

having looked at the expression for pressure which is given as $p = p_0 + \rho g h$ this being the atmospheric pressure as we have discussed and this is the pressure due to the liquid column of height h 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 in a storage tank is 20 meters 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 tap

so the question is calculate the pressure at the tap and of course given that density of water equal to $1000 \text{ kg per meter cube}$ this density is denoted by a quantity called as ρ which almost looks like p but please do not distinguish this from p it is called ρ so this is equal to ρ of water

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

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

so the essentially the pressure difference is simply given by

so Δp is the pressure difference which is simply given by $\rho g h$ where ρ is of that of water so this is equal to $1000 \text{ kg per meter cube}$ g is $9.8 \text{ meter per second square}$ and h here is 20 meters if you do this it becomes $1.96 \times 10^5 \text{ newton per meter square}$ which is also called as $1.96 \times 10^5 \text{ pascals}$

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

so this is a simple example let us do another one again a plugin type however it is 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

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 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 $1060 \text{ kg per meter cube}$ just take a note that this value for water is $1000 \text{ kg per meter cube}$ so blood is a little more dense than water

so again the pressure difference is given by $\Delta p = \rho g h$ ρ for blood is given as $1060 \text{ kg per meter cube}$ with the g to be nine point eight meter per second square multiplied by one point six zero feet and this comes out as $1.662 \times 10^4 \text{ newton per meter square}$ ok

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

so let us do another problem and the problem concerns 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 ears and what happens is that there is a pop in the ear 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're 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 ah 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 ear starts aching so the question is um what is the force so when you not what is when you ah run up a tall hill or run down the hill quickly the ears pop and as i told you 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 ah 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 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 $h \rho g$ 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 9.8 meters per second square and this thing when you calculate it it comes out to be 12642 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 a force that is exerted on the ear ah now you can take this as suppose just for the argument's sake or making matters simple let's take g equal to 10 for now and which means that there's a weight of 0.6 kg that is exerted on the ear 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 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 p_h inside the liquid at a depth h from the surface and used that result to compute some simple problems so far we have talked about the the pressure due to h liquids h inside a container which is full of liquid and then we have calculated what is the force at a depth h from the surface now let us look at the pressure due to air or our atmosphere

so we will talk about the atmospheric pressure however atmospheric pressure p_h has a large variation with the height measured say from the surface of the earth and

so it's not like really like liquids where the the pressure really doesn't or rather the density doesn't change much here of course the density will change a lot given the fact that air is significantly compressible so it is done in the spirit of a problem i think this is a better way of doing this problem

so we will write down the problem and then it's not a numerical problem its only a problem of finding the pressure in the earth's atmosphere as a function of the height measured from the sea level

so determine the variation in pressure in the earth's atmosphere as a function of p as a function of of the height y above sea level assuming g to be constant constant means constant over the distance that we are considering so over a height h measured from the sea level

so g is not varying and that the density of air of air is is proportional to pressure

so we p_h need to know the variation of pressure p_h as a function of the height height being measured from the sea level there is an additional part to this problem which says also at what elevation elevation is the air pressure is a air pressure equal to half the pressure at sea level and p_h the atmospheric pressure let us just call it as p_{atm} or p_{atm} its equal to one point zero one three into ten to the power five newton per meter square same as pascal so p_h we have the first part is about deriving an expression for p as a function of y and the second part is that at what y or what height the pressure is equal to half of the atmospheric pressure the atmospheric pressure is given there

so the clue is given in this part that the density of air is proportional to pressure this you would learn in a different context will not go into that will take this data and write that ρ by ρ_0 which is equal to p by p_0

so this p_{atm} will often be written as p_0

so that is the standard atmospheric pressure

so we will write it as p_0 .

so ρ is the density at the height that we intend to find ρ_0 is the density at the sea level p_0 is the pressure at the c level and p is what we intend to find

so we have learnt earlier that p d y equal to minus ρg this is how the pressure varies with height by and you can you can get that p as a function of y by solving this differential equation this we have elaborately discussed earlier

so now i am going to replace this row by using this equation let us call this as equation one and lets call this as equation two so i will put equation one p_h draw from equation one and put it into two

so ρ from equation one comes out to be p over p_0 into ρ_0

so that will give me putting it in equation two is dp by dy equal to minus p over p_0 multiplied by ρ_0 and g let us call this as equation 3 now since i need to solve this equation there is a dp here and a p here

so let us take all the the pressures in one side

so $\frac{dp}{p}$ becomes equal to $-\rho_0 g$ divided by p_0 and dy now this equation should be the guiding equation to get p as a function of y so i can integrate it both sides in order to solve for p as a function of y now in order to integrate you need to put limits and the limits are as follows that let's take the y equal to 0 to be the c level so this is the c level and where p equal to p_0 so this is the atmospheric pressure

