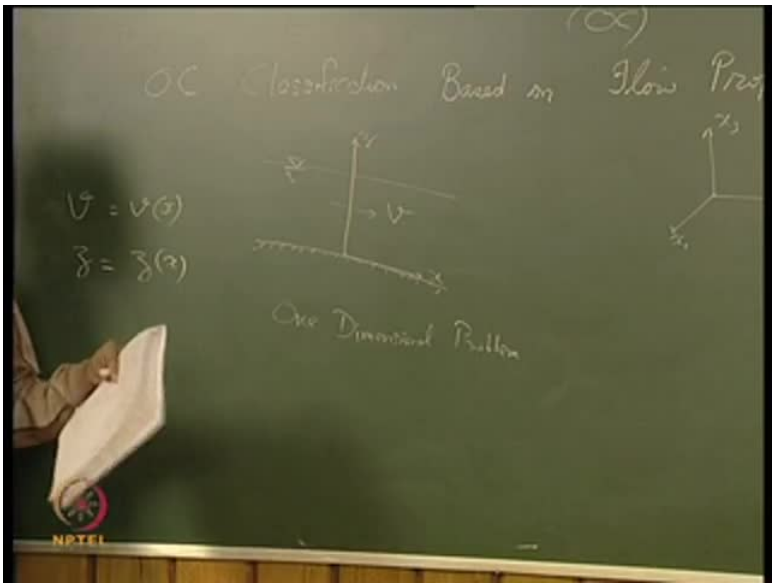

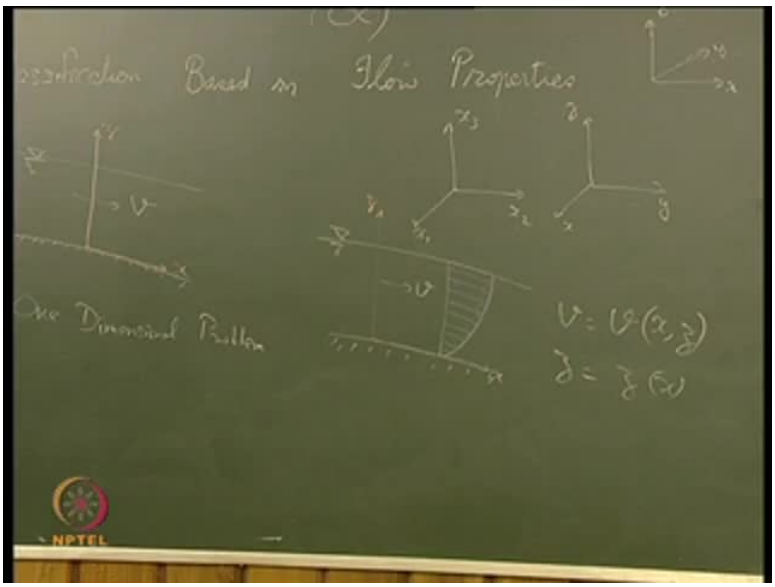

So, how a one dimensional problem how a one dimensional problem varies in a Cartesian coordinate system? Let us take the channel bed and all for a one one dimensional problem. If if you are taking velocity as the property, if you want to identify velocity as the property here, based on your same coordinate systems. Let us suggest say this is z axis x axis at any location at any x, you may see the velocity of the flow is v especially in the x direction the flow is in the x direction, x y z in the x y z Cartesian coordinate system.

Here in the one dimensional problem, we are assuming the flow is in x direction and you will see that velocity here this will be function of only x velocity in the one dimensional

problem is not being suggested to vary with respect to the height in the z coordinate system. So, it is only a function of x you may also see that the z coordinate itself is function of x in such situations so this is a one-dimensional fluid flow proper representation. A two dimensional fluid flow representation you may give them say again based on the coordinate system x z. You will see that any fluid property v any fluid property v it varies, that is it varies with respect to the height z as well as it varies with respect to the x coordinate system. Here you can write v as function of x and z similarly, again z is also a function of x in this case.

So, you can represent velocity in both the coordinates that is why it is a two dimensional problem, in this case only one dimension was used to represent the fluid property whereas, here two-dimensions were used that is how you classify them you can again classify for a three-dimensional case for a three dimensional case say if there is a large cross section of a river.

