

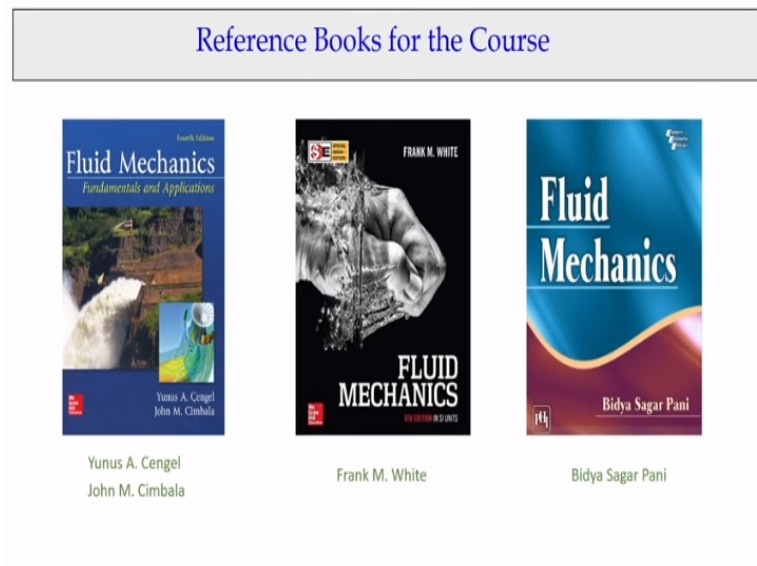
**Fluid Mechanics for Civil and Mechanical Engineering**  
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**Lecture No 12**  
**Bernoulli Equation and its Applications**

Welcome all of you for this very interesting lectures on Bernoulli Equation and its Applications. The last class we discuss about Bernoulli equation starting from its history of Bernoulli equation. Very briefly, I can say that because of the Bernoulli equation, having a simplification to the fluid flow problems, the industrial revolutions what it happened in Europe, the contribution of Bernoulli equation also helped a lot to design pipe flow, channel flow in Europe after this equations was suggested long back in 1752.

Now, today I will give a very simple way representation of this Bernoulli equation, how we can use for real fluid flow problems with some correction factors or we can use this Bernoulli equation as hydraulic gradient line, energy gradient line and we can apply these equations for a systems having pump and the turbine. So, basically today, I will talk more applications and how we can use the Bernoulli equation for real fluid flow problems. That is the basic concept what I will do and these are the reference books.

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And most of these materials partly we follow Cengel, Cimbala and F.M. White book.

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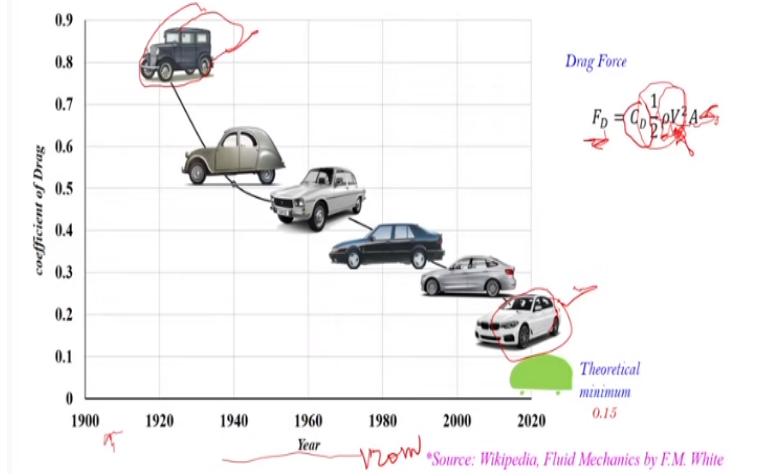
I will start with the applications, very interesting applications I will show to you, then I will go for orifice meter experiment in IIT, Guwahati, then I will talk about kinetic energy corrections factors. That means, for a non-uniform distribution of flow, when you apply this Bernoulli equations, we need to have a corrections factors if we are using average velocity. That correction factors for Bernoulli equations.

Fourth part, I will talk about how we can define the three different types of pressures; static, dynamic and stagnation pressures. Then will come hydraulic and energy gradient lines, that is the basic concept what we will talk about. Then I will talk about if we have a pipe flow systems, with a series of pump turbine systems, then how we apply it and how we can quantify different energy mechanical energy also the efficiency to the fluid flow problems.

Then, we will solve around four fluid flow problems, which are the gate and the engineering service problems will solve, which is part of the Bernoulli equations applications. Then concluding this lecture, we talk about, how our sense of balance is there. So okay, how it is works.

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## Applications



So, let us go back to very interesting examples, as you know it people say as of now, we have very fuel efficient car. That means the mostly car we talk about the drag force. The more the drag force, then you have to have more fuel to be spent it, fuel to burn it. So the basic idea is to, because  $V$  stands for the design velocities, area is a projected area, which is more or less constant. So,  $\rho$  is the density of air. Only the  $C_D$  can be changed. That is what it happened the evolution of the  $C_D$  change from almost 120 years, okay.

Starting from 1800s to 2020. So, the coefficient of drags, which earlier is close to the 0.8, that means the force is equal to 0.8 times of  $\rho V^2$  into the area that becomes reduced to the 0.15, theoretical minimum value, very close to theoretical value. And that because of you can see the shape of the cars, okay. And the shape of the cars are changing, the streamline, the drag force patterns are changing the flow around these cars when you are moving with a design velocity.

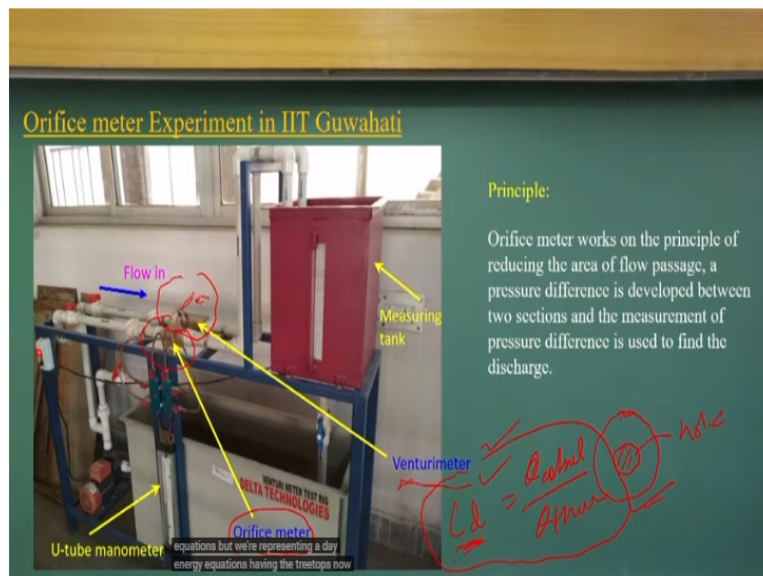
That is what it changes it, with a design velocity. The cars is moving with the  $V$ , which is the design velocity. On that, what is the drag force component. So that is what if you look it, we have achieved, within 100 years, the theoretical minimum value which is 0.15, very close to that. And you look the shape of the cars what today we have, which if you move with a design speed, then we will have a drag coefficient close to 0.15 and which is a strength of the fluid mechanics evolved the automobile sectors with a very efficient the fluid cars.

What is today is available and their drag ratio starts from the coefficient of drag  $C_D$  from point 0.8 to 0.15. That means as equivalent to  $1/6$ . So, for example the 6 liters of the car if it

is taking this one for one particular distance to travel it, now, we need just 1 liter, the same distance can be traveled because of the drag coefficient is almost 1/6. So, this is what is the evolutions happened is from the CD equal to 0.8 to 0.15.