so this is my the height is 0 at the c level and there the p equal to p_0 and at a general height y i want to find what is the pressure that is developed so i will integrate this from p_0 to p so that the lower limit of dy goes to 0 and it goes up to y so and remember that all these quantities are constants where ρ_0 is the density at the c level and if i solve this equation rather evaluate the integral it becomes \log because you see the $\frac{dp}{p}$ is a $\log p$ now putting the limits upper limit and lower limit so $\log p$ by p_0 equal to $-\rho_0 g$ by p_0 and y

so this is the equation that we need to keep in mind ah there is a negative sign there which has the same meaning as we have discussed in the case of solids that the p becomes

so p is uh p decreases um

so the atmospheric pressure decreases with its increase in height or the other way around the atmospheric pressure increases as y is decreased now this can be written in a little more compact fashion

so let us erase this but keep in mind that we have to calculate the second part which is a numerical problem where you need to find the height at which ah the atmosphere the pressure is half of that of the atmospheric pressure so this is equal to so this is \log of p minus $\log p_0$ which is equal to or let us write this as

so i am skipping one step and i you can write it as exponential minus $-\rho_0 g$ by p_0 and y

so this is how the pressure varies with the height y measured from the sea level

so the pressure as i told you that as i increase my height the pressure decreases and at y equal to 0 which is the c level

so if i put y equal to 0 here p will become equal to p_0 and the decrease of pressure here is exponential

so the pressure decreases exponentially at the height is increased starting from the sea level

so let us do the numerical part of the problem for which we need to calculate this constant ah as per the given problem all these quantities are constant and ah

so ρ_0 which is the density of water or density of air i am

so sorry density of air at the sea level is 1.29 ah kg per meter cube multiplied by 9.8 meter per second square divided by p_0 which is equal to 1.013 into 10 to the power 5 newton per meter square and this has a value one point two five into ten to the power minus four and this will have ah an unit of meter inverse or one over meter

so that this y being measured in meters will cancel this and your exponential will have to be the argument of the exponential will have to be dimensionless

so in order to calculate where my p becomes p_0 over 2 i need to find that y where my p becomes equal to p_0 by 2 .

so in order to find that i simply take this equation and put p_0 by 2 on the left hand side which becomes p_0 and exponential minus this quantity 1.25

into 10 to the power minus 4 meter inverse and y
 so this gives me i can take a log of both sides to calculate y y becomes log of
 two one point two five and ten to the power minus four meter inverse ah do
 you remember what is log two from your radioactivity classes
 so $\log_2 2$ is equal to 0.693
 so this is equal to 0.693 divided by 1.25 into ten to the power minus four
 meter ah
 so the meter will go up and this becomes equal to five five five zero meter
 so this is the height at which the pressure ah falls to half the atmospheric
 pressure and sometimes it becomes important to know what is the this height
 expressed in feet because sometimes especially in the mountains and tall
 hills are measured in feet so this is actually equal to eighteen thousand feet
 so at eighteen thousand feet the pressure falls to half the atmospheric
 pressure so this is the reason that the mountaineers or the mountain
 climbers they carry oxygen tanks along with them because it is quite
 difficult to breathe at an altitude of eighteen thousand feet
 so let us discuss now two things one is atmospheric pressure which we have
 been discussing and and gage pressure will tell you what gage pressure is
 so the atmospheric pressure ah at the sea level which we just called as p_0
 is equal to one point zero one three into ten to the power five newton per
 meter square in fact there is another unit other than the newton per meter
 square or the pascal that we have talked about
 so far there is another unit that is preferred more by the meteorological
 department which is called as bar and 1 bar
 so 1 bar equal to 1 into 10 to the power 5 newton per meter square
 so in fact the pressure atmospheric pressure at the sea level is slightly
 more than a bar the difference between one and one point zero one three
 so now you understand that this is quite a large pressure okay the large
 pressure means the if it corresponds to a force which we know the relation
 between force and pressure
 so f is equal to p into a
 so if the pressure is this much you know that the force is going to be also
 quite large
 so how does human body accepts or adjust to this kind of pressure and the
 answer is that all the living cells in our body gives an equal and opposite
 uh pressure rather a pressure which is uh appropriate to adjust the pressure
 that is enormous pressure that we have outside
 so there are
 so pressures in the cells because of various things that are inside the
 cells there is a cell pressure which adjusts with the pressure that is
 outside you have seen a balloon ah which is given a certain when you fill in
 air ah it retains at least for some time and this is the the
 so basically that filled in because of the shape of the balloon it retains the
 extra pressure or rather it withstands atmospheric pressure for some time
 and over a period of time it kind of gets deflated and same with the tires
 that you we have ah in the in the cars and in other automobiles that these
 cars are also given pressure the filled in air and because of this robust
 structure it retains the air for quite a number of days even when it's in
 running condition so how do we uh
 so this you have seen that when you go to actually fill in air in your cycle
 tire or your motorcycle tire or the car tires they measure it with a device
 which is called as a tire gauge and this tire gage measures the pressure that
 is there inside the tube and it is actually specified that suppose we talk
 about a vehicle a car which is smaller car requires probably lesser pressure

