so good morning everyone

so we are we have looked at in the last chapter we have looked   at the mechanical properties of solids ah in this chapter we are going to talk about mechanical properties of fluids um and i will just tell you that what we mean by fluids   there are essentially three states of matter namely the solid liquid and the gases   and the solids are characterized by um having specific shapes and sizes okay and if you apply   pressure to it the change in volume is negligible and sometimes it's

so small that it cannot be   recorded while the same is true for liquids but the liquids cannot take shear stress at all

so it does not have any specific shape or size and it takes the shape of the container   that it is put into and when we come to gases ah they have a different property   in fact the change in volume by application of pressure in gases is enormous or can be enormous   and like when you uh fill in uh automobile tire uh with air and by using um you know a device

so as   to fill in air the air doesn't go and settle in the bottom of the tire rather it just fills the   space available to it uniformly while the liquid actually if you pour in liquid it will just go to   the bottom run to the bottom and start building up from there the gases do not have that property and because the gases ah and the liquids they do not have any specific shape ah they can flow and that's why they are called as fluids

so when we talk about so   we are discussing mechanical properties of fluids and in that

so far we have defined solids ah liquids and gases its these two collectively are called as fluids

so its the liquid and the gases   both can flow and anything that can flow is called as a fluid now there is another ah state of matter in addition to the three   which happens at very large temperature when the atoms are actually stripped of their   electrons and they acquire a charge and these are called as ions

so atoms ah either   i mean which are devoid of some electrons ah essentially which are at the outermost shell   and they form ions and this state of matter is called as plasma and some scientists are of the opinion that the colloids which are the suspension of   tiny particles in a liquid such as milk should also be considered as a separate state of matter   but nevertheless we shall talk about primarily these three states of matter solids liquids   and gases and as i have told that we have mostly dealt with solids in the last chapter

so we shall   be more uh concerned about liquids and gases ah or collectively which are known as fluids   um now

so uh we have fluids all around us and the air that we breathe in is a fluid human body consists of water which is also a fluid which mostly consists of water and a lot of   processes that go on in human bodies or in other living beings even in plants ah they   are mediated by ah fluids ah such as water or some other ah you know liquid

so ah its very   important that we understand the properties of the fluids and the way actually to characterize them

so let us just go into understanding uh fluids uh and also solids from an inter atomic or an   intermolecular perspective point of view

so uh solids as we know that have definite shape and size ah do not have ah do not have definite shape and size and the reason being that the intermolecular force of attraction in solids is very large so   those attractions or the interactions that keep the molecules stay together and thus the solids   have a definite shape the intermolecular force of attraction in liquids is small but   not negligible however the intermolecular forces or

inter atomic forces in gases are negligible

so these are the sort of from the microscopic point of view we can distinguish the solids liquids and gases in this particular manner but what is important for us in this chapter is to understand some of the properties which   distinguish them mechanically that is some of the mechanical properties which are of relevance to us such as density and specific gravity

so if i ask this question whether a block of wood is heavier or a block of iron you definitely say that a block of iron is heavier but that's not true a large log of wood   is definitely heavier than a nail or a small block of iron

so what property distinguishes   these two wood and iron

so let's talk about density to begin with

so the word density mean ah let us denote it by a symbol rho which is equal to   mass divided by the volume

so ah m is equal to mass of the of the substance and v is the volume

so ah

so its density is the property of the substance

so whether big or small   when a particle or when a particular substance is made of certain material no matter what shape or   size it takes it will have the same density

so and the s i unit of density is kg per meter cube and of course the it also ah sometimes its the cgs units   unit is used of density is gram per centimeter or simply its written as ah gram per cc ah in general pressure and temperature will affect the value of the density for a given substance

so while coating the density it is customary to talk about or to mention about the temperature   and pressure at which it is calculated

so i will give you some examples of   the densities of certain substances and you would know that that what are the ranges of densities   of solids liquids and gases

so let us just give you some examples

so

we have solids um liquids and gases um and lets write the material and row

so this symbol is called as row

so this is in ah kg per meter cube ah again we have material and rho in kg per meter cube and um all right

so we have iron having a density 7.8 into 10 cube we have an aluminium which has a density of 2.7 into 10 cube kg per meter cube ah   wood ah usually it is taken as a pine wood ah it has a density about 0.5 into ten cube and the glass its two point five into ten q now coming to the liquids its water ah and it is very   important to say that at 4 degree centigrade or 277 kelvin the value is 1 into 10 cube and seawater is 1.025 and into 10 to the power 3 seawater is known to be more dense than ordinary water ah and then you have mercury which is 13.6 into 10 cube and now we have ethyl alcohol is equal to 0.79 into 10 cube

