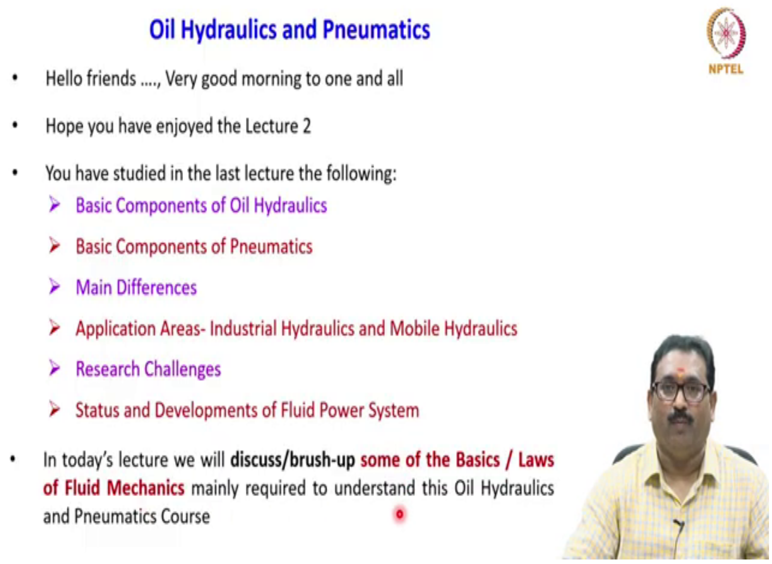
Oil Hydraulics and Pneumatics

Prof. Somashekhar S
Department of Mechanical Engineering
Indian Institute of Technology, Madras

Basic Laws of Oil Hydraulics and Pneumatics
Lecture – 07
Part 1 : Pascal's law and its application – Hydraulic jack, Hydraulic brake and Numerical

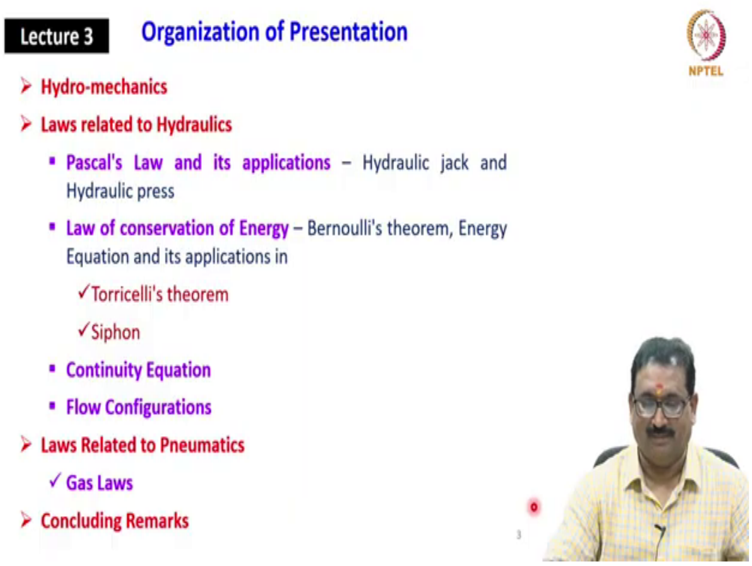
(Refer Slide Time: 00:23)



My name is Somashekhar, course faculty for this course. Hello friends, very good morning to one and all; hope you have enjoyed lecture 2. You have studied in the last lecture the followings; basic components of oil hydraulics, basic components of pneumatics, main differences between the oil hydraulics and pneumatics, application areas as a industrial hydraulics, where power pack is fixed and mobile hydraulics where power pack is moving along with the equipment.

Also we discussed the research challenges in the fluid power system and finally, we ended with status and development of fluid power system in the lecture 2. In today's lecture, we will discuss or brush up some of the Basics or Laws of fluid mechanics mainly required to understand this oil hydraulics and pneumatics course better.

