so we are going to talk about the blood flow to the heart and its relevance to bernoulli's principle
so we know that blood flows through the art and the inner walls of the blood flows through the arteries and the inner walls of the arteries have elasticity or they are elastic in nature and because of that there is a smooth flow of blood however if there is an increased blood pressure these elasticity could be affected and in which case it will lead to damage of the artery and the smooth blood flow will be interrupted and this is related to the elastic properties of the arteries which we have seen while we have discussed the elastic properties of matter now we are specifically going to talk about blood flow to the heart and the pumping of the heart
so what happens is that blood flows to the heart through coronary arteries and because of various reasons which include age and as well as you know unhealthy lifestyle or rather unhealthy food habits plucks accumulate inside the arteries inside the walls of the arteries and otherwise there is a smooth flow of blood through the arteries and they reach the heart
so these are oxygenated blood and blood pumps that oxygenated blood and sends it to various parts of the body however if there is a pluck deposition in the inside of the artery then what happens is that the the flow of blood gets chalked and when it gets chalked the flow gets interrupted and there is the smooth flow of blood to the heart oxygenated blood to the heart gets affected
so these are some of the symptoms that one sees in heart disease
so how is it related to bernoulli's principle
so what happens is that
so we have
so these arteries
so these are the arteries and there are in the inner walls of the arteries there are plugs that form
so these are the flux and this is basically the artery specifically the arteries which carry blood to the heart are called coronary arteries
so let us say this is a one of the coronary arteries
so because of this restricted flow of blood the heart would still pump but will not get the oxygenated blood as would have otherwise arrived in a healthy case
so what happens uh because of that is that if one or more coronary arteries gets completely choked because of this plug that you are seeing here that will lead to heart attack let's see bernoulli's principle how is it related to understanding of heart attack
so bernoullis principle just to remind you says that ah the kinetic head plus the potential head plus the pressure head is constant for a for an incompressible fluid non viscous incompressible fluid
so as there is a blockage in one of the coronary arteries that is carrying blood to the heart
so the heart would pump and when it pumps the blood will rush through these arteries that will change or rather increase the kinetic head or the kinetic energy at this moment let us forget about this potential head and not take it into serious consideration here
so if this kinetic head increases because of the increased rate of blood flow then the pressure will fall
so if the pressure falls the
so pressure inside the arteries fall and when it falls the external pressure that tries to collapse the artery and when he tries to collapse the artery the heart pumps stronger or faster and if that happens then of course

there is again a rush of blood
so the velocity increases which ultimately increases the kinetic part of this
 principle and again the pressure falls and repeated occurring of this leads
to heart attack okay
so when the pressure falls inside the artery because of the pressure from
outside will try to collapse the heart tries to resist that and pumps faster
and the speed of flow or the flow of blood increases through the artery which
will lead to drop for the drop in the pressure ok
so this is the ah the example of bernoulli's principle in in human body in
relation to the heart attack
so let us talk about the next topic which is called as the viscosity is
basically a property of the fluid just like that we have seen in surface
tension
so suppose we have an ideal fluid ideal fluid means the fluid which is a non
viscous fluid does not have viscosity consider the flow of such a fluid inside
 a pipe
so this is a pipe and we have a non viscous fluid an ideal fluid
so an ideal fluid means non viscous fluid
so lets see in this fluid different layers of the fluid
so all of these layers of fluid which is flowing through this pipe move with
the same velocity ok however for non-ideal fluids or rather the fluids that
are really seen in everyday life those have all have some viscosity and
because of that what happens to the same flow is the following
so
the drawing has not been very good but what i am trying to show is that each
of these layers actually move with different velocities and the layer that's
right at the middle of the pipe that moves fastest that is with the greatest
speed and the one that is in contact with the periphery or the inner wall of
the tube it doesn't move at all
so the velocity gradually decreases
so let us call this velocity as v 1 this one as v 2 this one as v 3 this one
as v 4 and then lets this velocity v 5 which is equal to 0
so we have v 1 greater than v 2 greater than v 3 greater than v 4 and of
course greater than v 5 which is equal to 0.
so that means that the inner uh the liquid which is right at the center moves
with a ah much bigger velocity than uh the velocity that is there with the
which is uh here ah which is just in contact with the inner wall of the tube
doesn't move ah at all and this happens in viscous fluids and and ah one
practical example you can always see that ah even though a car is driving very
fast there will be a thin layer of dust which will stick to the body of the
car and will never go away no matter how fast the car is moving that's because
of the fact that that thin layer of dust ah has zero relative velocity with
respect to the car and it will always be there and will not get wiped off
even if the car is speeding
so let us have a quantitative understanding of viscosity and for that let us
take this figure
so
there is a viscous fluid enclosed here ah which has ah in between two slabs
ah of area a the cross sectional area a for both the bottom ah for the top
and the bottom here and it encloses a viscous fluid
so now what happens is that will apply a force to the top layer okay and
the figure becomes like this
so
this one ah this top layer which is here a moves with the velocity v and the