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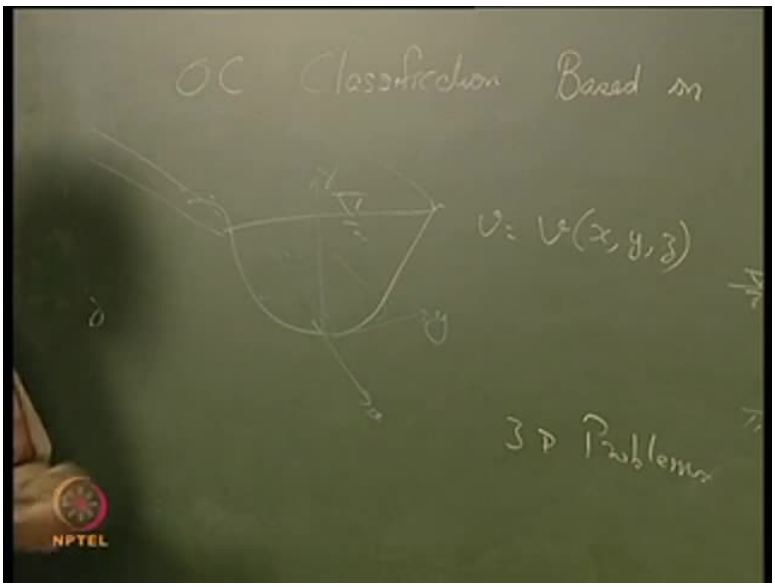

The entire quantity here velocity it may depend on say if your coordinate system x y z. Suppose if these are the coordinate systems or let us suggest that x y z, the positive tends to the following coordinate system is being employed here x y z. You will see that the flow if it is predominantly even though if it is in this direction the velocity here at any location it will be function of x axis y axis z axis. You mean the identities in x y and z to

describe the velocity vector, there you can describe may be y and z with respect to x if if that is possible in such flows and all that will be dealt.

So, higher order three-dimensional problems and all using various computational methods, one will be able to solve them. So, this is how you can classify using flow properties, various type of flow properties. What is meant by uniform flow and non uniform flow? What do you mean by them? This is also classification based on flow properties.

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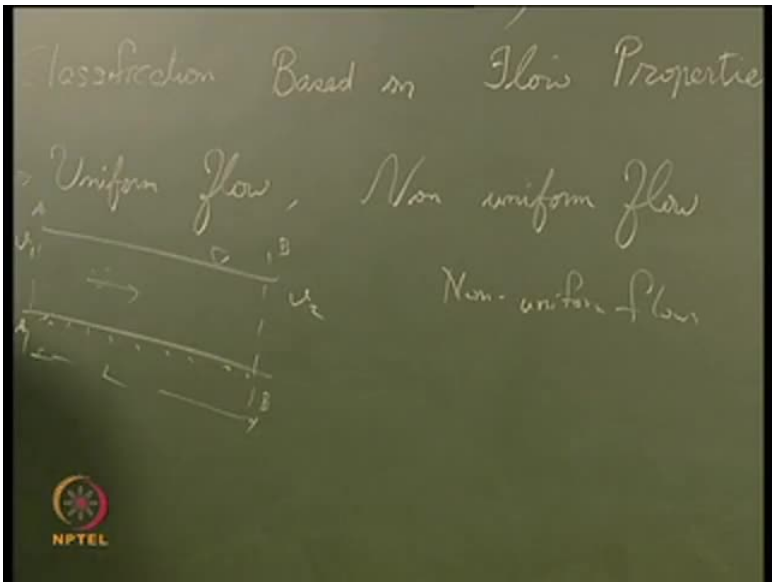

Uniform flow as the name suggests say any fluid properties velocity discharge height depth whatever be, whatever properties you are taking if these properties are uniformed for a considerable stretch of the channel, then such type of flow are called uniform flow. Say if a channel stretch of length l if it is taken and if it is found that this velocity v from section A A to section B B, if it is having the same velocity throughout this length then that is called uniform flow.

Suppose, if the velocity is varying at section A A, it is v 1 at section B B it is v 2 and if it is varying with respect to as it goes in the flow direction, then such type of flows are called non uniform flows. So, in nature you will see most of the time non uniform flow and as well as if you will see unsteady flows with respect to time and all. Another classification based on flow properties is as we have mentioned non uniform flow uniform flow and non uniform flow.