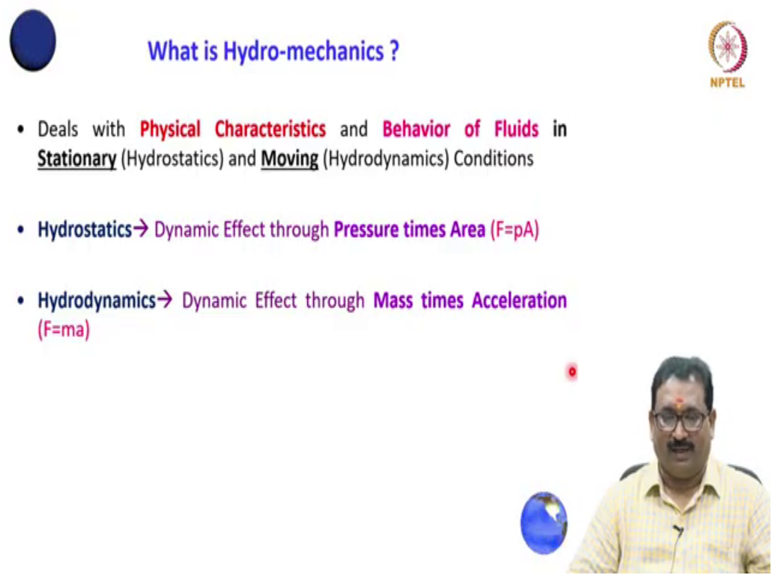
(Refer Slide Time: 01:35)



This is organization of presentation of lecture 3. We will start with hydro mechanics, laws related to hydraulics; here we will discuss Pascal's law and its application, specifically for hydraulic jack and hydraulic press. Law of conservation of energy, here we will discuss some of the theorems like a Torricelli's theorem, siphon.

Later we will move onto continuity equation, flow configurations, laws related to pneumatics; here we will discuss various types of gas laws, Boyles law, Charles law, Gay-Lussac law and Ideal Gas laws. And finally, we will conclude this lecture with concluding remarks.

(Refer Slide Time: 02:42)



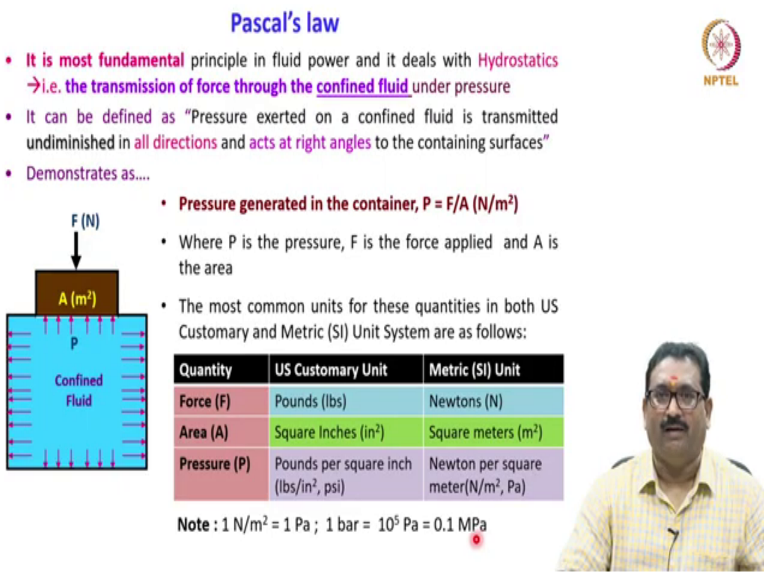
Can you please tell me friends, what is a hydro mechanics. Yes, it deals with physical characteristics and behavior of fluid in stationary and moving conditions. In stationary, we can call it as a hydrostatics; in moving fluids, we can call it as a hydrodynamic. Hydrostatics here, the dynamic effect through pressure times an area very important.

Please note here, in hydrostatic we are studying the dynamic effect in the fluid through pressure times an area, F equal to p into A. Similarly in the hydrodynamics, dynamic effect through mass times acceleration; F equal to m into a; please remember friends, in hydro mechanics we are studying the hydrostatics and hydrodynamics.

(Refer Slide Time: 03:50)

Now, we will move to the first and primary law Pascal's law. Blaise Pascal was a French philosopher, mathematician, scientist, inventor and theologian developed a law applicable to fluid inside a closed container meaning hydrostatics, known as Pascal's principle or a Pascal's law.

(Refer Slide Time: 04:27)



It is the most fundamental principle in fluid power and deals with hydrostatics; that is the transmission of force through a confined fluid under pressure. It can be defined as pressure exerted on a confined fluid is transmitted undiminished in all direction and it right angles to the containing surfaces.

It is easily demonstrated as follows. Take the closed container in the cylinder, fitted with the piston what I will call a plunger with an area A, apply the force F on the plunger, which in turn generate the pressure P; because pressure is force by an area. The generated pressure is transmitted undiminished and acts perpendicular to the wall surfaces.