And that because of series of the experiments done for the automobile sectors to find out what could be the best shape of the cars. So that, the coefficient of drag should be minimum or should be coming to closer to theoretical minimum value of 0.15. So that is what it happened in the evolutions of what has happened. And that is the reasons we have a fuel efficient cars available nowadays and with a CD value close to the theoretical minimum and this is what is possible because of the fluid mechanics as evolution with last 120 years.

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Now come back to the where simple experimental setups, we generally do the measuring the flow in a pipe, either in a venturimeter or the orifice meter. The orifice meter is a smaller device, that means it will be a circle and there is a hole inside this. This is called the orifice. In case of the venturimeter you have a diverging zone and converging zone. But in case of orifice, we do not have a diverging and converging zone, only you have a reduction of the flow area that is what is the orifice meter.

That means you have a simple plate with a hole with a constant, a particular diameter and that is what is fixed here. So, we can measure the pressure difference at two locations; one is at the fiber locations where the cross section is really is less and another is the off stream locations. That pressure difference and if you apply simple Bernoulli equations and the mass conservation equation, you can find out what will be the discharge passing through venturimeter or

orifice meters.

But as I said it earlier, that whenever flow goes through these venturimeter or orifice meter, there will be energy losses. Because of the energy losses, there will be a difference between theoretical discharge and actual discharge. Since the Bernoulli equations that we applied, we do not consider the energy loss components. We consider there is no energy losses, okay. No the frictional resistance is more or there is no vortex formations and all. But in the real fluid flow, there is energy losses.

Because of that, what do you will have, your theoretical discharge computed from the Bernoulli equations and the mass conservations will be more than actual discharge. So actual discharge, the difference between these, we introduce a coefficient of discharge, that means the CD. The CD will be the actual discharge by Q theoretical discharge, the coefficient of discharge, okay. Coefficient of discharge is CD here, it is not a coefficient of drag, please do not have a conclusions between the two terms.

If you look at the device where we have a setup of venturimeters and orifice meters, the basically in a venturimeter we have a converging zones and diverging zones and in orifice we do not have a converging diverging zones, but we just incorporated a plate with holes, okay, with a internal hole of this. Because of that, it also create, the converging zones and the diverging zone.

And because of that, we can have a energy losses in a flow systems when the streamline are converging and the diverging, definitely there will be energy losses with this systems. As the energy losses will be there, the theoretical discharge computed using Bernoulli equations and the conservation equations will be higher than the actual discharge. That is the reason, we introduce the coefficient of the discharge, the CD value, which is the ratio between actual discharge by theoretical discharge.

So, we introduced the coefficient of discharge in this and many of the times we have to compute it, what is the coefficient of discharge. So now if you can try to understand it that many of the times we do not go inside in this fluid flow problems within the venturimeter or the orifice meter that how the flow streamlines, how the energy dissipater happens, that what we do not look it, that in depth. But in terms of these flow patterns, what is it the gross

characteristics in terms of energy losses, in terms of reductions in a discharge.

That is what we introduce as a CD coefficient, the coefficient of discharge. So, these are gross representations of change of the flow patterns, the pressure and velocity patterns. Because of that and flow structures. We need we do not look it very microscopically, how it is changing it, but as a gross representation, we just look it the coefficient of discharge as the relationship between the theoretical and the actual. There is a link between now experimental work and analytical farm work.

So, the Bernoulli equations is strength there that this is the equations we can easily incorporate the experimental relationship into these Bernoulli equations. So, that is the strength of the Bernoulli equations as compared to the other Euler forms or other Navier-Stokes equations form, where Bernoulli equations are very suitable, appropriate to incorporate any energy losses, energy to this a fluid flow systems or taking out from the fluid flow system.

All we can incorporate it in a Bernoulli equations looking as energy conservation equations, looking as a energy conservation equations. But we remember, this is a equations for along a streamlines, is a momentum equations, but we are representing as a energy equations, having the three talks.

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**Kinetic Energy Correction Factor**

- The flow entering or leaving a port is not strictly one-dimensional.
- In a particular the velocity may vary over the cross section, in this case the kinetic energy term in Energy equation should be modified by a dimensionless correction factor  $\alpha$  is termed as **kinetic energy correction factor**

$$\int_{port} \left( \frac{1}{2} V^2 \right) \rho (V \cdot n) dA \equiv \alpha \left( \frac{1}{2} V_{av}^2 \right) \dot{m}$$

$$V_{av} = \frac{1}{A} \int u dA \quad \text{For incompressible flow}$$

$$\frac{1}{2} \rho \int u^2 dA = \frac{1}{2} \rho \alpha V_{av}^2 A$$

$$\alpha = \frac{1}{A} \int \left( \frac{u}{V_{av}} \right)^3 dA \quad \alpha = 2 \quad \text{for fully developed laminar flow}$$

$$= 1.04 - 1.11 \quad \text{for turbulent pipe flow}$$

Now, let us come back that whenever you have a fluid flow problems, like fluid flow through a pipe. So definitely the velocity distributions is not uniform. The velocity distributions will

be change it, from laminar to the turbulent. The turbulent will have logarithmic profiles and the laminar will be parabolic profiles. So velocity distribution changes, so what we do it that, it is very difficult for us to put it as the average velocity to compute the kinetic energy.

Because the flow within these pipes follow, having a parabolic flow velocity distributions. Now, we are looking it, if I consider the flow velocity distributions. Because of that velocity distribution, what is the total amount of kinetic energy? I can compute it with simple integrations, considering the velocity distributions. Then I will compute it, if I consider the average velocity, what will be the total kinetic energy. And since I am going to use average velocity, not the velocity distributions.

I apply a correction factor for that, which is called kinetic energy correction factors. Let me repeat these things, what we are looking at that in a real fluid flow problems, always we have flow is not uniform, non-uniform distribution. that means it will have a either a parabolic distribution, logarithmic distributions. It depends upon the flow, through pipes, or open channels. The flow velocity distributions varies in a space.

So, when you apply the kinetic energy, we look at the total kinetic energy, which is we can integrate over that a small  $dA$  element with  $a$ . This is a mass flux,  $\rho V \cdot n$  is a mass flux and this is a half  $\rho V^2$  is the mass flux into  $V^2$  by 2 is a kinetic energy flux. That is what we will do the integrations over the total area  $dA$  and we have the kinetic energy. So, if you look it, the kinetic energy computations, using the  $V^2$ ,  $V$  average values will have the kinetic energy computed using average velocities.

Times of  $\alpha$ ,  $\alpha$  is kinetic energy correction factors. The basically what it indicates that, if you look it, compute the kinetic energy best on average velocity, then what could be the correction factors for non-uniform distributions of velocity in the particular flow field condition. So, if I equating these things, then my  $\alpha$  will comes like this part, it is very simple part. As you know,  $V$  average we compute, is average velocity, we can compute like this.

So  $\alpha$  can consider it  $V$  average  $u$  to the power 3 or cubic power  $dA$  and this integrations will give us the  $\alpha$ . For fully developed laminar flow, this  $\alpha$  value is about 2. Turbulent pipe flow, this is what varies from 1.04 to 1.1. That is what is the biggest problems

many of the fluid mechanics book, they do not give the alpha value, they consider the alpha value is close to the 1 or indirectly they represent that flow is turbulent. The alpha value variations of 1.04 to 1.11, they do not consider it.

