

now we are going to talk about pascal's principle

so this is ah after ah blaise pascal ah from 1623 to 1662 ah and pascal was a philosopher and a scientist from france a french philosopher and scientist

so what is said will learn that but before that try and understand that suppose you have a big container or maybe a lake or a pond ah and you want to know the pressure which is at a distance say hundred meter from the surface so this is hundred meter and this is the surface of water and we need to know the pressure

so this the pressure at this point a is equal to the atmospheric pressure plus ah  $\rho g h$  where  $\rho$  is the that of a liquid say its water here so the  $\rho$  is ah  $10^3$  kg per meter cube for water ah  $g$  is of course we are not considering any variation of  $g$  which is nine point eight meter per second square and  $h$  equal to hundred meter now understand that ah this has to be added this product of these three things that is that appears here has to be added with the atmospheric pressure ah which is what we have discussed so far in order to get the pressure here and that pressure is same at any level which is at a height of 100 meter from the surface which is understandable now what pascal said is that in a confined fluid if you apply a pressure the pressure gets uniformly distributed ah throughout the fluid let's see how do we write down the principle

so the principle states that the pressure applied to a confined fluid increases the pressure throughout by the same amount so this is the statement of the principle laid down by pascal that the pressure that is applied to a confined fluid increases the pressure throughout the fluid by the same amount and this has a large number of applications in devising machines and some of them are a hydraulic brake and hydraulic lifts

so let us see what they are and these are machines which are devised based on pascal's law

so let us see the first of them which is a hydraulic brake

so we have a schematic geometry as this this is called as the master cylinder i will write that

so

not a perfect drawing but this is called as the master cylinder ah there is a fluid everywhere and a pressure is applied or a force is applied to this either by a piston or by some braking mechanism and these are called as brake pads and there is a disc here which is attached

so this is the wheel disc

so there is a disc like thing which is in between the brake pads and let us call it as a disc wheel disc

so this is in in the context of a of an auto mobile say for example

so you have you apply a pressure on a brake

so you apply a pressure on a master cylinder which contains a fluid ah

so this fluid has a geometry like this ah the rather the tube has a geometry like this and they just go and they are attached to two brake pads which are here these are called brake pads and these brake pads are they sandwich a disc of a wheel in between

so when there is a pressure being applied the brake pads come closer and jam that disc

so that the the wheel that was rotating rather the disc that was rotating along with the wheel will come to a halt

so this called as a hydraulic brake ah a more interesting application comes ah for a hydraulic lift where you have something like a youtube again which has

the two arms of the youtube are reasonably different i have not made it too different but they are they can be quite different and there is a piston here ah there is a piston say for example there and this piston a platform in which there is a car

so this is a lift that will be used to lift a car

so to lift a car you need to give a lot of force but this mechanism if you give a small force here let's call this force given is  $f_{in}$  let's call this uh area of cross section of this piston or this arm of the youtube be  $a_{in}$  and the pressure here applied is equal to  $p_{in}$  and the same quantities here let us call that as  $p_{out}$  and  $a_{out}$  be the area of cross section of this bigger arm of the youtube and you have a force which is  $f_{out}$  that is applied upward on the this arm or this piston and by which the the car can be lifted up so we have

so all these parameters in the left arm which is thinner arm or rather has lower cross section they are  $f_{in}$ ,  $a_{in}$  and  $p_{in}$   $f$  stands for pressure  $a$  stands for area of cross section  $p$  stands for the pressure  $f$  stands for force  $p$  stands for pressure and  $a$  stands for the area of cross sections similar quantities are  $f_{out}$ ,  $p_{out}$  and  $a_{out}$  and by pascal's principle if you apply a pressure the pressure will get uniformly distributed everywhere so the pressure will increase uniformly all throughout the liquid so there is a liquid here which i of course forgot to say but this is understood

so there is a leak there is a liquid

so by pascal's law your  $p_{in}$  has to be same as  $p_{out}$  this is what the principle says that the pressure is uniform everywhere and

so this tells you that  $f_{in}$  divided by  $a_{in}$  which is equal to  $f_{out}$  divided by  $a_{out}$

so  $f_{out}$  is equal to  $f_{in}$  multiplied by  $a_{out}$  divided by  $a_{in}$

so this is the principle of working of a hydraulic lift

so what it says is that if you apply a small force and make the ratio of the out cross section to that of the in cross section that is the cross section in the right arm by the cross section in the left arm if you make this ratio large you by applying a small force at this point at the input point you can get a large force at the output which will help to lift the car okay and

so if you change ah by applying a small  $f_{in}$  you can get a large  $f_{out}$

so this  $a_{out}$  by  $a_{in}$  which is a ratio in the hands of the designer of this hydraulic lift this can be called as the mechanical advantage of the device