in its tires than a big truck needs much more pressure in his tire because it carries a lot of load

so there is a specific amount of air that needs to be filled in anything more is not of course good but anything less is also not good because of the normal functioning of the vehicle would be affected if the tire pressures are continuously less than what is prescribed for them

so the tire gauge is put in to measure the pressure of the tire remember the tire gauge actually measures the pressure over and above the atmospheric pressure

so what i mean to say is that

so a tire gauge measures a pressure p which is equal to the atmospheric pressure p_0 plus the gauge pressure

so if a tire gauge measures the pressure of 200 kilo pascals i keep shuttling between this newton per meter square and pascals because they are same then the actual pressure is 200 kilo pascal plus 100 kilo pascal which is this i am taking this and this to be nearly same the atmospheric pressure i am taking it as loosely 1×10^5 newton per meter square or 1 into 10^5 pascal

so this is actually 300 kilo pascal

so the the gauge the tire gauge the instrument that they put inside the nozzle of the tire to measure the tire pressure will measure this however the actual pressure is ah 300 kilo pascal including the atmospheric pressure

so far we have seen what is pressure or rather the pressure exerted by fluids both for a pressure of a liquid as well as pressure of air and which what we also have defined is pressure due to the atmosphere which is called as atmospheric pressure now the question is ah how is pressure measured there are many devices that are invented to measure pressure we will only discuss only two of them here one is a very simple device such as a youtube

so we are talking about measurement of pressure

so this is a u-tube and it has a liquid that is present inside this

so this is a liquid which is usually mercury and

so mercury is filled inside the youtube and this is where the pressure is measured and let this pressure be p

so we have p is equal to p_0 plus $\rho g h$

so the pressure that you measure here is related to the height difference of the fluid or of the liquid that is there inside the tube and

so we have discussed that there is a gage pressure

so this $\rho g h$ is called as a gage pressure and the total pressure is actually ah the atmospheric pressure plus the gage pressure

so this h is the height difference is the height difference between the two hands of the youtube and this is the pressure that is measured here p_0 is the atmospheric pressure ρ is the density of the liquid that is there inside as we told that most of the times one uses mercury as a liquid inside h is the height difference between the left and the right arm in case the left arm has a level which is lower than that of the right arm then the pressure that is measured here will be lower than the atmospheric pressure and just as the case here when you have this height to be positive that is the left arm has more height than the right arm then the pressure is said to be more than the atmospheric pressure and there is a positive sign that exists between them all right

so this is how one measures pressure this is one of the ways to measure pressure and there are other ways of course we are coming to that in a while but this gage pressure or this $\rho g h$ factor is the important thing and to