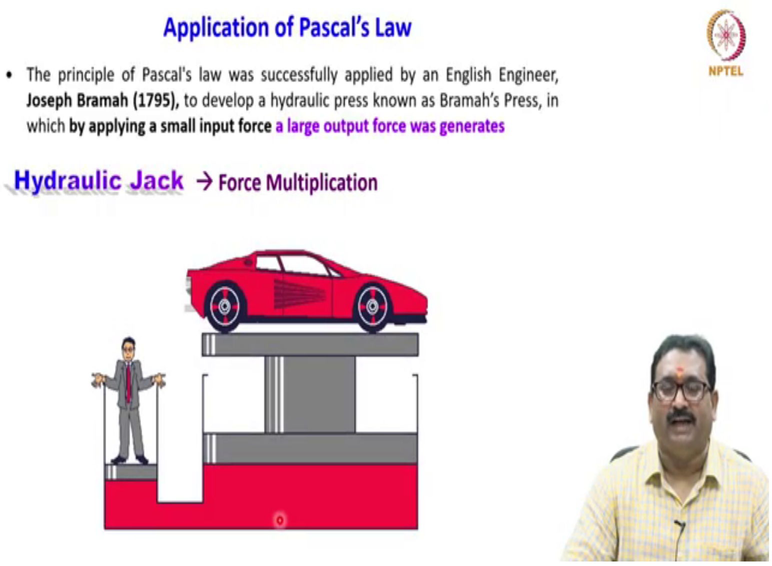
This is one of the principle developed by the Pascal, the pressure generated in the container P equal to F by A, where P is the pressure, F is the force applied and A is the area.

Here the most common units, these quantities in both US customary and metric SI unit are as follows; you will see here friends, I am listing here in the first column the quantity, the major quantities force, area and pressure. US customary unit force is a pounds, area is a square inch, the pressure is pounds per square inch.

Still many of the devices, pressure gauges are in psi in a pounds per square inch. That is why I am listing US customary unit, but generally we will follow the metric unit SI unit, in which forces is a Newton, area is a square meter; meaning force by an area is Newton's per square meter or it is also known as a Pascal.

Please note friends, 1 Newton per meter square equal to 1 Pascal or 1 bar equal to 10 to the power of 5 Pascal or 0.1 mega Pascal. Please remember pressure in oil hydraulics represented frequently in Pascal, bar, and mega Pascal.

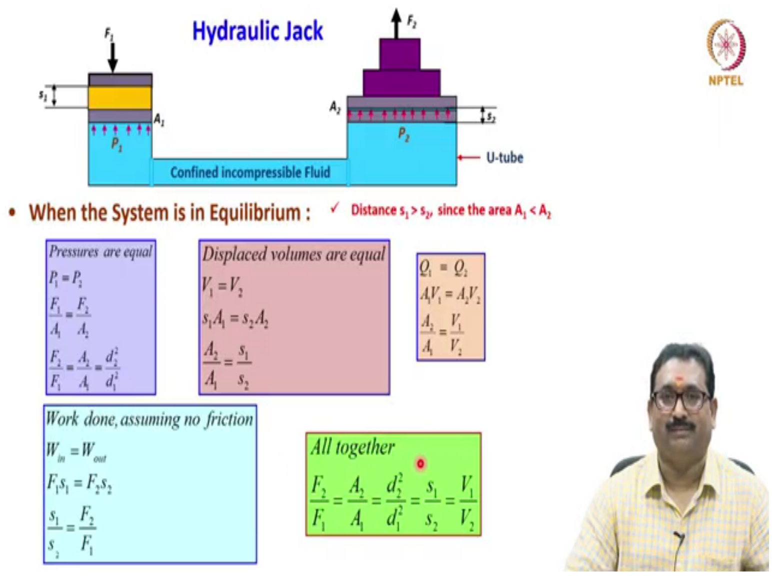
(Refer Slide Time: 07:26)



Let us we will see the application of the Pascal's law. The principle of Pascal law was successfully applied by an English engineer Joseph Bramah to develop a hydraulic press known as a Bramah's Press, in which by applying a small input force you will generate the larger output force. That is what we known as the hydraulic jack, in all hydraulic jack to lift the vehicle body; we are using the force multiplication, which is given by the Pascal. How it is I will demonstrate it here.

This is a U tube, you will see the friends here it is a U tube; you will apply the small force here, you will see here how the vehicle body car is lifting. But you will remember friends, in the U tube the fluid is incompressible fluid; it is applicable to closed container what I will call hydrostatic.

(Refer Slide Time: 08:41)



Let us we will see now, some of the parameter how we will arrive from the hydraulic jack. As I have told you here F 1 is a force acting on the plunger, this is a U tube and another other side is the large piston of area A 2.

And when you apply the small force F 1 on the plunger, it will generate the P 1 pressure; the P 1 pressure as we know in the closed container, it will act perpendicular to the wall surface and undiminished, which in turn acts on the larger piston area, which will generate the large pressure to lift the loads.