so these are for the liquids as you can see that   they are almost one order of magnitude less than than the solids while it is almost of the same density as the wood has in fact a lower density than that of mercury and even glass   has something glass has density which is lesser than mercury now let us go to the gases ah this is   air which as you know is a mixture of nitrogen oxygen and other gases ah and this is 1.29   ah remember there is no 10 to the power 3 here it's simply 1.29 kg per meter cube helium gas is ah 0.179 kg per meter cube and carbon dioxide has 1.98 kg per meter cube

so you see that   the gases have a density which are um pretty less very less in fact income as compared to   the the solids and the liquids three orders of magnitude less and this as we have discussed   is due to the negligible uh

force of attraction between the atoms or the molecules that constitute these gases and just to ah that these all these values that are coated they are coated at a temperature equal to 0 degree centigrade which is 273 kelvin and a pressure of 1 atmosphere in fact it is important ah to ah as i as we have talked earlier that these densities are actually functions of temperature and pressure

so it is important to mention the temperature and pressure at which they are they are calculated or their the values are coated except for water the value is equal to 1 into 10 cube kg per meter cube or 1 gram per cc at 4 degree centigrade

so let us now do a problem a simple numerical problem

so what is the what is the mass of a lead sphere of radius radius 0.5 meter given that the row of lead is equal to 11 300 kg per meter cube ah

so in order to calculate the mass ah we shall use the formula that ah mass is equal to ah density into the volume

so in order to find the volume ah it is a sphere

so the volume of a sphere is given by four third pi r cube which is equal to point five cube which is equal to ah point 5 2 3 meter cube and a mass is equal to the density of lead multiplied by this volume and that is equal to 11 300 kg per meter cube multiplied by 0.523 meter cube and if you simplify this it comes out as five nine one zero kg

so this is the um the the mass of a lead sphere which has a radius of 0.5 meter you understand that if we replace lead by an ion sphere or an aluminium sphere this mass is going to be different because this quantity even if the radius remains the same because the density of ion or density of aluminium are different than that of lead now we shall continue with more problems later let us now define the other quantity which is called as the specific gravity and specific gravity is defined it is defined as the ratio of a substance divided by the density a ratio of the density of the substance divided by the density of water at 4 degree centigrade

so it's a dimensionless quantity

so this is a density of a substance divided by density of water at four degree centigrade now the advantage of defining this let us write specific gravity with the s g ah this is just the abbreviations used for that for them ah since the density of water at 4 degree centigrade is equal to 1 kg per meter cube

so this becomes this is equal to 1 kg per meter cube

so the specific gravity of a substance is ah just the density of the substance multiplied by 10 to the power minus 3 ah in a kg per meter cube however it's numerically equal to the density in the cgs units ok

so this is equal to 10 to the power minus 3 into density of the substance and i should write numerical value because this is dimensionless in um and this is equal to simply equal to uh so

so if this quantity is quoted in cgs units then we will not have this 10 to the power -3

so this is how specific gravity is defined

so let's talk about an important concept in the context of fluids that is liquids and gases that is the concept of pressure as we know that pressure ah is defined as the force exerted per unit area

so let us write it with a symbol p is equal to f by a where f is the force um or the load ah that is given to a certain object and a is the area over which the force acts and the s i unit of pressure is is ah newton per meter square or it also has a name as pascal and ah one pascal is equal to one newton per meter square

so let's just consider that a person whose   weight is 60 kgs and his weight
say is equally distributed by his two legs and each foot   has an area of say
600 centimeters square
so the pressure that he would be giving on the ground so   his weight is equal
to ah 60 into g ah just for now let let's take g to be 10 meter per second
square
so this is equal to 600 newton is the force that is exerting and um
so this is equal to f and
so the pressure is ah f divided by his two feet which has say an area of 10
say 600 centimeter square
so this is equal to 600   newton divided by two into ah six hundred ah into
ten to the power minus four
so each feet   ah has an area of six hundred centimeter square
so there are two feet um each foot has a area of 600 centimeter square 2 feet
will have 1200 centimeter square so   this is equal to meter square
so 600 will cancel and this will be 0.5 into 10 to the power   minus 4 newton
per meter square
so that is the pressure that he exerts due to his   own weight
so now ah let us look at a important a point about pressure exerted by fluids