know that to know the exact pressure we just need to add the atmospheric pressure to the gauge pressure
 so at times in fact this product of ρg and h that is density multiplied by the acceleration due to gravity divided by the multiplied by the height difference between them between the two hands is simply represented in terms of the height
 so when you say that
 so many millimeter of mercury we really mean that you have to multiply to get the exact pressure difference you have to multiply the density of mercury by the way mercury is written with the symbol h_g
 so h is capital h small g that's the symbol for mercury in the periodic table
 so so
 so many millimeter of mercury means that the pressure difference will have to be represented if you want the exact pressure difference then you have to multiply it by the ρ and the g with that many millimeter
 so as to get the exact pressure either in newton per meter square or pascal or bar whichever unit you want to express it in similarly one can also use water and you can also use water in place of mercury the only simplicity that happens is that the density of water is known always and it's simple to remember as well and that's equal to 10^3 kg per meter cube as opposed to mercury which is more dense than that which is 13.6×10^3 kg per meter cube in any case so there is a unit it is called mmHg
 so 1 mmHg mm is for millimeter a g is mercury
 so 1 mmHg is equivalent to a pressure of 13.6×10^3 kg per meter cube g to be nine point eight meter per second square and one millimeter of mercury so will take one millimeter which is equal to 10^{-3} meter and this is equal to 133 newton per meter square and this has a special name called as torr equal to one tor
 so this is uh after the name of a scientist called evangelista torricelli who was there between 1608
 so e torricelli ah sixteen zero eight to sixteen forty seven so this is ah equal to one torr which means it is equal to 1 millimeter of mercury
 so let us see that we have introduced many units of pressure let us see what are the differences between them and also vis-a-vis the atmospheric pressure we discuss different units of pressure
 so we have one atmospheric pressure will simply write it as one atm means atmospheric pressure ah its equal to one point zero one three into ten to the power five newton per meter square which is equal to also equal to one point zero one three into ten to the power five pascals which is equal to hundred and one three kilo pascals ah now we have also introduced earlier another unit of pressure which is used by the meteorological department to talk about the development of pressure or low pressure in areas adjoining the sea while talking about the climates
 so there are this is one bar which is equal to one into ten to the power five newton per meter square so if you see that ah the atmospheric pressure is slightly more than a bar which is what we have mentioned earlier
 so this is equal to 1.013 bar which is same as will see that in just while that it's equal to 76 centimeter of the mercury ah just as we told that one millimeter mercury
 so this is the one atmosphere is equal to 76 centimeter of mercury
 so the atmospheric pressure is same as the pressure that is exerted by um a 76 centimeter height column of mercury which is of course equal to 760

millimeter of mercury and that's equal to by just the definition that we have talked about this is equal to 760 torr which is equal to 1.03×10^4 to the power 4 millimeter of water at four degree centigrade so its one atmospheric pressure is not only ah can be represented in a column of mercury but it can also be represented as a column of water the water that the pressure that is exerted by water of this much of height which is 1.03×10^4 millimeter

so these are the inter conversion of different units of pressure and sometimes they are quite important for example will give you the example of blood pressure

so if you go to a doctor and the doctor measures your blood pressure good but blood pressure which means ah healthy blood pressure is 120 by 80 which is what they will tell you and they simply write as 120 by 18 the medical records that are that are specific to you and they do not mention most of the time they do not mention what it is but it's actually 120

so this is 120 and 80 are the ranges of blood pressure um and this is actually in millimeter of mercury

so it's 120 millimeter of mercury for the higher one and eighty millimeter of mercury for the lower one

so ah however the atmospheric pressure is much more than the pressure that the blood exerts on the walls of the artery as the blood flows through the body however we have seen that because the living cells of the body exerts pressure in order to combat the pressure from outside that is from the atmosphere we maintain the shape that we are in and do not buckle to the pressure lets now talk about the second instrument by which pressure is measured which is called as a barometer and ah we are going to specifically talk about mercury barometer

so you take a tube like this full of mercury here we have told that mercury is represented by hg and the density of mercury is equal to 13.6×10^3 kg per meter cube

so its actually quite a dense liquid now if you invert this on a vessel containing mercury then this is what is going to happen

so i have taken a vessel which is completely full of mercury and invert it on this

so which means that it will look like this okay and what's going to happen is that they'll be

so given that this tube is long enough say something like meter then it is seen that the mercury is fills up to a certain level and there is a vacant portion on top of that where there is really a vacuum

so $p = 0$ is a vacuum and the height of the liquid column stands at 76 centimeter okay

so 76 centimeter of mercury as we have said is the atmospheric pressure that is in other words a 76 centimeter column of mercury 76 centimeter column of mercury exerts the same pressure as the atmospheric pressure

so that the pressure here is the same as the atmospheric pressure ah when you have inverted this tube that the whole thing is ah

so there is the mercury is static it's come to an equilibrium and there is a void that is created where there is a vacuum where the pressure is equal to zero the height of the mercury inside the tube is at 76 centimeter

so i repeat once more a 76 centimeter column of mercury exerts the same pressure as the atmospheric pressure or one atmospheric pressure

so 76 ah centimeter of mercury is said to be as we said that we will only coat the height

so 76 centimeter of mercury equal to one atmospheric pressure now suppose you

want to fill it with water not with mercury and if its with water which is h₂o which has a density of only 1 into 10³ kg per meter cube and in that case the height of the water column that you need is equal to so height is equal to 10 to the power 10.3 meter so instead of 76 centimeter if you use water you need a height the column of water should have a height 10.3 meter which means it is a very long it has to be a very long tube and this much of that is 10.3 meter of water column exerts the same pressure as one atmospheric pressure this has some implications in designing vacuum pumps no matter what however good a vacuum pump is it cannot lift water to a height more than 10 meters because of this reason and so sucking out water or draining out water from a deep tube well which is more than 10 meter is a problem using vacuum pumps you