Please remember here friends, when I will apply the force F 1, the piston will move to this by an displacement s 1, which in turn it will lift the larger piston by the distance s 2. Please note here s 1 is greater than s 2; because A 1 is less than A 2.

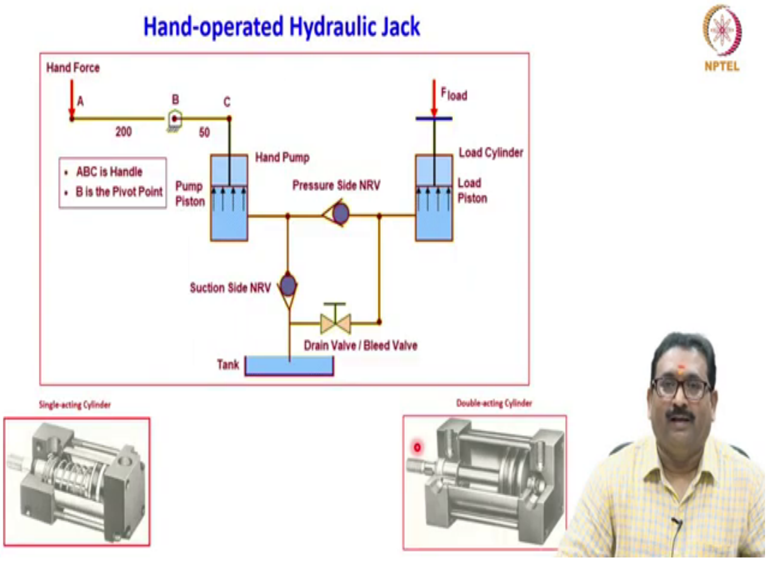
So, when the system is in equilibrium friends, when the system is in equilibrium will arrive the pressures are equal P 1 equal to P 2; the P 1 already know that forced by any area, me here it is P 1 is F 1 by A 1, here the pressure P 2 is F 2 by A 2. Or you will modify here by cross multiplying the parameter F 2 by F 1 equal to A 2 by A 1. What is A 2? A 2 is pi by 4 d 2 square, A 1 is pi by 4 d 1 square.

After cancelling some of the term, we will get d 2 square by d 1 square. Similarly, the displaced volumes are also equal in equilibrium condition; meaning what? The volume displaced V 1 equal to V 2; what is a V 1? s 1 into A 1 here and here it is s 2 into A 2; after cross multiplying, I will get A 2 by A 1 equal to s 1 by s 2.

Similarly, the quantity of fluid Q 1 equal to Q 2 meaning here A 1 V 1 equal to A 2 V 2; meaning what it is friends? A 2 by A 1 equal to V 1 by V 2. Similarly, the work done assuming no friction between the valves and a tubes, W in, here W in is equal to W out. Meaning what friends it is? F 1 into s 1 equal to F 2 into s 2; after cross multiplying I will get s 1 by s 2 equal to F 2 by F 1.

The finally friends, these parameter pressures are equal, displacements are equal, the volume flow equal and work done equal; meaning it is all together I will write here F 2 by F 1 equal to, you will see here F 2 by F 1 equal to A 2 by A 1 is equal to d 2 square by d 1 square, which is equal to s 1 by s 2 and V 1 by V 2. Please remember friends, when the system is in equilibrium, all these parameters follows this.

(Refer Slide Time: 12:17)



Now, I will explain you to you the simple hand operated hydraulic jack. Let us you will see here friends in the schematic diagram shown here, it consists of the hand pump and the load cylinder. The hand pump is connected to the hand lever here, you will see the ratio 200 to 50; A, B, C is a handle and B is a pivot point friends.