so fluids exert pressure on a body from all sides and
so lets particularly talk about pressure due to static fluids
so we have a container ah its filled up to water till that level and there is a
cube and this fluid exerts a force from all sides and this force acts normally
on the surface of the of the material or the cube   and what i mean by
normally is that the forces act perpendicularly as it is shown here   had
there been a non-perpendicular component that is a component which is not
normal to the   surfaces then there will be a component of the force which is
parallel to the surface   such as say this surface and if there is a component
that is parallel to this surface   by newton's third law this cube will in turn
exert a force on the fluid equal and opposite to that   and because of that
the fluid will be set in motion which is contrary to what we have   assumed
that the fluid is static so there can't be any component of force   which is
acting at a given angle to the surface it has to be always normal to the
surface of the   of the material
so this is the basic notion of pressure due to fluids let us now compute
that how to calculate the pressure due to a fluid for a given body
so let us take again   an open container as we have taken earlier let us take
a level of water and let us take a   say just to be keeping our discussion
simple let us take a cube and let this height be h and ah
so we are this cube is of ah height h the density of the liquid equals to rho
so ah the liquid exerts a pressure on the bottom surface of this cube   which
is of magnitude
so f is equal to mg and this is equal to h m is equal to v rho   and g and we
are talking about a column of water of volume v
so according to this   question v is equal to the height times the area of
cross section of these bottom section
so this is of area a and
so this is equal to h a rho g ah since pressure is defined as   force by area
so the pressure is equal to f over a which is equal to h rho g
so the pressure due to a fluid ah at a height h below the level of the fluid is
h rho g
so which   means that ah greater the height of the object the pressure will be
more

so p simply scales as h given that rho and g remain constant but there is a small problem there we are taking rho to be constant which means the density of the liquid remains constant which is uh pretty correct by and large correct in the context of liquids except for the case of ocean water where there is an enormous mass of water if you consider it a point at a depth h which is significantly below the sea level then there could be a change in the density of the of the water with height but without getting into that problem we can say that even for gases which are largely compressible uh there could be significant variation of density with ah with the height or with the distance from where it's being measured

so we actually need a more direct calculation of pressure how it varies as a function of depth ah in a fluid not necessarily in a liquid but in a fluid as soon as we talk about a liquid we can safely assume that the rho is constant however we need to know this relation

so for doing that let us take this case we will draw this same drawing as we have done accepting that

so this is the open container ah it's filled up to the water is filled or a liquid is filled up to this level and let us take a small disc like water or the liquid that we are considering and which is measured from the bottom which exists at a ah at a distance y from the bottom and the slab is of thickness b y ok

so we are going to calculate the pressure due to static fluid ah for that we are taking a fluid or a liquid in an open container and we are measuring the distances from the bottom of the container we have taken a certain mass of water which is at a distance y from the bottom has a thickness d y and the the liquid has density rho and we need to calculate the pressure so what are the forces acting on this there is a force that is acting upward or let's call it the pressure and multiplied by the area of cross section of the slab which is the force acting which is due to the fluid and in the upward direction there is also a force acting down which is a say a p plus a d p multiplied by a

so we have taken pressure at at a height or this is rather a distance of y as p and pressure at a height again which what i mean is distance is equal to p plus d p ah

so this is ah at height y plus d y again measured from the ground is p plus dp
so the force ah due to the fluid acting upward is pa on this bottom surface of this disc the force that is acting downward is p plus dp into a a denotes the area of the slab and of course we also should consider the effect of gravity

so the gravity this ah there will be
so just between before we write the gravity
so there is a a p a um
so this will be p plus d p a minus p a
so this is downward and this is upward
so this is the fluid pressure also due to the weight of
so let us write it as due to gravity let us write that as d f and g which is equal to d m into g
so this g subscript stands for gravity and this g stands for acceleration due to gravity
so dm is the mass of this disc of the liquid and this is equal to our rho g and dv which is equal to rho g a d y
so again this is acting downward
so the net force is equal to ah p plus d p a minus p a and a plus or we can write it net force upwards will be p a minus p plus d p a minus rho g a d y

now at equilibrium this net force is going to vanish

so then we can write that p a minus p plus dp a minus rho g a d y equal to 0.