so  $a_2$  by  $a_1$  or rather the  $a_{out}$  by  $a_{in}$  output to the input cross section ratio is called as the mechanical advantage of the machine

so let us take a moment to recapitulate what all we have done we have started with our discussion of fluids with density and specific gravity and then we have talked about pressure very elaborately what is meant by the atmospheric pressure how pressure is measured ah how atmospheric pressure is calculated computed how it decreases as you go high up from the sea level and then that what is gauge pressure and measurement of pressure by using a open tube open youtube and also by using a barometer and now we have talked about pascal's principle and two very important devices which are made out of it one is called as a hydraulic brake that are there in cars in order for an efficient stopping when it's needed for the for the vehicle to stop to avoid an accident and also ah this is the hydraulic lift which is there in any car servicing garage which has to lift the car in order to see that what parts have gone wrong on what needs to be rectified by using this

so you don't need to give a very large force in order to get a don't have to

give a very large force here in order to get a large output force here you can tune the ratio and choose the liquid which will give you a large thrust upwards so having learnt pascal's law and how to use pascal's law for designing machines such as hydraulic brakes and hydraulic lift let us learn buoyancy and archimedes principle the question is uh what is buoyancy buoyancy uh you have felt it a lot of times that any object when it's placed in water it weighs less or even something that floats on water so which means that it is lighter than ah water so it floats on the water so in both the cases buoyancy plays an important role so buoyancy is the upward force that's given by the fluid and so the exact weight of this object in air ah becomes less because of this upward force that is given by the fluid so why how do this buoyant forces arise so the buoyant forces are arising because of the fluid pressure that it gives so this is a cylinder immersed totally immersed in a vessel containing a liquid so the liquid has say density  $\rho$  and this is at a height  $h_1$  the bottom is at a height  $h_2$  so this is  $h_2$  minus  $h_1$  which is equal to  $h$  so that is the height of the cylinder and it has a it has an area of cross section which is equal to  $a$  and  $ah$  so the fluid gives a downward pressure on the top surface of the cylinder and also there is an upward pressure on the bottom surface of the cylinder by the liquid that is there inside this container so now so let us call this pressure as  $p_1$  and this pressure as  $p_2$  so  $p_1$  is the pressure on the on the top surface and let us write it downwards  $p_2$  is the pressure on the bottom surface surface this is upwards  $ah$   $a$  is the area of cross section of the cylinder area of cross section  $h_1$   $ah$  height of the top measured from surface and  $h_2$  is the height of the bottom measured from surf measured from the surface again so now my  $p_1$  that is the pressure that is exerted downward is  $ah$  given by it is a  $\rho g h_1$   $\rho$  is the density of the liquid  $g$  is acceleration due to gravity  $h_1$  is the height that i have shown here and my corresponding force that is exerted on the top surface downward is equal to  $p_1$  into  $a$  where  $a$  is the area of cross section so this is equal to  $\rho g h_1 a$  a similarly the pressure acting upward on the bottom surface is  $p$  equal to  $\rho g h_2$  and the corresponding force acting upward is given by  $\rho g h_2$  into  $a$  now at equilibrium that is  $ah$  the net force acting on the cylinder is equal to  $f_2$  minus  $f_1$  which is equal to  $\rho g h_2$  minus  $h_1$  multiplied by  $a$  which is equal to  $\rho g h$  into  $a$  so the net force that acts on the cylinder is equal to  $\rho g h$  into  $a$  now if you recognize that  $h$  into  $a$  is nothing but the volume of the cylinder which is equal to  $\rho g v$  where remember this  $\rho$  is the density of the liquid so now  $\rho$  into  $v$  will give me the mass of the liquid that is displaced here so this is equal to  $mg$  but this  $m$  is not the mass of the cylinder its mass of the liquid because this  $\rho$  is the density of the liquid so this is the mass of the liquid that is displaced because of the cylinder so the net force is equal to uh  $m$  into  $g$   $m$  being the mass of the mass of the fluid or the liquid that otherwise would have taken the volume of the cylinder so this is known as archimedes principle and and it is stated as the following