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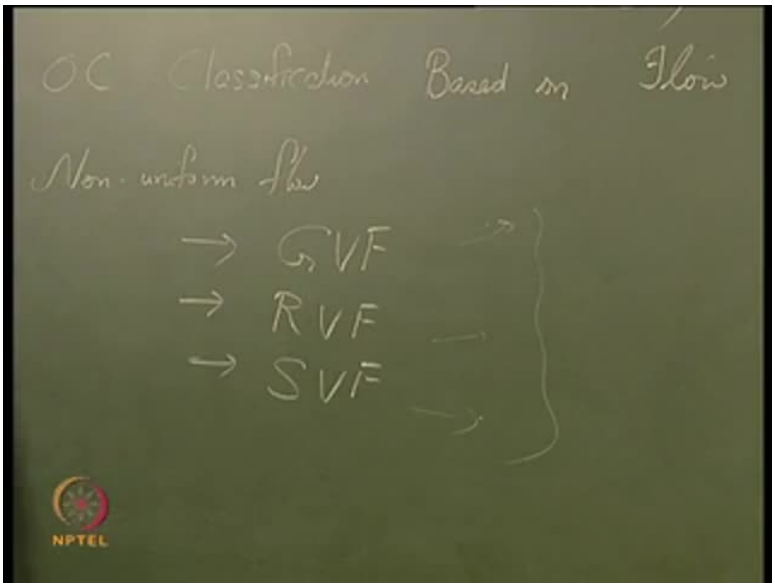

In the non uniform flow category, you can describe gradually varied flow, rapidly varied flow, spatially varied flow. Just a brief one line description that gradually varied flow means where the properties whichever are taken into consideration, if it varies gradually along the length of the channel, then the those types of flow are called non gradually varied flow, those type of non uniform flows are called gradually varied flow. In a rapidly varied flow as a name suggest the fluid properties it will be varying rapidly, for example, the height of water or the velocity of water, it may change rapidly from one section to another section.

Spatially varied flow suppose if some quantities of water or volume of water if it is added in between two sections or if it is continuously added at some locations and all the amount of water is getting changed, the total volume of water is getting changed specially it is changing, so that type of flows are called spatially varied flow. And we have separate modules to discuss on these aspects which we are not going to describe it in this particular module.

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What do you mean by say in a particular if you take an arbitrary channel, an arbitrary channel you can describe you can describe say the depth of channel as y forget about the Cartesian coordinate system, which you are given earlier. Let me talk it in terms of y here the depth of water at any channel section that is this y, you can represent it as a quantity, the bottom width you can represent it as a quantity, you can also represent the top width of the channel that is also a quantity. You can also represent say the wetted perimeter that is this, much length of the or this much length of the perimeter it is wetted by water in any cross section, you can define it as a channel geometric term terminology. so that is called wetted perimeter p.

So, you can define it for any cross section, say in the rectangular cross section in the trapezoidal cross section in the triangular cross section may be semicircular cross section whichever cross sectional forms. You observe in the, in your various courses or whichever labs or even in fields and all whichever type of cross sectional canals you have observed. You can define these terminologies, these terminologies are almost standard in almost all text books and all we will be using some of the properties to define some hydraulic properties for example, you might have heard about the term called hydraulic radius. What is meant by hydraulic radius? It can be defined based on the geometries given, whatever geometries has been given, it can be defined and that definition is unique it irrespective of the type of channel sections you can name it appropriately fine.

So, what is meant by hydraulic radius? It is a term developed from the channel cross section, it is very much used in our fluid flow analysis especially the channel flow analysis and all various place instances. You will find the term hydraulic radius from the channel geometry irrespective of whatever type of channel cross sections available. Hydraulic radius is defined as the area of the cross section divided by the wetted perimeter given to you say, if it is a rectangular cross section your p is nothing but B plus 2 y. If it is triangular cross section, you know the area, how to evaluate the area? If y is given to you, and if this width is given to you, if it is a semicircular one.

So, irrespective of the channel cross sectional areas you can define the term called hydraulic radius as A by p similarly, another term is called hydraulic depth that also we will be dealing in some of the other classes. So, today lecture we would like to wind wind up. Now, we will also be conducting quiz number two based on today's lecture so please note some of the questions for quiz number two. So, in quiz two you have to tell the difference between prismatic and non prismatic channels, in two line prismatic and non prismatic channel difference in two sentences maximum two sentences. Next question is based on the parameter randomness. Based on the parameter randomness, you can define any fluid property as dash and dash that is how do you define a fluid property based on the parameter randomness?

If randomness is present and randomness is absent, what are those that you have to fill in the blanks. The third question for the quiz you have to define what is hydraulic radius? So, in the quiz number two we will be having only three questions. The solutions, the solutions for quiz one.