so if we ah cancel a from ah all from both the sides that is divide both sides by a i get a simple differential equation of the form d p d y equal to minus g

so this solution of this differential equation solution of this differential equation will give me the variation of pressure as a function of y there's a negative sign which tells you that the pressure will be more if the height that is this distance from the bottom is less which means that if you talk about the height from the uh from the top surface then pressure will actually become more as the height or the depth into the water as i mean as it increases the pressure will be more since the distance is measured from the bottom surface we are getting a minus sign which is uh which makes sense because we need to have the as the water column gets bigger and bigger it is going to exert more force at a at a given point so this is my defining equation which should give me the variation of pressure as a function of the distance either measured from the from the bottom of the container or in other words it can be measured at the top of the container

so what we are trying to get at is the following that we ah should we have considered here the fluid pressure and pressure due to ah or rather the ah this is the force due to the fluid pressure and this is the the force due to gravity but there could be uh an additional pressure that is that could be acting which is usually the atmospheric pressure let us see that how we actually get this atmospheric pressure

so i hope this part of the discussion is clear

so now we go ahead and calculate p as a function of y by solving this differential equation which means that we are going to integrate this equation in order to get p as a function of y

so that is obtained ah

so a dp integrated from a p 1 2 p 2 these values of p 1 and p 2 are really arbitrary which can be fixed according to the given problem and now i am going to write this as minus rho g d y and integrate it from y 1 to y 2.

so there are two points y 1 and y 2 which are say arbitrary y 1 is the distance of this point say point a from the bottom of the container y 2 is the distance of the point b from the again from the bottom of the container where respectively the pressures are p 1 here at a and p 2 here at b

so we have to solve this equation this is fairly easy to solve we simply integrate it um and we continue writing with a minus sign and

so p 2 minus p1 equal to minus rho g y2 minus y1 you must have noticed that here we have taken rho and g to be constants and that is why they are taken out of the integral however as we told that either for gases or for ah for liquids in a huge water mass such as an ocean you may not have rho to be constant rho could be a function of y and that functional dependent needs to be known in order to put it into this equation and integrate suppose rho is a linear function of y suppose in some problem rho is equal to alpha y in which case we should not put rho to be a constant and take it out of the integral rather this alpha which is assumed to be a constant here which can be taken out of the integral and this will be an integration of y d y in which case it will not be y two minus y one but it will be y two square ah minus y1 square divided by 2 in any case we are not specifying the functional dependence of rho and it's taken to be a constant here and we can write this equation

so this is how the pressure difference between two points which varies with the distance measured of the two points from the bottom of the containers to

be like this now let us assume that that my y2 is this entire ah height of the water column measured from the bottom in which case my p 2 becomes simply equal to p 0 which is the atmospheric pressure

so this is the pressure due to the atmosphere which is known as the atmospheric pressure

so that is equal to ah p2 and my y2 for this particular case my 2 is equal to call it ah 0 or rather let us call it as h and we can we can get or if you if you call this as the total height of the the water column and now we can measure it from here and absorb the negative sign in which case we can write this instead of h we can write this as 0 that is we are now no longer measuring the the distance from the bottom surface but we are measuring it from the top surface in which case my y 2 becomes equal to 0 and my y 1 let us say becomes equal to h and then my p 1 becomes equal to p that i want to calculate and y one becomes equal to h

so under these two condition i can put it in which case what i want to do is that i want to absorb this negative sign and call y2 to be equal to 0 because now no longer i am measuring it from the bottom surface i am measuring it from the top surface and now my p2 minus p1 which becomes equal to my p 0 minus p and my the right hand side which is minus rho g y 2 minus y 1 now becomes equal to rho g h and my pressure becomes equal to p 0 plus rho g h

so this is the final result that we wanted to obtain which says that the pressure at any given point which is at a depth h measured from the top surface of the of the liquid ah the pressure at a height h at a depth age inside the liquid is equal to the atmospheric pressure plus uh the rho times g times h and

so that is the expression for pressure that we wanted to calculate so this part is due to the atmospheric pressure and this part is due to the fluid having looked at the expression for pressure which is given as p equal to p 0 plus rho g h ah this being the atmospheric pressure as we have discussed and this is the pressure due to the liquid column of height h ah we now want to do some problems using this formula that is pressure due to liquids which is given by this

so let us do a problem which says that the surface of water water in a storage tank is is a 20 meter above the water tap in the kitchen of a house

so this is understandable that there is a storage overhead storage water storage tank which is there on the terrace and the distance where the kitchen is or the kitchen tap is the storage tank is located 20 meters above the kitchen tab

so the question is calculate the pressure at the tap tap and of course given that density of water equal to 1 into 10 cube kg per meter cube ah this density is denoted by a quantity called as rho which almost looks like p but please do not distinguish this from p it is called rho r h o

so this is equal to rho of water

so now the pressure at the surface of the tank that is at the surface of water inside the tank um

so there is atmospheric pressure and the same atmospheric pressure also is there at when the water is issuing out from the tap