But that is not correct, any fluid flow problems, we should compute what is the alpha value and whenever we apply the Bernoulli equations, considering the velocity distributions, the kinetic energy, correction factors needs to be done it and that is the value which is varies for the turbulent pipe flow and for the laminar flow, which is equal to 2 value.

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The Bernoulli Equation: Unsteady, Compressible flow

For Unsteady compressible flow

$$\int \frac{dP}{\rho} + \int \frac{\partial V}{\partial t} ds + \frac{V^2}{2} + gz = \text{const.}$$

Static, Dynamic Pressures

The Bernoulli equation states that the sum of the flow, kinetic, and potential Energies of a fluid particle along a streamline is constant.

$$P + \frac{\rho V^2}{2} + \rho gz = \text{const. (along a streamline)}$$

Static Pressure      Hydrostatic Pressure  
dynamic Pressure

The sum of the static, dynamic, and hydrostatic pressures is called the total pressure.

*Handwritten notes on the right side of the slide:*  
 Pitot-static probe  
 Pitot tube  
 Proportional to P<sub>stag</sub>  
 Stagnation point  
 P: Static Pressure  
 P<sub>dyn</sub>: Dynamic Pressure  
 P<sub>stag</sub>: Stagnation pressure

Now, let us come back to this Bernoulli equation what we have derived, that in case of unsteady compressible, will have the two integrals component. Then we have V square by 2 gz, which is the elevation head is equal to the constant. But in case we make it the steady and incompressible, then we get it these three forms as earlier I discuss it, this is summations of three energies, flow energy, which is because of the pressure at that locations.

How much work is done by that pressure, that is what will be the flow energy. You have a velocity field, which have a kinetic energy and the fluid particles or virtual fluid balls staying a particular height and from a (0) (19:30), which gives potential energy. So, three energy along a streamline is a constant. The sum of these three energy flow, kinetics and the potential energy of a fluid particles along a streamline is constant. That is what we have written it.

Now, in terms of pressures, if you talk about, one is static pressure, that is the presses act on



this fluid particles another is the dynamic pressure because of the velocity components. Please remember this  $\rho V^2$  we have used when you come the drag force, okay. And we have a  $\rho g z$ , which is the hydrostatic pressure. So, we have three pressure components, in terms of pressure if you look it. In terms of energy, we can define it is a flow energy, kinetic energy and potential energy of a fluid particles along a streamline is a constant.

Now, let me demonstrate it if I have pipe flow, flow is going through this, it has a velocity distribution. As you know it, the velocity near to wall is 0 and whatever the height of the fluid go, this is what will be represent is me the pressure. That is what will be represent me the pressure head, that is what the static pressures. So, basically this height will be the static pressure and that is what we measure through piezometers. But, if I insert a tube and put it inside this.

And as the flow is moving with velocity  $V$  and stuck over this, since it is a contact, it is a fixed point, the velocity has to be zero at that point. So, the stagnation point will be work on this. So, because of that, what will be happen it, the two energy components what we have the flow energy and the kinetic energy that what convert to as a head, as equivalent water head or the liquid head will get it that. So difference between these two will give us  $\rho V^2$ .

That is what is the kinetic energy head. The difference between this Pitot tube and the piezometer will give us the difference of these energy  $\rho V^2$ . But you can say that, what about the potential energy. These two energies are so high that, we do not consider the  $z$  difference what we have that may not have a that significance. That is the reason, we do not consider the potential energy part, but we can measure. When you have a pipe flow we can measure, using the piezometer you can measure the pressure.

Using the pitot tube, which (0) (22:46) can insert and have a sharp point to rise the fluid inside the tube. That is what measures both the components, the dynamic pressure as well as the static pressures. The dynamic pressure and the static pressure. Since we know the static pressure, you just compute what is will be the dynamic pressure. The stagnation pressure is a sum of static pressure and dynamic pressure.

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### Stagnation Pressure

The sum of the static and dynamic pressures is called the stagnation pressure.

$$P_{stag} = P + \rho \frac{V^2}{2}$$

Pressure at a point where the fluid is brought to a complete stop isentropically.

The static and stagnation pressures are measured at a specific location, the fluid velocity at that location is calculated from:

$$V = \sqrt{\frac{2(P_{stag} - P)}{\rho}}$$

Useful in the measurement of flow velocity when a static pressure tap and a Pitot tube is used.

Now, if you look at that same concept that we are talking about. As I said that the sum of the static and dynamic pressure is called the stagnation pressure. That whenever you have an object, which is at stationary conditions, it is at rest conditions. At that point, the pressure will be the same, because the velocity at that point of the fluid flow has to be zero. So when we get the stagnation pressure, we will have two components.

The static pressure component and the dynamic pressure component. So that is what we get it, because pressure at a point where fluid is brought to a complete stop, then we will have a stagnation pressure which will be two components, one is a static pressure component and the other is a dynamic pressure component and those equations we can rearrange to compute what will be the velocity. I think this is what is used even in the modern era, in any aircraft wings, you can see there are pressure sensors and based on these pressure sensors, we can easily compute it, what will be the air speed.

So to measure the air speed in any modern aircraft, still also use the same concept of measuring the pressure and as you measure the pressures at this stagnation point and you know the atmospheric pressures, then we can easily find out what could be the airspeed is coming that. This is the equation used for this to measure the flow velocity when a static pressure tap and a Pitot tube is used.

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Pitot tube

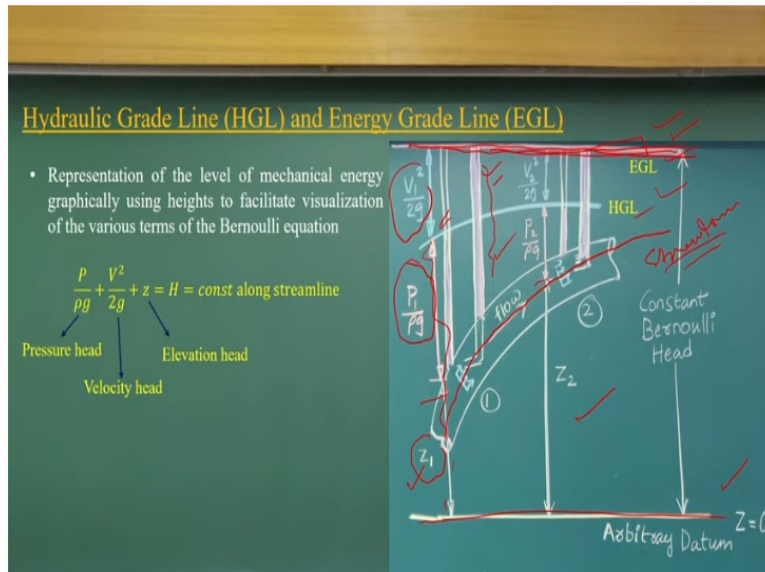
- A Pitot tube is aligned into the flow.
- It measures the stagnation pressure.
- When a stationary body is immersed in a flowing stream, the fluid is brought to a stop at the nose of the body (the stagnation point).
- The flow streamline that extends from far upstream to the stagnation point is called the stagnation streamline.

This is the same concept of the pitot tubes as I explained to you, the basically it measures the stagnation pressures, which have both the components and if you have the piezometer, then you can differentiate and find the dynamic pressures and once you know the dynamic pressure, you can compute what could be the velocities. The flow streamline that extend from upstream to the stagnation point is called stagnation streamline, the basically this streamline, which is just come it hit over the mouth.

Just pinpoint of this hole, this is what the pitot tube, this is not a big instrument, this is a small tube inclined here. So, there is a pressure hole, at this point. This is the pressure holes to measure it, this is the points where the stagnation pressure is develop it and that is what will be the two components, static pressure and dynamic pressure and using these with the help of the manometer we can measure the pressure.