the bottom layer has got a velocity is equal to 0 and let this height be h
so over a height h the fluid layers ah now this is called as a laminar flow
because each of these ah the disc or the layers that we have drawn layers of
the fluid that we have drawn is called as a lamina and that's why this is
called as a laminar flow ah
so the top lamina is moving with the velocity v because of the application of
this force and the subsequent ah lamina below that are moving but moving with
lesser velocity and the velocity actually goes down to zero as you come down
to the bottom layer and ah more the viscosity of the fluid more force would
be required to keep it in motion and
so as each layer moves it is subjected to a viscous force from its neighbors
so each of these layers face a viscous force from the layer that is
immediately below or immediately above and
so this applied force the the job of this applied force is to compensate for
this viscous force and this force that we have just discussed this force the
applied force depends on a the surface area which we have shown here the
surface area of this of this top surface or the bottom surface surface area a
 and
so this it's a direct proportionality f is proportional to a it is the speed
v and f is proportional to v and finally it also depends upon this height
h and f is in fact inversely proportional to h and if we take into all these
dependencies of this applied force f which as i said compensates for the
viscous force that exists between the layers or the lamina of the fluid then f
is proportional to a v over h and we can write it with as an equation by
introducing a constant called as eta where eta ah this is called eta eta is
called as the coefficient of viscosity
so this force that is needed to keep the top layer in motion and the
subsequent layers will follow with gradually lesser and lesser velocity with
the ultimately the the bottom layer will not be moving at all just the way we
have seen it flow of the liquid through a pipe and this motionless situation
happens because there is a strong interaction between the fluid molecules or
the liquid molecules along with the molecules of the uh this cover or this ah
you know the container or the pipe or whatever it is uh through which the
fluid is flowing and we said that the more viscous the fluid is the greater
would be the force required and
so basically we know the examples of viscous fluids as may be glycerin or
honey they are quite viscous fluids and this force would go as eta av over h
where eta is called as a coefficient of viscosity a is the area of cross
section of these various layers v is the speed of the top layer and h is the
height over which the fluid is confined
so now ah to know about the coefficient of viscosity let us see that this
coefficient eta is equal to f h divided by a and v
so f has unit as newton l h has in meter ah a is in meter square and this
is meter per second
so this is equal to newton uh per meter square into second or this is also
called as a pascal second
so the unit of this coefficient of viscosity is called as pascal second pascal
is one pascal is one newton per meter square ah there is also a common unit
or rather ah the commonly used units is called as poise ah and it is written
with a p
so
one poise or rather ah one one poise is equal to zero point one pascal
second
so it is simply divided by a factor of 10 the pascal second is divided by a

factor of 10 in order to get a voice

so that's the practical unit or commonly used unit for the coefficient of viscosity

so let us see now some of the fluids

so viscosity of some of the common fluids

so fluid and as we have done earlier um almost in all cases that there is a strong temperature dependence ah or at least there is some temperature dependence even if it is not strong

so we will have to mention the temperature at which the viscosity is calculated

so fluid and temperature at which it is calculated and the value of eta or call it a viscosity ah now this is expressed in 10 to the power minus 3 pascal second

so lets take air at 0 degree centigrade it is equal to 0.0171 and as i have written that it is 0.0171 into 10 to the power minus 3 pascal second then for helium is 20 degree centigrade or we can say that the temperature actually measured in degree centigrade