so essentially the pressure difference is simply given by

so delta p is the pressure difference which is simply given by rho g into h where rho is of that of water

so this is equal to 1 into 10 cube kg per meter cube ah g is 9.8 meter per second square and h here is 20 meters if you do this it becomes 1.96 into 10 to the power 5 newton per meter square which is also called as 1.96 into 10 to

the power 5 pascals

so this is the ah pressure difference that is there at the between the surface of the ah water level inside the tank to the tap the nozzle of the tap from which water issues out

so this is a simple plug-in type of ah example let us do another one again ah plugging type however ah its related to human body again

so what is the difference in blood pressure between the top of the head and the bottom of the feet of a 1.60 meter tall person standing vertically ah

so so there is a person whose 1.60 meters tall and you are needed to find the the pressure the blood pressure the difference in the blood pressure between the top of his head from the bottom of his feet and the person is standing vertically now the the input that needs to be given in this case is the density of blood and ah just keep in mind that this density of blood that i am going to give you is actually the average density of blood because the blood consists of the blood plasma which has a little less density as compared to the other cells that make up for the blood which has a little more density

so this is the average density of blood which is ah 1060 kg per meter cube just take a note that ah this value for water is 1000 kg per meter cube so blood is a little more dense than water

so again the pressure difference is given by ah delta p it is equal to rho g h ah rho for blur is given as one zero six zero kg per meter cube with the g to be nine point eight meter per second square multiplied by one point six zero feet and this comes out as ah one six six two zero point eight newton per meter square ok

so ah this is the ah the blood pressure difference ah between the top of his head to the bottom of his feet um

so let's do another problem and the problem concerns um which all of you might have felt at times that you have either traveled up in a through a hill and or traveled down very quickly descended from a hill very quickly or it might have happened when you have traveled in an airplane inside the airplane the pressure is pretty much taken care of but still one feels uncomfortable at times because there is a pressure buildup in the years and what happens is that there is a pop in the year which means that some air is released to equalize the pressure between the inner part of the eardrum to the outer part of the eardrum and this as i told you that this can also happen if you are climbing a hill or you are getting down from a hill very quickly and this can cause this popping of the air as it says

so if it does not pop then there is a pressure that builds up or rather there is a force that is developed and that's why the year starts aching

so the question is what is the

so so when you not what is when you ah run up a tall hail or run down the hill quickly the years pop and as i told pop means that some air is released from the ears and this is due to the buildup of the pressure due to that that the body takes a little while to get accustomed to suppose you are climbing down a hill very quickly or you are running down a hill very quickly

so the pressure difference that you initially had and after you have gotten down ah quite a few say thousand feet quickly

so then ah this pressure buildup can happen ah the question is suppose this did not happen did not happen what would be the force force on the ear drum ear drum of area 0.5 centimeter square ah if a change in altitude which means height altitude or you can just simply write it as height ah of 1000 meter takes place

so if there is a a height difference of thousand meter that takes place and if the ears don't pop

so what's the pressure developed and   because of that pressure developed what is the force that is exerted on the eardrum

so again p equal to ah the pressure is equal to h rho and g ah now its   has to be given that the row of air that is the density of air is 1.29 kg per meter cube

so 1000 meter ah multiplied by 1.29 ah kg per meter cube ah multiplied by nine point eight   meters per second square and this thing when you calculate it it comes out to be one two six four   two newton per meter square ah

so this is the pressure that is developed between the inner   part and the outer part of the ear drum because of this pressure there is going to be a force which is equal to the pressure multiplied by the area which is 1 2 6 4 2 newton per meter square   and you multiplied by point five into ten to the power minus four   meter square ah

so the meter square will cancel and this becomes equal to 6.32 newton

so ah this 6.32 newton ah is is the force that is exerted on the year ah now you can take   this as suppose just for the argument's sake or making matters simple let us take g equal to 10   for now and which means that there's a weight of 0.6 kg that is exerted on the on the years   and this is uh most of the times this is not an unbearable situation but however   you would find actually children crying inside the airplane and the reason more often than not is   going to be because of this pressure that develops and that creates an ache in this and the child   cries

so we have looked at mainly ah

so far the density of liquids we have defined density and   we have also looked at density of solids liquids and gases and we saw that the density of gases is   at least something like three orders of magnitude less than that of the other solids and liquids   and we have also learned about specific gravity and also we looked at the pressure that is exerted   by a liquid column of height h or the pressure that is felt at a point inside the liquid   at a depth age from the surface and used that result to compute some simple problems so far you