so let me now erase this this is not no longer relevant for discussion  
so archimedes principle is stated as  
so archimedes it's 287 to 212 bc means before christ  
so this um in fact it was proposed in which is before christ during that  
period and  
so the buoyant force on the cylinder is equal to the weight of the liquid  
displaced by the cylinder  
so this is known as archimedes principle i will read it once again it says  
that the buoyant force on the cylinder is equal to the weight of the liquid  
displaced by the cylinder  
so this is known as archimedes principle and it is true for also for bodies  
which are floating on the surface of a liquid or a surface of water say for  
example it doesn't have to be fully immersed as we have considered the case  
to be here it is also valid for objects which are floating on in on on the  
surface of the water  
so let us and this also this principle is equally applicable to all irregular  
shaped bodies not only a regular shaped cylinder that we have shown any  
shape this this statement is independent of shape and size of the object that  
you are going to consider  
so let us give a very elegant proof of archimedes principle  
so let us take a container which is again full with say water in principle  
any liquid and there is a irregular shaped object that is there inside the  
water and  
so there will be forces which we have just seen  
so there will be buoyant forces as well as forces due to gravity that is  
that its own weight so this body will start descending if the weight of the  
body lets call this body as a if the weight of the body is greater than the  
buoyant force let us call the buoyant force to be  $f_b$  in fact in the last  
example when we were showing we have written  $f_{net}$  to be equal to  $f_2$  minus  
 $f_1$  where we have considered a cylinder here which is totally immersed in  
liquid and the force acting here is  $f_1$  and the force acting there was in the  
bottom surface was  $f_2$  so this is called as  $f_b$  which is the net force acting  
on the body  
so this net force acting on the body if it's lower than the weight of the body  
the body will continue to descend now let us consider the same example here  
but now we shall replace the the body by a liquid film of the same irregular  
shape this and this has the same irregular shape of course i cannot draw an  
irregular shape to be exactly alike but you consider them to be of the same  
so i have just replaced the object by a liquid film here and  
so there is no object here and let us call this as a prime is just the liquid  
film which i have it's an imaginary film which is i have taken it to be  
separate from the the the rest of the fluid and let's call that as a prime  
and of course i know that this liquid film is in equilibrium with the rest of  
the liquid and in that case my  $w_a$  prime it is equal to  $f_b$  right because ah  
there is this weight of the liquid film is  $w_a$  prime and which should be  
same as the buoyant force that is acting because the same it's a part of the  
liquid that i have considered just the shape to be regular that of this of  
the object  
so now you can understand that this the bowen force is exactly same as the  
liquid or the or the volume of water or the weight of the water that is  
displaced by this object okay and this is the statement of archimedes principle  
and remember he as i told that he discovered it in some between 287 and 212 bc  
when science itself was in a very nascent stage  
so let us do a problem to emphasize this argumentus principle

so it says that a 10 kg solid object has an apparent weight of 8.4 kg when submerged in a fluid of density  $3.2 \times 10^3 \text{ kg per meter cube}$

so the question is what is the density of the solid object

so a solid object which is a 10 kg object of weight 10 kg or rather mass 10 kg is when it submerged in a liquid of this density  $3.2 \times 10^3 \text{ kg per meter cube}$  it weighs only 8.4 kg and this of course now we know that it happens because of the buoyancy that is acting on the object or on the body now question is what is the density of this solid object under consideration so the apparent weight let us call it  $w_{\text{apparent}}$  this is equal to some giving you the solution of this

so  $w_{\text{apparent}}$  is equal to  $w_{\text{real}}$  and a  $w_{\text{b}}$  which is due to the buoyant forces

so this is the apparent weight in the liquid inside the liquid this is of course measured outside the liquid that is in air and there is a buoyant force that is that is given here

so this is equal to  $\rho_s g v$  minus  $\rho_f g v$  where  $\rho_s$

so  $w_{\text{real}}$  is equal to the actual weight or let us call it as actual instead of real actual

so  $w_{\text{actual}}$  is  $\rho_s$  which is the density of the solid

so let  $\rho_s$  be the density of the solid

so its  $\rho_s g v$  minus  $w_{\text{b}}$  which is the weight due to the buoyant force is equal to  $\rho_f g v$  which is what we have calculated

so  $\rho_s$  is that of the fluid which is given as  $3.2 \times 10^3 \text{ kg per meter cube}$  and you have to find this quantity

so now we can do a bit of simplification and we can write  $w_{\text{actual}}$  divided by  $w_{\text{actual}}$  minus  $w_{\text{apparent}}$  this is equal to  $\rho_s g v$  and

so we don't know the shape of the object it is we just know that the volume is  $v$  the volume is immaterial and will cancel out and that's why it is not important to know what is the volume and this also goes back to say that it is Archimedes principle is true for any irregular shaped object and does not have to be a of that of a regular shape so  $\rho_s g v$  divided by  $\rho_f g v$  and these  $v$  will cancel and the  $g$  will cancel as well

so this is equal to  $\rho_s$  divided by  $\rho_f$  which is equal to  $\rho_s / \rho_f$

so this is equal to  $w_{\text{actual}}$  which is 10 kgs and divided by this is 10 kg minus 8.4 kg

so my  $\rho_s$  can be calculated as 10 divided by  $1.6 \times 3.2 \times 10^3 \text{ kg per meter cube}$  so this is equal to  $\rho_s$  and then the  $\rho_f$  will go to the other side and now I have this equal to 2