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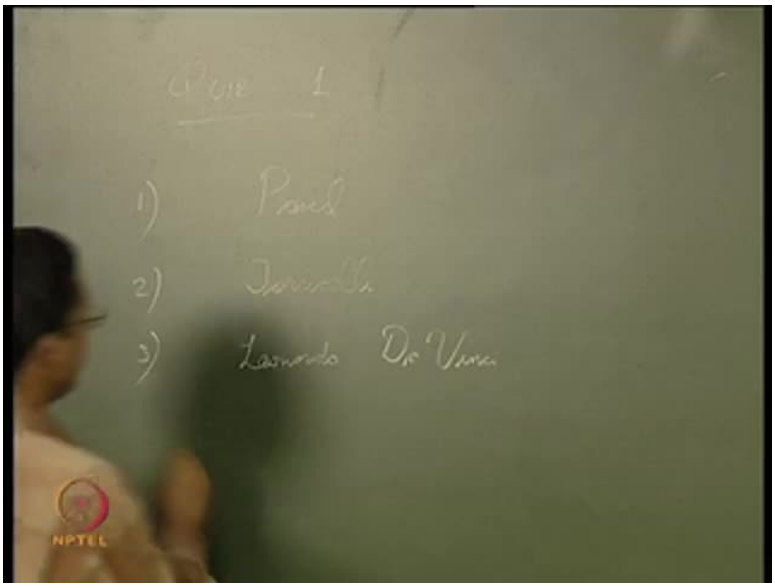

The first question is asked you was, who suggested the quantity called pressure is not having any direction? It was scientist Pascal. The second question raised to you was who was the scientist who developed barometer first? It was the scientist Torricelli. So, name the scientist who measured velocity of flow in a river by his own pedometer methods? Leonardo da Vinci. Give the names of some well known hydraulic projects in India and that is an individual question. I hope some of you might have or all of you might have answered according to his or her own choices. There are various hydraulic projects in India, I do not want to illustrate them it is up to you to illustrate some five names.

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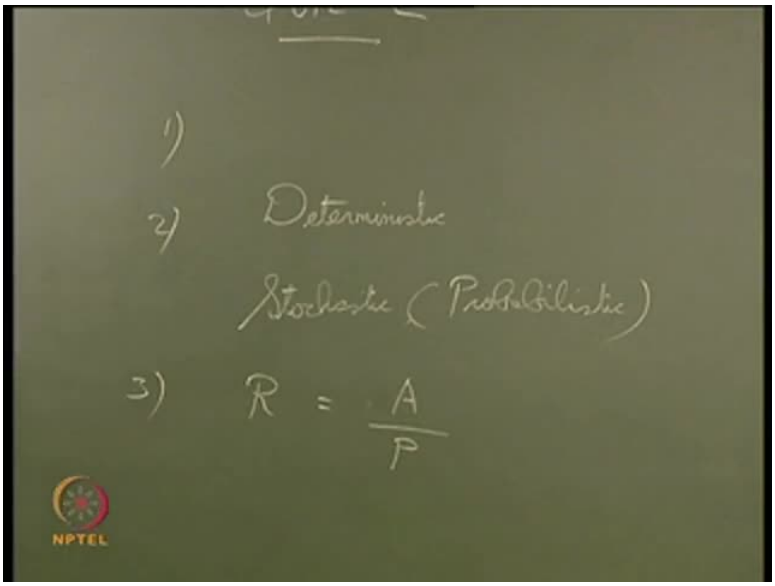

The solution for quiz two what is meant by prismatic and non prismatic channel the solution is, if the cross sectional area of a channel, if it is uniform for a considerable stretch or length of the channel then that channel is called prismatic channel. If the cross sectionity is varying with respect to time, then the sorry with respect to the channel length that is called non prismatic channel, as you see in rivers natural rivers and drains. Next, second question asked to you was based on the parameter randomness. You can define any fluid properties as say if randomness is not present, then that property is called deterministic fluid property.

If randomness is present then that fluid property we suggest it is having stochastic or probabilistic property. The third question asked to you was what is meant by hydraulic radius? Hydraulic radius we gave it symbolically as r it is the area of cross section divided by wetted perimeter fine. So, like this we would like to wind up today's lecture. In the next lecture we will continue with the same module on the different topics, which are to be covered. There you are requested to come prepared in the next class, as well and also be attentive in the next lecture.

Thank you.