And once you know the pressures, you can compute it dynamic pressures and you can compute the velocity. It is a just a applications of Bernoulli's equation.

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Now, another interesting applications of Bernoulli equations is that energy gradient line and the hydraulic gradient line. This is very great simplifications of the fluid flow problems. Like you may have fluid flow problems with pipe arrangement, the dock arrangement and all. Any flow, as I say that, it can have the flow distributions. But as total energy, along a streamline, if you can draw a streamlines and you want to quantify how these energies are changing it, okay,

That itself as you know it, fluid flows from higher energy to the lower energy, not the higher elevation to lower elevation. Please do not have that things. The fluid flows from higher energy to the lower energy. As it flows from any pipe flow, the channel flow, any doc flow, okay, always there will be a flow which starts from the higher energy to lower energy. Whenever flow from higher energy to lower energy, definitely there is an energy loss is happens.

And these energy losses if you can quantify experimentally, that is what I will discuss when I discuss the pipe flow, how very interestingly this energy losses in the pipe are quantified and then you apply the Bernoulli's equation for designing total pipe network. Same way if you know it in a different type of open channel flow, how much of energy losses is happening, you apply this Bernoulli's equation. Also, you can design the open channel flow.

The basic concept here is called that we should always gauge energy gradient line, hydraulic gradient line. So, any flow patterns, we have to draw the energy gradient line and hydraulic gradient line. What is energy gradient line? Now, we are representing the Bernoulli's

equation again in a different forms, it is the same things, okay. Same energy we talk about in terms of head, in terms of meter, okay. That means as equivalent if I have any liquid will be there, how much the lift will be there because of the pressure.

Because of the flow energy, because of the kinetic energy, because of the potential energy. That is the reason, we define it as a head. The pressure head, the velocity head, and the elevation head. It is nothing else, they are all three energy, the flow energy, kinetic energy, and the potential energy, constant along a streamline. And this energy gradient line and the hydraulic lines, what the difference between that. Energy gradient lines consider all these points.

That means, you have  $Z_1$ , this is a flow energy, this is the kinetic energy. If you do not have the kinetic energy or the velocity head, then we can have the piezometer lines. If you consider the velocity head, then we have energy gradient. So, always we should have a flow from higher energy to lower energy, okay. This gauge is not that appropriate, that should be the gradient of energy gradient lines. Otherwise, it is not possible to have a flow, okay.

If having a flow, if there is flat energy gradient line, there will be no flow. There is no flow when you have a constant energy gradient, there is no slope of energy gradient line. So, definitely there will be slope of energy gradient line, okay. And that what is drive the flow. So, you have energy gradient line and you can have a pitot tube and the piezometer to measure the hydraulic gradient and the energy gradient, and the energy gradient line and then we can sketch it as energy gradient line to get the hydraulic gradient line.

And many of the times, we can consider a **(0) (30:50)** from where you can compute the  $Z_1$   $Z_2$ , the elevations head of the, that means we define a streamline, then we are just drawing the energy gradient lines for this streamline, for this streamline we are drawing the energy gradient line, we are drawing the hydraulic gradient lines. The hydraulic gradient lines is not, it does not consider velocity head, it just consider pressure head and the elevations head.

Just like you just put a piezometer, then you get it what is the pressure head, also the elevation head is know to us that the what will come it. As soon as you put the piezometers whatever the point to will come it, that what will define us hydraulic gradient line, if I put a pitot tube, the line what will by the top surface will be the energy gradient line. So, whenever

we design the pipe flow or channel flow and all, we need to draw energy gradient line and the hydraulic gradient line.

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**Hydraulic Grade Line (HGL)**

- If **piezometer** tapped into a pressurized tube the liquid would rise to a height of  $P/\rho g$  above the tube centre.
- The HGL can be obtained by drawing the curve through the levels in piezometer at several locations along the tube.
- The vertical distance above the pipe centre is a measure of pressure within the pipe.
- The line that represents the sum of the static pressure and the elevation heads,  $P/\rho g + z$ , is called the **hydraulic grade line**.

The diagram illustrates a pipe with piezometers at various points. The Hydraulic Grade Line (HGL) is shown as a curve connecting the liquid levels in the piezometers. The Energy Grade Line (EGL) is shown as a curve above the HGL, representing the total energy head. The vertical distance between the HGL and the pipe centerline is the pressure head. The vertical distance between the EGL and the HGL is the velocity head. The diagram also shows a datum (Z=0) and a constant Bernoulli head.

That is what I have explaining it that, so the basically piezometers and the hydraulic gradient line what I have said it and the hydraulic gradient line has some of the static pressures and the elevations. And the vertical distance above the pipe center is measure of the pressure within the pipe, okay. Within the pipe, what is the distance above the pipe centers, is a measure of the pipe pressure within this.

What is talking about this sentence is that even if you are putting it here, what is the pressure we are getting it that what is the pressures within the pipe, it is measure it, more or less the same value, the elevations will not be that difference.

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### Energy Grade Line (EGL)

- If a **Pitot tube** (measures static + dynamic pressure) is tapped into a pipe, the liquid would rise to a height of  $\frac{P}{\rho g} + \frac{V^2}{2g}$  above the pipe centre, or a distance of  $\frac{V^2}{2g}$  above the HGL.
- The energy grade line (EGL) is obtained by doing this at several locations along the pipe and drawing a curve through the liquid levels in the Pitot tubes.
- The line that represents the total head of the fluid,  $\frac{P}{\rho g} + \frac{V^2}{2g} + z$ , is called the EGL.

The diagram shows a pipe with several Pitot tubes. The Energy Grade Line (EGL) is the upper curve, and the Hydraulic Grade Line (HGL) is the lower curve. The vertical distance between them is labeled as 'Constant Bernoulli Head'. The datum is at  $Z=0$ . Handwritten red annotations include 'Bernoulli' and circles around the formula  $\frac{P}{\rho g} + \frac{V^2}{2g} + z$ .

This is what I explain it, if a pitot tube is tapped in the pipe, the liquid could rise in height, which will have the static head and the dynamic head above the pipe and that will be above of dynamic pressure of the  $V$  square by  $2g$ . The velocity head part and that is what we can draw it, represents a total head using energy gradient line, which represents the total head of the fluid flow energy, kinetic energy and the potential energy, whenever we draw a streamline, we can compute the energy gradient line, hydraulic gradient line.

So, again I continue to say that energy gradient line should have some slope, so there is will be the flow. The flow will be from higher energy level to the lower energy level. The hydraulic gradient may have the difference, okay that is not a big problems, but the flow goes from high energy level to low energy level.

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### Hydraulic Grade Line (HGL) and Energy Grade Line (EGL)

- The **difference** between the heights of EGL and HGL is equal to the dynamic head,  $\frac{V^2}{2g}$ .
- For **stationary bodies** such as reservoirs or lakes, the EGL and HGL coincide with the free surface of the liquid.
- These two curves approach each other as the velocity decreases, and they diverge as the velocity increases.
- In an idealized Bernoulli-type flow, EGL is horizontal and its height remains constant. This would also be the case for HGL when the flow velocity is constant.
- For **open-channel flow**, the HGL coincides with the free surface of the liquid, and the EGL is a distance  $\frac{V^2}{2g}$  above the free surface.

The diagram shows a channel with a free surface. The Hydraulic Grade Line (HGL) is the free surface, and the Energy Grade Line (EGL) is a horizontal line above it. The vertical distance between them is labeled as  $\frac{V^2}{2g}$ . Handwritten red annotations include 'EGL', 'HGL', and 'V^2/2g'.