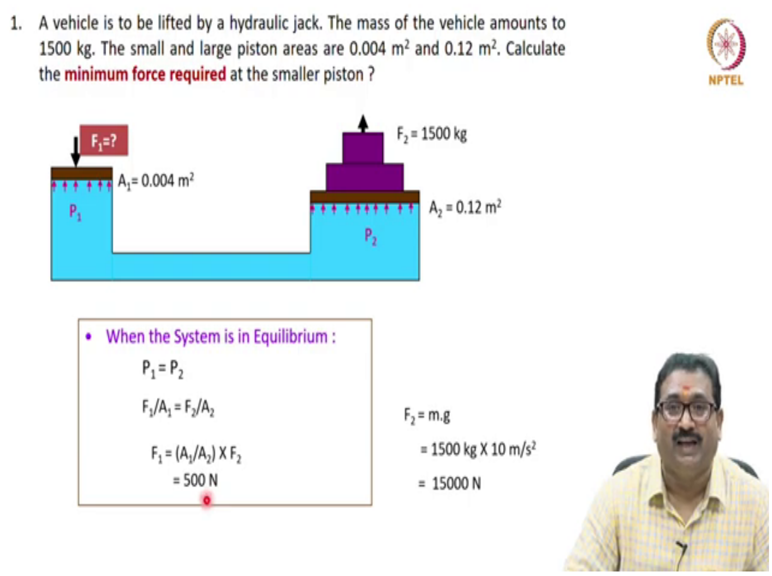
And this hand pump is connected to the what I will call, this is a power pack, it is a suction side non return valve, tank and a drain valve or a bleed valve; why it is required I will tell you. You will see friends here, these are the main components in the hand operated hydraulic jack. How it operates friends?

When you will apply the force here what happens, it is intern connected to the piston of the hand pump, when you will push this, this will move. Immediately what happened, here the suction will create; it will lift the fluid from the tank, it will enter here. When you will move up what happens friends, the fluid sucked here; it will go to the load cylinder through the pressure side non return valve; it will not go here, because it is a only unidirectional.

It will allow the flow from here to here, not from here to here; then only when you will move up, whatever the fluid is there, it will push to the load cylinder through the pressure side NRV. Then what happen, here whatever the load you will kept here vehicle body, it will lift up. But when you want to lower the vehicle, what it will do?

If to lower the vehicle, the fluid will not go through this NRV; because it is unidirectional. Then only way is to lower the weight what you will do; you will open the drain valve, manually drain valve or a bleed valve you will open, then fluid present here it will go to the tank directly. This is a very very simple hand operated hydraulic jack works on the closed container; fluid is in the closed container, not open flow.

(Refer Slide Time: 14:50)



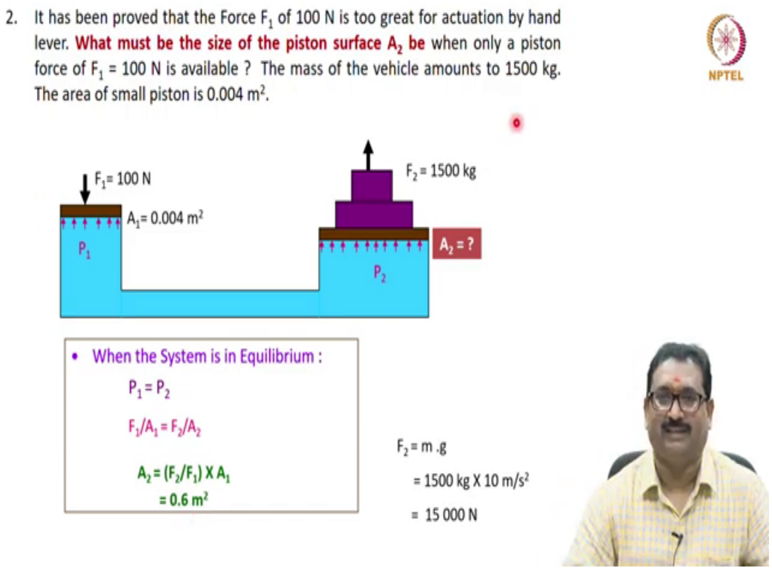
Let us we will see now, to understand this I will give you a simple numerical here; a vehicle is to be lifted by a hydraulic jack. The mass of the vehicle amounts to 1500 kg. The small and larger piston areas are 0.004 meter square and 0.12 meter square. Calculate the minimum force required at the smaller piston.

As I have told you it is a hydraulic jack, the figure is like this; here the given parameters are A 1 is given and A 2 is given and the load is given. Then what is our objective? Our objective is to calculate what is a minimum force required to lift the 1500 kg load. As we know that when the system is in equilibrium, P 1 equal to P 2; what is a P 1?

F 1 by A 1 equal to F 2 by A 2. Then what is a F 1? F 1 equal to A 1 by A 2 into F 2. Meaning how much I will get? F 2 F 1 required F 1 required to lift the F 2 is 500 Newton. Please note here, because mass of the vehicle is given as in kg; what I did? I multiplied by a with g 9.81; I am taken round figure as a 10 meter per second square, you will get this.

Please note friends, by applying the very small force; how much? 500 Newton, I am able to lift 1500 kg or 15000 Newton, using the confined incompressible fluid in the U tube.