so it is at 20 it's equal to 0.0196 this is a blood when i say blood i usually mean whole whole blood uh there is also another component or rather one term called as a blood plasma which varies from the whole blood by just a little bit we just code this value even while we have coated for surface tension and others we have quoted it for the whole blood it's at 37 degree centigrade and the value is very close to four glycerin which is known to be a very viscous fluid it's at 20 degree centigrade this is 1500

so um two orders of magnitude more than this and at least something like six 6 orders of magnitude more than the gaseous two entries here ah then it is methanol ah at zero degree centigrade its point five eight four and of course we have to coat water which is the most common liquid ah and we will coat this value for 0 20 and 40 degree centigrade for 0 degree centigrade it's 1.78 for 20 degrees 1.0 and for 40 degrees 0.651

so if you see that the viscosity goes down with the rise in temperature for water and these are the temperature mentioned corresponding to the fluid and these are the values of viscosity that are noted as you see that glycerin is of course very dense and

so is very viscous

so now ah in this connection let us do one law called as the poison is law

so this quantifies ah viscosity ah or rather of the flow of rate of flow of a liquid through a pipe or a tube and the quantities that it depends upon and links it to the coefficient of viscosity okay

so let us consider a pipe which could be you know you have seen those hypodermic syringes which are pushed into the veins in order to give an injection by which a medicine is administered and let's say this is some kind of that kind of a pipe which has a length l here we don't talk about the area of cross section but it is same to talk about the radius and the pressure is measured here by say some gauge is p 2 and the pressure measured here again by some gage is p1 where p2 is greater than p1

so now we want to know the rate of the flow of the fluid through this pipe and how it depends upon these quantities such as p r and l

so this flow rate it is usually mentioned denoted by q the flow rate of the fluid through the through the pipe of radius r length l and and having a pressure difference of p 2 minus p 1 along the length

so this flow rate ah q

so q is proportional to p 2 minus p 1 that is the more pressure difference is the flow rate will be higher it is uh also as we have seen earlier it's

proportional to the 1 over l the length of the tube and little surprisingly it's proportional to the fourth power of the radius of the tube

so this is the radius of the tube

so it's proportional to the fourth power and the flow rate is written as ah

so the proportionality constant has got a slightly non-trivial expression

so it is like pi r 4 p 2 minus p 1 divided by 8 eta l ok

so this is my constant of proportionality which is not simply you one can write it with some some eta prime but that eta prime equal to pi by 8 eta

so this is the constant of proportionality and it depends on the pressure difference between the two ends

so we have said that this pressure is p2 and this pressure is p1 it's inversely proportional to the length of the tube it's directly proportional to the fourth power of the radius and this expression is called as boy julie's law

so let us ah do a problem on surface tension ah to remind you surface tension is the force per unit length and it walk it basically works along any line on the surface of a liquid and we have seen a number of consequences of having surface tension that is even you know a small water filled balloon can actually float on the water surface of the water or an insect can actually walk on the water without getting drowned and all of them may have more uh they they could be more dense than the liquid or on which they are they are being supported at the surface and

so let us do a problem on um surface tension

so the surface tension is an example problem the surface tension of a soap solution is ah 0.03 newton per meter what amount of work is required is required for producing a soap bubble of radius 0.05 meter

so ah there is a soap solution and we need to make a bubble out of it of this radius 0.05 meter ah there is certain amount of surface tension and the surface tension is given by 0.0.03 newton per meter and we need to find out the work done in order to do that

so the solution can be written as follows

so the work done in making a bubble this is equal to the surface tension this we have discussed earlier that the surface tension is also defined as work per unit area or joule per meter square it has a unit of joule per meter square

so the surface tension into the total surface area now this total surface area is important because there is an inner surface and there is an outer surface but the bubbles are very thin

so we can take the radii of each of the surfaces to be same as this radius however the total surface area will be twice the surface area of of the sphere that is having this radius

so this as i told that this means that the surface tension into inner plus outer ah surface area

so this is equal to 0.03 newton per meter into twice and a 4 pi twice because inner plus outer and this will be 4 pi r square which is equal to 0.05 ah meter square and when you work this out this becomes equal to 1.884 into 10 to the power minus 3 joules

so that's the work done or there's a work required to produce a soap bubble of a 0.05 meter radius where the surface tension of the liquid or the solution is 0.03 uh newton per meter

so let us recapitulate uh that what we have learned about the properties of fluids in this chapter and we have started our discussion with the definition and the importance of density and specific gravity we have seen what the definitions are and what are the for some common fluids what are the