And okay, we are not discussing about open channel flow heads, but in case of open channel flow, the hydraulic gradient lines coincides with the free surface of the liquid okay. Because there is no pressure head. So, whatever the water surface free surface, that what will be hydraulic gradient line and the energy gradient lines will have a included the velocity head above the free surface. That means, if you consider a open channel flow, this is the free surface.

This free surface will be representing us hydraulic gradient line and  $V^2/2g$  of this, adding this velocity head, will get energy gradient line, okay, in case of open channel flow because there is no pressure head. But in case of the pipes, we can have a piezometer to measure it, what could be the hydraulic gradient lines. Energy gradient line to measure it we need to have a pitot tube to compute what will be these things.

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**Hydraulic Grade Line (HGL) and Energy Grade Line (EGL)**

- At a pipe exit, the pressure head is zero (atmospheric pressure) and thus the HGL coincides with the pipe outlet.
- The mechanical energy loss due to frictional effects (conversion to thermal energy) causes the EGL and HGL to slope downward in the direction of flow.
- The gage pressure of a fluid is zero at locations where the HGL intersects the fluid.
- The pressure in a flow section that lies above the HGL is negative, and the pressure in a section that lies below the HGL is positive

Now very basic things we should understand it, whenever a pipe exit, that means flow is going out. The pressure head becomes atmospheric pressure, no doubt about that. And that is the reason, the hydraulic gradient lines coincidence with the pipe outlet. So, when the pressure head becomes zero, that is what we said it, in case of open channel flow, when there is no pressure, is pressure is atmospheric pressure, that the surface becomes hydraulic gradient line.

Exactly same way, when you exiting, a pipe is exiting the flow to the atmosphere, that means your hydraulic gradient line should coincidence with the pipe outlet. Mechanical energy losses due to the frictional effects, which is converting from thermal energy, the causes the



energy gradient line, hydraulic gradient line, to a slope downwards in the directions of the flow, that is what I try to explaining to you. That there will be energy losses whenever you have the flow systems, okay.

So, there will be a slow downward in the direction of flow of energy gradient line and also the hydraulic gradient lines. But energy gradient lines should have this, but sometimes maybe hydraulic gradient may not have the slope downward in direction of the flow. The gauge pressure of the is zero at the locations when the hydraulic gradient line intersect the fluids. The same things I think we are repeating it whatever we have said it in the first point.

This is the same point what we are talking about here, that it happens it, if there is a gauge pressure, okay. Pressures in a flow sections lies above the hydraulic gradient line is negative. Pressure in a section when the lies below the hydraulic gradient line is positive and the negative that is the difference what we get it. Pressure in a flow section that lies above the hydraulic gradient line is negative and pressure in a section that lies below the hydraulic gradient line will be the positive value.

So whenever will solve the pipe flow problems, will show it how the pressure it changes negative to positive directions in respect to the hydraulic gradient line.

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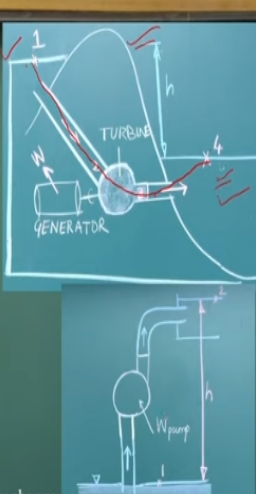
### MECHANICAL ENERGY

- **Mechanical Energy** is defined as the form of energy that can be converted to mechanical work completely and directly by an ideal mechanical device such as an ideal turbine.
- **Pump:** It transfers mechanical energy to a fluid by raising its pressure.
- **Turbine:** It extracts mechanical energy from a fluid by dropping its pressure.
- **Pressure** itself is not a form of energy; rather, it can be thought of as a measure of **stored potential energy (flow energy) per unit volume**.
- The mechanical energy of a flowing fluid can be expressed on a unit-mass basis as:

$e_{mech} = \frac{p}{\rho} + \frac{V^2}{2} + gz$ 

$$\Delta e_{mech} = \frac{P_2 - P_1}{\rho} + \frac{V_2^2 - V_1^2}{2} + g(z_2 - z_1)$$

mechanical energy change



Now, let us consider is the problems when we generally use as a engineer having a pump and turbine systems. As you know it, the pump is transfer from mechanical energy to fluid by rising pressures, okay. Transfer the mechanical energy to a fluid. So, fluid gains the energy

because of the pumping systems by rising its pressures, that is the. Similar way, the turbine does opposite things, that it takes out or extract the mechanical energy from the fluid by dropping its pressure.

So, this is what the **(0) (38:27)** turbine. So, when you have a flow systems and a pipe network of your campus, you can see there is a series of pumps are there to increase the energy in the flow systems, the mechanical energy in the flow systems. And the turbines are there wherever you have a hydropower projects. So you need to have a turbine, they extract the energy from the flow systems by dropping its pressures. So increasing the pressure and dropping the pressure.

Pressure itself is not a form of energy as we all say that, it is just a flow energy or storage potential energy per unit volume that is the pressures. So, if I look it this, again coming back to the Bernoulli equations, I have the three terms which will be define us as an energy term, okay. And if I have a two points, I am differentiating between these two energy, the difference part will show me the net energy difference will come it. That means, for example, I have a these systems.

There is a dam, the reservoir, water is going through a turbine and generators, coming out at the three, then it is related to the tail end reservoir. So, we have upstream reservoir, I have a tail end reservoir, there is a connections between the pipes and in between, I have the turbines and the generators. If you look it, if I take a flow streamlines, assuming the flow is comes like this and coming to this point, okay. So, I can find out what is the mechanical energy difference between these two part, just differentiating this energy at the one end flow level locations.

Similar way, two and three locations we can find out. And this is a very simple pumping arrangement you can know it that we use a pumping to enhance the mechanical energy in the fluid flow systems by rising its pressures and because of that we have a lifting the waters in a water head tank as you know it.

**(Refer Slide Time: 40:43)**

### MECHANICAL ENERGY

- The transfer of mechanical energy is usually accomplished by a rotating shaft, and thus mechanical work is often referred to as shaft work.
- Pump:** It receives shaft work (usually from an electric motor) and transfers it to the fluid as mechanical energy (less frictional losses).
- Turbine:** It converts the mechanical energy of a fluid to shaft work.
- Mechanical energy of a fluid does not change during flow if its pressure, density, velocity, and elevation remains constant.
- The maximum (ideal) power generated by a turbine is

$$\dot{W}_{\max} = \dot{m} \Delta e_{\text{mech}} = \dot{m} g (z_1 - z_4) = \dot{m} g h$$

since  $p_1 \approx p_4 = p_{\text{atm}}$  and  $V_1 = V_4 \approx 0$

$$\dot{W}_{\max} = \dot{m} \Delta e_{\text{mech}} = \dot{m} g \frac{(p_2 - p_3)}{\rho} = \dot{m} \frac{\Delta p}{\rho}$$

since  $V_2 \approx V_3$  and  $z_2 \approx z_3$

This mechanical energy what we get it and if I multiply with a mass rate, I will get the work done part, okay. How much of work done we are getting it or how much power we are getting it, maximum ideal power generated by turbines will be  $\dot{m} g h$  and the energy part, mass flux part which we will be talk about work per unit time is the power. So, basically, we are looking for the power part, which will be, since this energy per unit mass, so we have multiplied with the mass rate to find out what will be the power will be there.