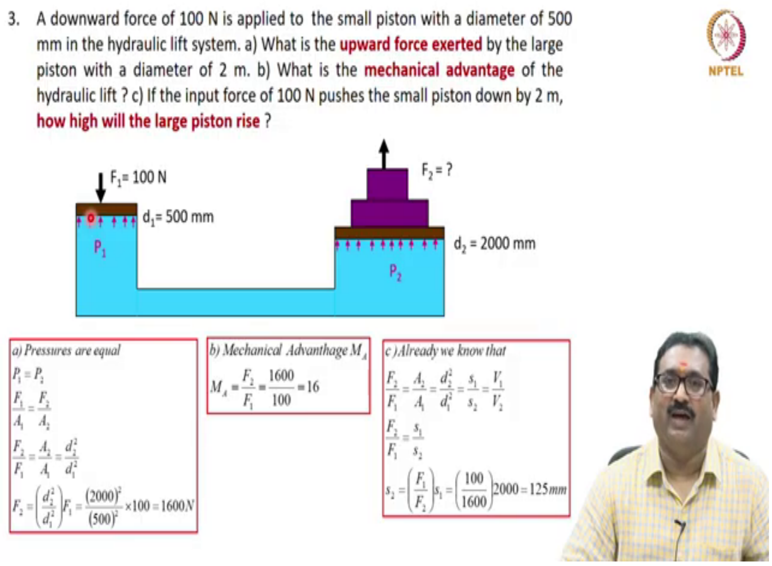
(Refer Slide Time: 16:57)



One more example we will see now, it has been proved that the force F 1 of 100 Newton is too great for actuation by hand lever. What must be the size of the piston area A 2 be when only a piston force of F 1 equal to 100 Newton is available? Again as usual the mass of the vehicle amounts to 1500 kg, the area of the small piston given is 0.004 meter square. As usual, what are the things given here friends?

Again I drawn here schematic of the hydraulic jack; here the given parameter is F 1 is given, A 1 is given and F 2 is given. Now, our objective is to find out, what is the area of the larger piston to lift this load? As usual when the system is in equilibrium P 1 equal to P 2 and F 1 by A 1 equal to F 2 by A 2; then A 2 is 0.6 meter square, correct. Very simple friends it is; any problem we will do by understanding the basic principle of Pascal's law applicable to hydraulic jacks.

(Refer Slide Time: 18:19)



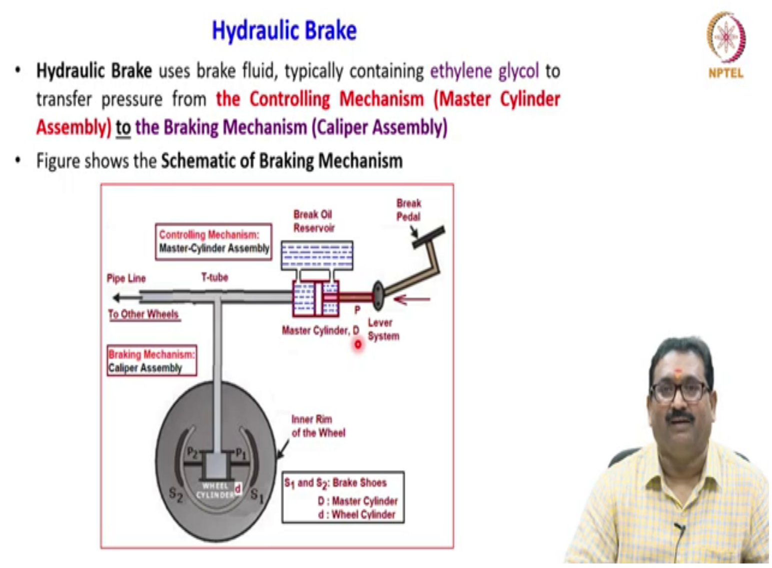
I will show you one more example for easy understanding, a downward force of 100 Newton is applied to the small piston with a diameter of 500 mm in a hydraulic lift system. What is the upward force exerted by the larger piston with a diameter of 2 meter? What is the mechanical advantage of the hydraulic lift? If the input force of 100 Newton pushes the small piston by 2 meter; how high will be the large piston rise?

Same as usual it is same here friends, what are the things here; diameter of the smaller piston is given as 500 mm, diameter of the larger piston is given as 2 meter, meaning 2000 mm I am writing. Now, F 1 is also given small force; our objective is to find out what is my F 2 and mechanical advantages and what it is and if the small distance if will give, what is a the distance moved up?

Now, we will see as we know that, pressures are equal when the system is in equilibrium P 1 by P 2; then after substituting all, I will get F 2 equal to 1600 Newton. Similarly, the mechanical advantage is given by the ratio of F 2 by F 1; already F 2 I am getting here 1600, F 1 I know already 100, meaning mechanical advantage is 16.