so this is equal to  $2 \times 10^3 \text{ kg per meter cube}$

so many solids have this kind of a density I don't know which solid that you can one can find out from the data the density data for different substances and

so the solid has this density

so we'll proceed further and now we shall talk about fluids in motion we have been talking about fluids at rest and for the first time now we'll talk about fluids in motion and what we what we need to know about fluids in motion are some of the interesting things that will constitute the discussion for the next part of the lecture and let us start with streamline flow and also we will talk about equation of continuity ok

so what we mean by streamline flow is the following that if you open the water tap just a little then water flows out smoothly from the tap but when you open it a lot then the flow of water becomes irregular and uneven and it gushes out very quickly onto the basin now we are talking about in this case

we are talking about the first situation in which water issues out smoothly so what is the technical definition of such a flow which we would call as streamline flow the technical definition would be that the the tangent to the uh the trajectory tangent drawn at any point of the trajectory of the fluid should point in the direction of the flow and in no case it would point in a direction which is different than the direction of flow and that can happen if the liquid trajectories cross in some form so these are liquid trajectories of different you know liquid molecules and at this point where there is a crossing of the trajectories the tangents are pointing along different directions so it is not clear that which way subsequently at later times the fluid will flow

so we are not talking about this kind of motion rather we are talking about smooth motion

so let us look at the case here where we take three ah points rather three points with three different cross sections and the flow is considered here so this is a point p this is a point q and this is a point r and the flow of the liquid is given by the arrows of course we are not saying that the flow remains constant at all points in fact you would see that the flow is different the the liquid has different velocity here then it's here then it's here and

so on however there is no crossing of trajectories and they just flow like this and

so we can coin terms define the velocities at p q r to be  $v_p$   $v_q$  and  $v_r$  so these are the speeds of the or rather velocities of the ah the molecule the liquid molecules that are flowing through these points p q and r a p is a q and a r are the areas of cross section of these uh of these objects or rather these points through which the fluid is passing consider this to be an envelope of a pipe through which ah fluid is passing and also the densities at row p row q and rho are to be the densities

so these are velocities at p q r these are areas of cross section and these are densities

so now we can write down that whatever liquid is actually going through this area is passing through this area and is also going through this area

so the liquid the volume of liquid has to be constant in a during a time  $\Delta t$  at all these three points p q and r

so we have our  $\rho_p a_p v_p$  and  $a \Delta t$  has to be equal to  $a_h \rho_q a_q v_q$  and  $\Delta t$  equal to  $\rho_r a_r v_r$  and  $\Delta t$

so this is

so to say that the mass of liquid flowing is constant  $v \Delta t$  is the length element traversed by the liquid in a time  $\Delta t$

so  $v_p$  is the speed or the velocity

so  $v_p$  into  $\Delta t$  is the the length element that is traversed in a time  $\Delta t$  because  $v_p$  is your length divided by time or a  $\Delta t$  of length  $\Delta t$  of time and that you are multiplying it with  $\Delta t$  of time which would give me  $\Delta t$  of length

so this is a  $\Delta t$  of length that is the length traversed by the liquid in a time  $\Delta t$  similarly this one is the length traversed in ah time  $\Delta t$  here at the point q and similarly here

so if we take that as some length or some distance

so that everything put together will give me the mass

so we have a length into area will give me volume volume into rho will give me mass

so in any case ah now we can consider the liquid to be incompressible and

which tells the liquid to be incompressible means that  $\rho_p$  becomes equal to  $\rho_q$  becomes equal to  $\rho_r$  which means that the liquid density of the liquid at all three points remain the same which is a good assumption and in that case I have I also can cancel  $\Delta t$  from all sides so I have  $a_p v_p$  equal to  $a_q v_q$  equal to  $a_r v_r$  which means that  $a \cdot v$  is constant so this defines streamline flow  $a \cdot v$  is called as the flux or the flow rate so  $a \cdot v$  is called as the flux or the flow rate so the streamline flow is defined by a constant flux of the liquid  $a \cdot v$  through a given area that's the definition of streamline flow so when is this streamline flow gets disturbed when you have some obstacle placed in the path of this so there are these water streams say coming and there is an obstacle that is there so what will happen is that this will try to go around this obstacle and will instead will have you know this kind of flow will get modified on the right side of the obstacle like this and this is no longer a streamline flow because you see that here if you calculate the tangent it is not really pointing in the direction in which the liquid is moving and hence this is an example of a non-streamline flow this is what happens in you may have seen that near a dam or where the water reservoir big water reservoirs they actually cut down or rather reduce the speed of water in a river by constructing some cylindrical obstacles such that the speed comes down and the water goes around it so these are also the seen in white water rapids or those so you may have seen those adventure sports in which they are going um you know rapids and their boats that are driven in the rapids and it's a of course is an adventure sports which is not advocated without professionals you