For example, if I take it the same problems, I need to know it what is the maximum ideal power generated by this turbine. Assuming it that all are 100% efficient systems that maximum power generated from these one and two four points. As you know it, the pressure at these two points will be atmospheric pressures and both are the same. The velocity at one and four, the velocity becomes zero, only this elevations difference, the potential difference what will be get it, that what is maximum ideal power generate by the turbine, okay.

But if I consider the two and three, this before turbine and after turbine. At that locations, I have a  $V_2 = V_3$   $z_2 = z_3$ . Substitute this value, I will get it the power generated by the turbine will have a mass flux and  $\Delta p$ , the pressure difference between  $p_2$  and  $p_3$  by the  $\rho$  value. So, these are very simple calculations, you can do it.

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### MECHANICAL EFFICIENCY

- Mechanical energy cannot be converted entirely from one mechanical form to another due to, and the mechanical efficiency of a device or process is defined as:
 
$$\eta_{mech} = \frac{\text{Mechanical energy output}}{\text{Mechanical energy input}} = \frac{E_{mech, out}}{E_{mech, in}} = 1 - \frac{E_{mech, loss}}{E_{mech, in}}$$
- Pump Efficiency:
 
$$\eta_{pump} = \frac{\text{Mechanical power increase of the fluid}}{\text{Mechanical power input}} = \frac{\dot{\Delta E}_{mech, fluid}}{\dot{W}_{shaft, in}} = \frac{\dot{W}_{pump, u}}{\dot{W}_{pump}}$$

Useful Pumping Power
- Turbine Efficiency:
 
$$\eta_{turbine} = \frac{\text{Mechanical power output}}{\text{Mechanical power decrease of the fluid}} = \frac{\dot{W}_{shaft, out}}{|\dot{\Delta E}_{mech, fluid}|} = \frac{\dot{W}_{turbine}}{\dot{W}_{turbine, e}}$$

Mechanical Power extracted from the fluid by the turbine

Now, whenever we have a systems, there is energy losses. We cannot convert total mechanical energy entirely from mechanical pump or pump. There will be some heat energy losses, the sound energy losses, will have the energy losses from that. Because of that, there is an efficiency looped to that. If efficiency equal to 1, that means whatever input that what we get the output. Like we are quantifying what is the mechanical efficiency of the systems. If mechanical energy input and output, the ratio, that is what is efficiency of that.

Or in terms of loss, we can also quantify it, like this, very simple. Similar way, pump efficiency and the turbine efficiency, input and output. The ratio is between output to input, that is what is the efficiency of the pump or the turbine. The mechanical power increases of the fluid, by mechanical power input, turbine mechanical power output by mechanical power decreased by of the fluid. That is what will gives the turbine, the efficiency of the turbine systems.

And these are the basic powers, in terms of powers also we have defined them as a efficiency components.

**(Refer Slide Time: 43:59)**

### MECHANICAL EFFICIENCY

- Motor Efficiency:
 
$$\eta_{\text{motor}} = \frac{\text{Mechanical power output}}{\text{Electric power input}} = \frac{\dot{W}_{\text{shaft, out}}}{\dot{W}_{\text{elect, in}}}$$
- Generator Efficiency:
 
$$\eta_{\text{generator}} = \frac{\text{Electric power output}}{\text{Mechanical power input}} = \frac{\dot{W}_{\text{elect, out}}}{\dot{W}_{\text{shaft, in}}}$$
- Combined or overall efficiency:
 

$$\eta_{\text{pump-motor}} = \eta_{\text{pump}} \cdot \eta_{\text{motor}} = \frac{\dot{W}_{\text{pump, u}}}{\dot{W}_{\text{elect, in}}} = \frac{\dot{E}_{\text{mech, fluid}}}{\dot{W}_{\text{elect, in}}}$$

$$\eta_{\text{turbine-generator}} = \eta_{\text{turbine}} \cdot \eta_{\text{generator}} = \frac{\dot{W}_{\text{elect, out}}}{\dot{W}_{\text{turbine, e}}}$$

$$= \frac{\dot{W}_{\text{elect, out}}}{|\Delta \dot{E}_{\text{mech, fluid}}|}$$

Similar way, you can have a motor efficiency and the generator efficiency. Electrical power input for the motors, what is the mechanical power output. Motor generates from electric to the mechanical power. That is the reasons you have a input is electrical power, output is mechanical power. That ratio we get it. Similar way, generators we have the mechanical power to electrical, but when you have a combined systems, pump on motors, then you have a efficiency of the both the systems you have to input.

Pump and the motors, that is what we will define it. Similar way, if you have a turbine and generator, you have efficiency up to the things which are independent, you need to know the combined efficiency, that means you have to have a multiplication factor for that and that what is given here.

Now let us come it to the example problems, okay, which are GATE and engineering service problems.

**(Refer Slide Time: 45:00)**

**Example 1**

A constriction in a pipe will cause the velocity to rise and the pressure to fall at section 2 in the throat. The pressure difference is a measure of the flow rate through the pipe. The smoothly necked-down system shown in figure is called a venturi tube. Find an expression for the mass flux in the tube as a function of the pressure change.

**Flow classification:**  
 One dimensional  
 Incompressible flow  
 Steady flow  
 Frictionless flow

**Control Volume:**  
 Fixed control volume

**Assumption:**  
 flow along a streamline

These are very easy problems, here we will apply mass conservations and Bernoulli equations, that is all. We are not going to do much here. Mass conservations and the Bernoulli equation what will be use it. But I always encourage you gauge the control volumes as well as draw streamlines. After the drawing the streamlines, the apply the Bernoulli equation for the two points, okay. That to be looked it this part and always highlight it, what are the assumptions behind that.

What are the assumptions you have put it, that should be highlighted before solving any fluid flow problems. Now, look at this example one, which is a constrict in a pipe will cause the velocity to rise it definitely. Okay, there are, just like a venturimeter, here there is a converging zones and the diverging zone, okay. And because it is converging zones, the velocities to rises, pressure to be fall it. That is what we know it very beginning of Bernoulli equations.

The pressure difference is a measured of flow rate through the pipe. The smooth neck down system shown in the figure is called venturi tube. Find an expression for the mass flux in the tube as a function of the pressure and the pressure change, which is very simple things. Will just highlight it how to use mass conservation equation and Bernoulli equations. Now, let us gauge it, what are the flow classifications. Here we can assume it one dimensional flow because incompressible, steady and frictionless.

That is what is our strength is, because we are directly applying the Bernoulli equations as there is no energy loss component, we are not including that. Fixed control volumes and we

need to apply this Bernoulli equations along a streamline. The streamlines could be like this. There will be converging zones and the diverging zones, streamlines will be the converging and the diverging. Or you put the virtual fluid balls you can have the track of the flow path.

The path lines of the virtual fluid balls also could be like this, okay. They will converge it, more or less parallel in these regions. So, there will be no curvatures of streamlines in this regions. Then they will be the divergence on the streamlines, okay. So that the flow structures what we get it in venturi tube.