Similarly, already we know this formula in the previous slide; then what is our objective? Our objective is to find out what is my s 2 here, if I know the s 1 here; you will get s 2 equal to 125 mm. Any parameter if you will vary in this in the problem, you are able to calculate the unknown parameter in the hydraulic jack; very simple friends it is, very very simple.

(Refer Slide Time: 20:41)



Now, we will see one more application of the Pascal's law is a hydraulic brake. You come across this in the two wheeler as well as in the 4 wheeler hydraulic brake; very very accurate, they will stop at a instant at the same place. This is the beauty of hydraulic brake; how it will works, we will see now.

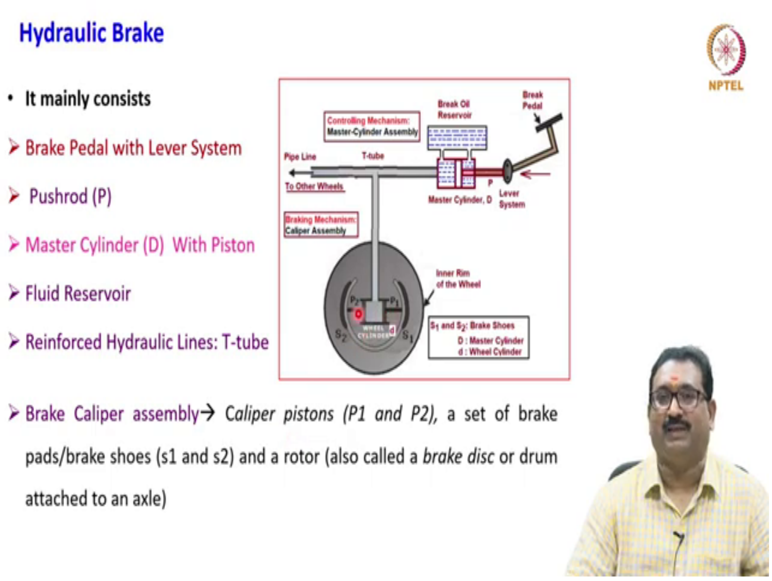
As we know that, hydraulic brake uses a brake fluid, typically a ethylene glycol to transfer a pressure from the controlling mechanism to the braking mechanism. Here controlling mechanism is a master cylinder assembly, braking mechanism is a caliper assembly. I will show you how these systems are connected in the hydraulic brake.

Figure shows us schematic diagram of the braking mechanism; you will see friends as I have told you here, there are two important devices; master cylinder assembly, what you call a controlling mechanism and another is a braking assembly, caliper assembly in the wheel side.

Understand here friends, what are the components are there you will see here; here this is what they will call break pedal, then it is connected to the lever through the piston. This is a master cylinder having diameter capital D, which is connected to the oil reservoir, ethylene glycol or a brake fluids are here.

And then what happens, the whatever when you will push this when you apply this, it will move; then whatever the fluid is there, it will come here and push the what it is. Here you will see the braking mechanism, here the wheel cylinder is there, diameter is D here; P 1 and P 2 are the two piston connected to the what is that brake shoes S 1 and S 2.

(Refer Slide Time: 22:37)

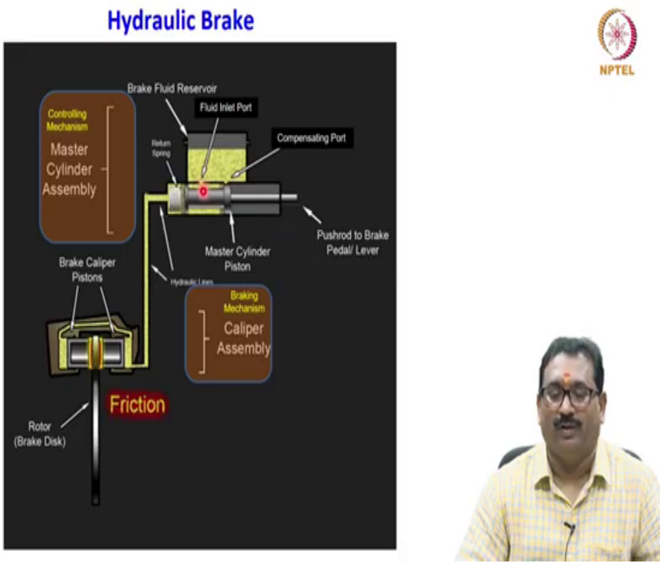


How it is I will explain to you in the next slide. This is a mechanism what I have shown in the previous slide. Already we know that, it consists of a brake pedal; see here a brake pedal with a lever P, push button, push rod it is, P is nothing but the push rod, the master cylinder diameter with piston.