densities and the corresponding specific gravities then we have very elaborately talked about pressure

so we have talked about pressure exerted by a fluid at a distance or a depth h from the surface which is given by p equal to h rho g further we have also talked about or rather demonstrated how the pressure due to the atmospheric atmosphere changes with the height as we go away from the sea level

so having discussed pressure we have then talked about measurement of pressure and water known as gauge pressure etcetera

so we have talked about of course atmospheric pressure and gauge pressure and we know that the the pressure that is measured is uh has to be the atmospheric pressure has to be actually added to that ah to the gauge pressure uh in order to calculate the exact pressure

so if at some place the pressure is quoted as say 2.7 atmospheric pressure ah the actual pressure is 3.7 atmospheric pressure because one atmospheric pressure has to be added then we have learned the interconnection or rather the different units of pressure or rather different representations of pressure and the pressure can be expressed in bars or pressure can be expressed in you know pascal or pressure can be expressed in kilo pascal or it can be expressed in atmospheric pressure or it can be expressed in

so many millimeters of mercury and what are their relations interrelations between one unit to another unit we have seen that then we have uh talked about um some commonly used pressure devices such as

so measurement of pressure and

so we have talked about barometer we have talked about a youtube youtube manometer for measuring pressure ah and then we have talked about pascal's principle

so uh which tells you that the pressure applied to a confined fluid actually increases the pressure throughout the throw the volume of the fluid by the same amount and this has very important applications in the automobile industry where it is used the hydraulic brakes are used to stop a speeding car or there are hydraulic machines which are required to lift heavy objects such as trucks or other heavy vehicles where a small pressure can be applied at one end of the youtube which is thinner and the pressure gets transmitted and at the end at the other end of the youtube which is much broader uh you one gets a lot of force by which one can lift a heavy vehicle even a very heavy vehicle

so these are some of the applications of pascal's principle and then we have also talked about equation of continuity which says that for an incompressible fluid non viscous incompressible fluid the product of the area of cross section through which the fluid is flowing multiplied by the velocity of the fluid will remain constant and then we have talked about buoyancy and archimedes principle which nicely shows that the weight of the or rather the reduction in weight of an object inside a liquid is equal to the the mass of the or rather the weight of the displaced liquid and we have proved that using some general consideration after that we have talked about surface tension and surface energy here we have defined surface tension and surface energy and said that the actually the not only inside the fluid it's also the surface of the fluid acts quite interestingly and it acts like a membrane which is stretched and under tension

so uh this it happens because of the surface tension that acts at the surface along a line and is defined as a force per unit length and we have seen some very interesting consequences where liquids such as water and mercury can be distinguished by the angle of contact that it makes when it's kept in a beaker

so what happens is that water level rises a little uh towards the end which is

because the force of adhesion is more for the water molecules   along
so the water molecules bind tightly with the molecules that the beaker is made
of whereas for the uh for the mercury it dips a little bit towards the end
and that tells you the force of cohesion among the molecules of the mercury is
more than the force of adhesion and these are
so this way one can talk about or one can distinguish between various liquids
and we have defined an angle of contact in that context
so this is called as capillarity and then we have talked about bernoulli's
equation
so bernoulli's equation has been derived which says that uh the kinetic head
plus the potential head that plus the pressure head should remain constant
for a non-viscous fluid for a streamline flow and this has important
consequences or other applications as one of the applications was seen in
venturi meter venturi meter shows uh or rather measures the speed or the
velocity of a fluid through certain region of of a pipe that it's flowing
through and we have also seen it in the context of blood flow to the heart
and why there could be chances of heart attack when because of the increased
blood pressure through the arteries especially the arteries that carry blood
to the heart which are known as coronary arteries and finally we have looked
at the viscosity where we have defined viscosity which is a property of the
fluid because of which different layers of the fluid moves with different
velocities and if you're talking about a flow through the pipe the central
lamina moves with a greater speed with the speed going to zero for the layer
that is in contact with the inner periphery of the pipe and in that
connection we have defined coefficient of viscosity and also define poisson
formula which talks about the the flow rate and how it depends on the
pressure difference between the two ends uh on the length of the tube through
which the fluid is flowing or on the radius of cross section through which the
fluid is flowing you