**(Refer Slide Time: 47:47)**

**Example 1**

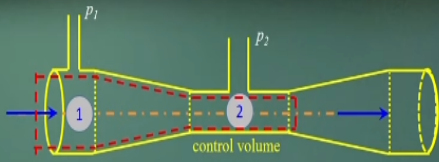
**Pressure Distribution:**  
different Pressures at both section

**Velocity Distribution:**  
Considering average velocity  $V_{avg}$

**Mass Conservation:**

$$A_1 V_1 = A_2 V_2$$

**Bernoulli equation:**

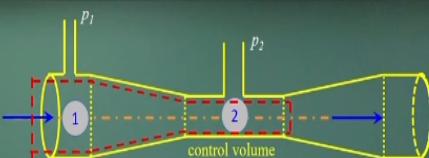
$$\frac{p_1}{\rho g} + \frac{1}{2g} V_1^2 + z_1 = \frac{p_2}{\rho g} + \frac{1}{2g} V_2^2 + z_2 = \text{const along a streamline}$$


And we need to compute it in terms of average velocities. So, we are not considering is turbulent or laminar velocity things. We are not putting any kinetic energy correction factors, which supposed to be done it, but in this case we have not done it. We just apply the mass conservations and the Bernoulli equations assuming that there is a uniform flow distribution, it does not happen like that. We use the average velocity here.

**(Refer Slide Time: 48:19)**

**Example 1**

If the tube is horizontal  $z_1 = z_2$

$$V_2^2 - V_1^2 = \frac{2\Delta p}{\rho} \quad \Delta p = p_1 - p_2$$


From continuity equation

$$V_1 = \beta^2 V_2 \quad \beta = \frac{D_2}{D_1}$$

$$V_2 = \left[ \frac{2\Delta p}{\rho(1 - \beta^4)} \right]^{1/2} \quad \dot{m} = \rho A_2 V_2 = A_2 \left( \frac{2\rho\Delta p}{1 - \beta^4} \right)^{1/2}$$

In practical we measure  $\dot{m}_{actual} = C_d \dot{m}_{ideal}$

*in theoretical. Cd from experimental study*

And applying this, as the tube is horizontal,  $z_1 = z_2$ , you can write in terms of velocity difference in terms of pressure and you apply the continuity equations to get it  $V_2$  in terms of pressure difference and the beta which the ratio between the  $d_2$  and  $d_1$ , representing the diameters and the sections 2 and the diameter at the sections 1, respectively. That is what we will get it and finally, the mass flux will be  $\rho AV$ ,  $\rho AV$ . So, area at the sections 2 you know it,  $V_2$  you know it, then we can compute it what will be the mass flux.

But please remember, as we have not considered energy losses, we need to incorporate a  $C_d$  value, which is the coefficient of discharge to these computations to find out what will be the actual value. This is what is  $\dot{m}$  theoretical value. And this  $C_d$  comes from experimental study. The  $C_d$  comes from the experimental study.

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**Example 2**

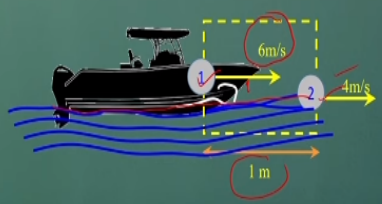
A body moving through still water at 6m/s produces a water velocity of 4m/s at a point 1m ahead. The difference in pressure between the nose and the point 1m ahead would be:

**Flow classification:**

- One dimensional
- Incompressible flow
- Steady flow
- Frictionless flow
- Irrotational
- Inviscid

**Control Volume:**

Moving control volume





Let us have another examples very, interesting examples that a body is moving with a still waters of 6 meter per second produces water velocity 4 meter per second at 1 meter ahead. That means there is a distance between these two points is 1 meters, this is what 6 meter per second, the flow is, there is a reservoir type of conditions where the still waters are there and the velocity at this point is 4 meter per seconds.

Now, we have to compute it, what could be the pressure difference between the nose and the point 1 meter ahead could be. So, we can assume, draw the streamlines, which is passing through this point 1 and point 2, incompressible flow, steady, frictionless, irrotational, inviscid, okay. It is a moving control volume, but we are not looking it as a moving control volume, we are just looking the pressure difference, we are not looking at the mass fluxes here.

So, we will just apply the Bernoulli equation between one and two, because they are at the same horizontal levels.

**(Refer Slide Time: 50:50)**

**Example 2**

Applying Bernoulli's equation between point '1' and point '2', we get :

$$\frac{p_1}{\rho g} + \frac{v_1^2}{2g} + z_1 = \frac{p_2}{\rho g} + \frac{v_2^2}{2g} + z_2 \quad z_1 = z_2 \text{ assumed}$$

$$\frac{p_1 - p_2}{\rho g} = \frac{v_1^2 - v_2^2}{2g} = \frac{4^2 - 6^2}{2g}$$

$$\frac{p_1 - p_2}{\rho g} = \frac{16 - 36}{2g}$$

$$p_1 - p_2 = \frac{1000}{2} (-20) = -1000 \text{ N/m}^2$$

The diagram shows a boat moving to the right with a velocity of 6 m/s. Two points, 1 and 2, are marked on the hull. Point 1 is at the bow, and point 2 is 1 meter ahead of point 1. The water velocity at point 2 is 4 m/s. The points 1 and 2 are at the same horizontal level.

The  $z_1 = z_2$  only will have the pressure difference will be equate with the pressure head is equate with the velocity head. And by substituting the pressures and the velocity, we will get it what will be pressure difference. It is very simple problems, but only you have to visualize the problems, how it looks like this. We have to sketch for that.

**(Refer Slide Time: 51:17)**

**Example 3**

Venturimeter having a diameter of 7.5 cm at the throat and 15 cm at the enlarge end is installed in horizontal pipeline of 15 cm diameter. Rate of fluid in pipe is 30 lit/sec. The difference of pressure head measured between enlarged and the throat is 2.45 m. Find coefficient of discharge of venturimeter. (GATE 2014 CE Set I)

**Flow classification:**  
 One dimensional  
 Incompressible flow  
 Steady flow  
 Frictionless flow  
 Irrotational  
 Inviscid

**Control Volume:**  
 Fixed control volume

**Assumption:**  
 flow along a streamline

Third problems, which is very easy. The similar way as we discuss for the venturimeter problems in example one, where in this, this is the GATE 2014 questions, where we have a venturimeter having a diameter 7.5 centimeters at the throat levels and 15 centimeter at enlarge is installed in a horizontal pipelines of 15 centimeter dia. Rate of the fluid pipe flow is 30 liters per second. The difference of presser head measure between the enlarged and the throat locations is 2.45 meters. Find the coefficient of discharge of venturimeters.

If you look at this problems, we already discussed in example one, the same problems only, the numerical values are given for us to solve it. So, I will not take much time for this, only you can see the same streamline you have to draw it and you apply mass conservation equations and the Bernoulli equations to solve it to find out because here, the actual discharge is given to us, we have to compute theoretical discharge. Once you know this theoretical discharge, you can compute the coefficient of discharge.

**(Refer Slide Time: 52:35)**

**Example 3**

If the tube is horizontal  $z_1 = z_2$

$$\frac{p_1 - p_2}{\rho g} = \frac{v_2^2 - v_1^2}{2g}$$

$$2.45 = \frac{1}{2g} \left( \frac{Q^2}{A_2^2} - \frac{Q^2}{A_1^2} \right)$$

$$Q_{\text{theoretical}} = \sqrt{\frac{2.45 A_1^2 A_2^2}{A_1^2 - A_2^2} \times 2g}$$

In practical we measure  $Q_{\text{actual}} = c_d Q_{\text{theo}} = 30 \text{ lit/sec}$

$$c_d = 0.95$$

Given:

$d_1$	=	15 cm
$d_2$	=	7.5 cm
$Q_{\text{act}}$	=	30 lit/sec = $30 \times 10^{-3} \text{ m}^3/\text{s}$

So, this is a very simple things. Again, we are putting the mass conservations equations and the Bernoulli equations, which is a energy conservation equations and by just putting the substituting these will get a theoretical discharge and we will get the actual discharge you know it, so you will get the Cd value, which comes out with 0.95.