Fluid reservoir correct and the reinforced hydraulic T tube; then you will see here friends, when you will push, some among the fluid go here, some of the fluid will go to the next wheels here, there are so many wheels are there. For example, in case of that 4 wheeler, it will go to the other wheels.

Then here you will see the braking mechanism or caliper assembly, it consists of what is this; caliper piston you will see P 1 and P 2 caliper piston, a set of brake pads s 1 and s 2 or a brake shoes and a rotor correct, it is connected it is connected to the rotor it is, inner rim of the wheel, correct.

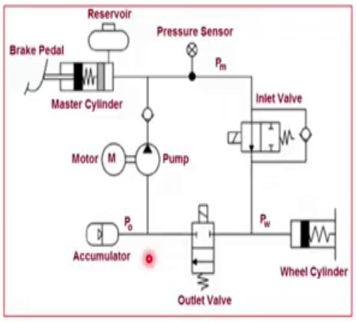
(Refer Slide Time: 23:54)



Now, we will see this the how it operates, I have shown you the very simple sketch here; when he will apply the push rod here, what happens here friends? You will see whatever the fluid is there here, it will go to the either side of the piston P 1 and P 2. P 1 and P 2 will push the rotating disk. Then already we know that the pressure generated here is acting equally in both the cylinder piston; meaning at a time the wheel will be stopped, because it is incompressible fluids, that is a beauty of in the hydraulic brake.

(Refer Slide Time: 24:38)

Simple Hydraulic Brake Circuit

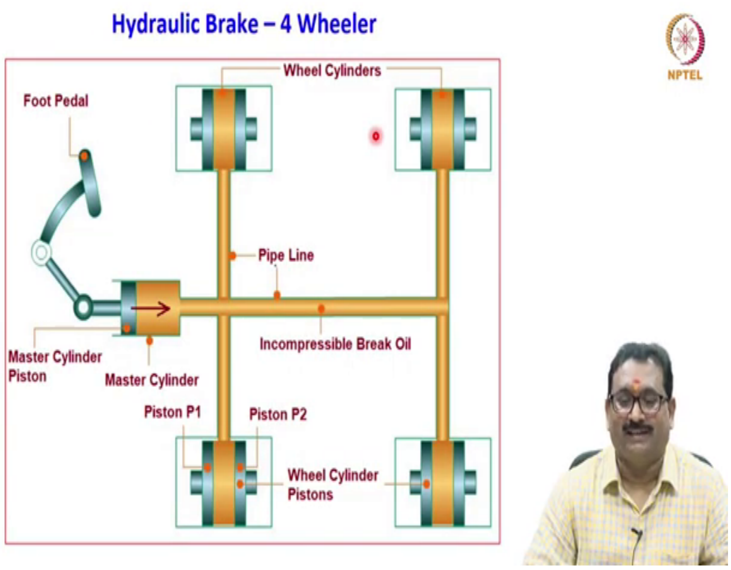


Hope you understood this, next we will I will show you the simple schematic diagram of the brake circuit. Here as usual as I have told you here, it is you will see here, the brake pedal I have shown here, it is a cylinder correct, the master cylinder; when you will push this, the fluid will come here through the 2 by 2. So, Raynaud approached the valve it is, then it will go to the wheel cylinder.

When brake will release here, fluid will come here, it will lift here, it will go to that reservoir again here. The some of the things are there here, motor and pump and accumulators and outlet valves.

This is a simple hydraulic brake circuit; these circuits will come to know that, when we are dealing with the circuit design. Now, we will understand only this; what is required here is, the brake pedal is connected to the master cylinder, then it is connected to the wheel cylinder through the sum of the valves, ok.

(Refer Slide Time: 25:46)



Now, we will see the schematic diagram in which the same hydraulic brake for the 4 wheelers, you will see here. Very simple here friends, again the foot pedal is there; from the foot pedal when you will, this is a master cylinder and these are the what it is the wheel cylinders, all are wheel cylinder, 4 wheel cylinders. Here you will see here, the yellow what I have shown, here it is moving the braking fluid.

When you will push this, the pressure generated here is acting equally without diminishing on these areas; automatically it will push the rod, piston rod to stop the wheel rotation immediately, ok.

But you will remember here, the Pascal's law is applicable to the closed contained fluids, not the open fluids; as because as we know in the Pascal law, when you will apply the pressure through the force, the generated pressure is acting equally in all the sides without diminishing. The same principle is used in the hydraulic brake.