**(Refer Slide Time: 52:58)**

**Example 4**

The sudden enlargement of a water pipeline from 200 mm to 400 mm. The hydraulic gradient rises by 10 mm. Estimate the discharge in the pipe.

Flow classification:

- One dimensional
- Incompressible flow
- Steady flow
- Frictionless flow
- Irrotational
- Inviscid

Control Volume:

- Fixed control volume

Assumption:

- flow along a streamline

Another problems, we are very interesting problem, here there is sudden enlargement of pipeline from 200 millimeter to 400 millimeters. The hydraulic gradient raises by 10 mm okay. It is just given, their hydraulic gradient lines has increased by 10 mm. Then, we can estimate what will be the discharge in the pipe. So, again we will apply same mass conservation equation and the energy conservation equations around the streamlines. You can see that mostly the streamlines will have a divergent.

And there will be energy distributions on these systems, but let us, we do not know how much of energy distribution, but we know it from data, there is the hydraulic gradient rise by the 10 mm.

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**Example 4**

Pressure Distribution:  
different Pressures at both section

Velocity Distribution:  
Considering average velocity  $V_{avg}$

Mass Conservation:

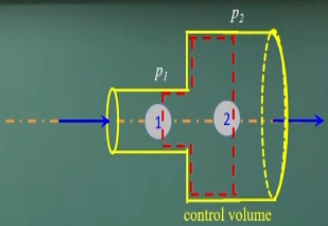
$$A_1 V_1 = A_2 V_2$$

$$\frac{\pi}{4} d_1^2 V_1 = \frac{\pi}{4} d_2^2 V_2$$

$$V_1 = 4V_2$$

Given:

$$d_1 = 200 \text{ mm}$$

$$d_2 = 400 \text{ mm}$$


So, you have a mass conservation equations and considering the average velocity not considering kinetic energy correction factors, so you can know it. This mass conservation equations as you know it,  $A_1 V_1 = A_2 V_2$  substituting this diameter we can get the relationship between  $V_1$  and the  $V_2$ .

(Refer Slide Time: 54:17)

**Example 4**

Bernoulli equation:

$$\frac{p_1}{\rho g} + \frac{1}{2g} V_1^2 + z_1 = \frac{p_2}{\rho g} + \frac{1}{2g} V_2^2 + z_2 = \text{const along a streamline}$$

$$\frac{p_1 - p_2}{\rho g} + (z_1 - z_2) = \frac{v_2^2 - v_1^2}{2g}$$

$$0.01 \text{ m} = \frac{6 v_2^2}{2g}$$

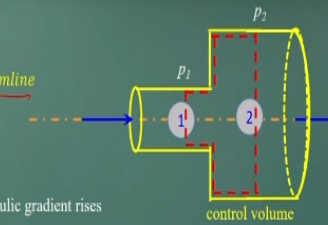
$$v_2 = 0.1808 \text{ m/s}$$

Given:

10 mm hydraulic gradient rises

$V_1 = 4 V_2$  from continuity equation

Discharge

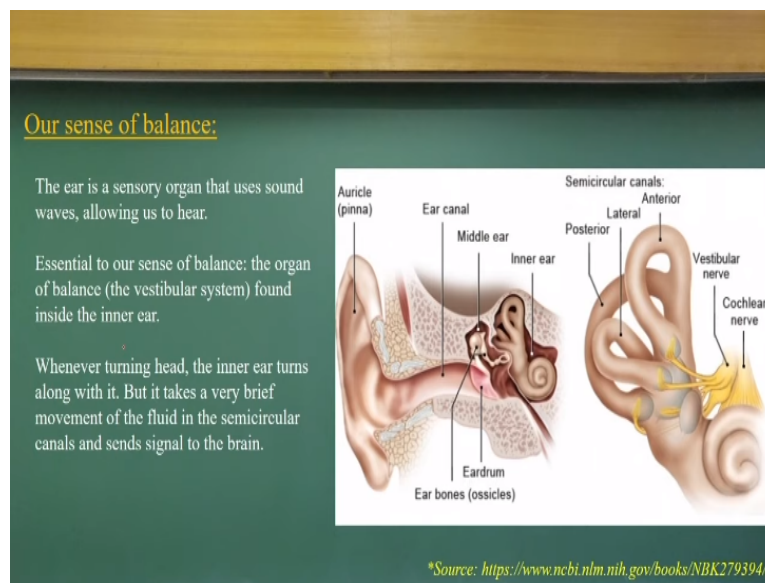
$$Q = A_2 v_2 = 0.0227 \text{ m}^3/\text{sec}$$


And then if I substitute the Bernoulli equations, okay, along this constant lines. So basically if you look it, these two head, the pressure head and the  $z_1 - z_2$  is not given to us, but that is what will be reflect in terms of piezometric head. That is what is given the difference

between the piezometric head is 0.01 meters. So we are substituting directly on that. We know this, the velocity and their relationship, we can compute the velocity. And once you know the velocity, we can compute the discharge.

So this way, it is very easy problems, only you have to look it, it has given the hydraulic gradient rise, that means it is representing us the pressure head and the elevations head. These two are we are including it when you put the two piezometers, what will be the raise, because of that, that is what we have of 10 mm hydraulic gradient raise and that is what we have substitutes.

**(Refer Slide Time: 55:30)**



Let me conclude this lectures with the sense of balance of a organ systems. If you know it, many of, we know it this ears is for the acoustic sound waves. That is the reasons we can hear it. And whatever I am speaking you can hear because of the ear, which is sensory organ to uses the sound waves allow us to hear it. But this ear also have a composition organ of balance inside the ear, which gives up the sense of balance.

Like, if I tilt it, I can get it from my brain, I am tilting it, okay. That is what the sense of balance. I'm not going to talk much details, but I am just telling you that the nature has given so beautiful arrangement of our body structures and the brain, which we cannot replicate it and this is what it happens all in the fluid flow sensorial organ systems. So, that way, we look it very smaller components what we teach in the fluid mechanics, but the human body is the structure still give us lot of lessons to be learnt about the fluid, about the sensing organs and all.

(Refer Slide Time: 56:56)

### Summary of the Lecture

1. Kinetic Energy Correction factor  $\alpha = \frac{1}{A} \int \left( \frac{u}{V_{av}} \right)^3 dA$
2. Static, Dynamic and Stagnation Pressure
 

$$P + \rho \frac{V^2}{2} + \rho g z = \text{Total Pressure}$$

Static Pressure
Hydrostatic Pressure

dynamic Pressure

Stagnation Pressure
3. Hydraulic and Energy Grade Lines
 

$$\frac{P}{\rho g} + \frac{V^2}{2g} + z = H = \text{const along streamline}$$

Pressure head
Elevation head

Velocity head

HGL

EGL
4. Mechanical Energy and Efficiency
 

$$\Delta e_{mech} = \frac{P_2 - P_1}{\rho} + \frac{V_2^2 - V_1^2}{2} + g(z_2 - z_1)$$

$\eta_{mech}, \eta_{pump}, \eta_{turbine}, \eta_{motor}, \text{ and } \eta_{generator}$

And that is the same things and this times we talk about the kinetic energy corrections factors, how we need to be compute when you have the velocity distributions is uniform. And we also seen Bernoulli equations, we can represent it in terms of the pressures, static pressures, dynamic pressures and hydrostatic pressures and two of the components that can represent us the stagnation pressures.

And we also discussed about the hydraulic gradient line and the energy gradient lines and the mechanical energy and the efficiency. With this, let us thank you all for this presence here.