Effective Engineering "Teaching" in Practice
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Lecture - 06
Active Learning

Welcome to the next lecture in the course Effective Engineering Teaching in Practice. This lecture will be on something called active learning. We will have to see what that is all about. So, what is active learning? The understanding is rather broad, right. So, there are very many different ways of addressing this. The understanding is something like this; let me give you two statements for understanding active learning.

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Anything that involves students in doing things and thinking about the things they are doing is called active learning. Anything that involves students and doing things and thinking about the things that they are doing was the definition given by or the understanding given by Bonwell and Eison in their paper in 1991; published in 1991. That is one way to understand it.

Let me give you another statement that will be helpful in understanding. Anything course-related that all students in a class session are called upon to do other than simply watching, listening, and taking notes is called active learning. This understanding was given in the paper by Felder and Brent in 2009. So, that is what it is, as we go along it will become clear what active learning is all about. So, although I do not state the learning outcomes explicitly, it is all there and if you look at the various chapters or various topics, it would be there in the background, and you could you may want to pick it up. The teacher must be aware of the learning outcomes.

And it is good that the students are also made aware of the learning outcomes in a certain case, different people have different styles of doing things. Let us move forward.

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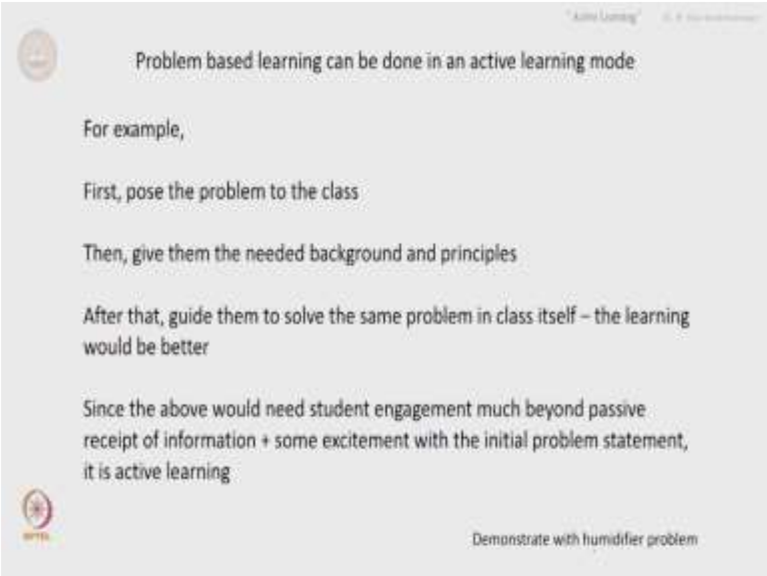

Problem based learning; that we introduced in one of the earlier chapters earlier topics, as a means of an extension of the tradition lecture can also be done in an active learning mode. Remember, I mentioned that problem based learning can be done in various different modes and I am going to present only one of the modes of relevance to extending the effectiveness of a lecture.

So, in this chapter we are going to look at problem based learning that can promote an active learning mode or that is implemented in an active learning mode. For example, first pose the problem to the class; this is what we did earlier also. Then give them the needed time or give them the needed background and principles. First pose the problem, then give the principles, the same thing that we mentioned earlier as an extension to the traditional lecture. After that guide them to solve the same problem in class itself; and the learning would be that much better. Earlier the teacher worked out the problem, the teacher gave the problem as a context to introducing the principles, then probably the teacher worked out the problem himself or herself to give, to present the principles in that context. Instead of that, if the teacher can guide the students to work it out themselves, the learning would be that much better. And we are all after learning by the students.

Since the above would need student engagement much beyond passive receipt of information, and some excitement which is generated with the initial problem statement; that extension itself would have generated some excitement, o how do I solve this particular aspect, it seems interesting and so on so forth in the students. And then, they are participating in the solution itself and this is active learning. I am going to demonstrate this with a problem that I mentioned earlier. It will all be done at various levels if you look at it that way. That way the appreciation is much better.

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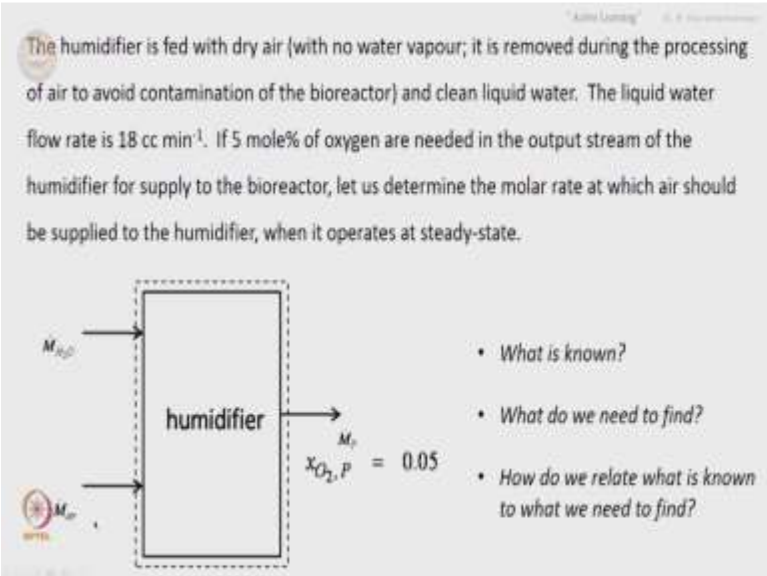

So, the same problem that was mentioned earlier; very briefly, I said you could pose this problem and then work it out or give the principles and then work it out. Here we slightly change things, we are going to pose the problem and then what comes next after posing is going to be slightly different.

Let me read this problem out in the context of this particular topic. The humidifier is fed with dry air, no water vapor, it is removed during the processing of air to avoid contamination of the bioreactor and clean liquid water. In other words, dry air and clean liquid water are fed to the humidifier. The liquid water flow rate is 18 centimeter cubed per minute, 5 mole percent of oxygen are needed in the in output stream of the humidifier for supply to the bioreactor.

Let us determine the molar rate at which or determine the molar rate at which air should be supplied to the humidifier when it operates at steady state. A diagram is given here, the humidifier here, this is the air flow, this is the water flow, the molar flow rate of water, the molar flow rate of air. This is the product flow; the molar flow rate of product and the mole fraction of oxygen in the product has to be 0.05. This is the condition of the problem, this is a humidifier.

So, if we apply our problem solving strategy here what is known. Many different things, that there is a water stream here and air stream here the water stream flow rate is known 18 cc per minute and the product stream is here, the product stream of composition, the oxygen composition has to be 5 mole percent or mole fraction needs to be 0.05. All this is known and there are many other things that are known which we would use, which will become clear as we go through. What do we need to find? The molar flow rate at which air should be supplied to the humidifier. This particular value, $\dot{M}_{air}$ and the stream has to be formed this is the molar flow rate of $\dot{M}_{air}$. How do we relate; what is known to what we need to find. This becomes a solution to the problem.

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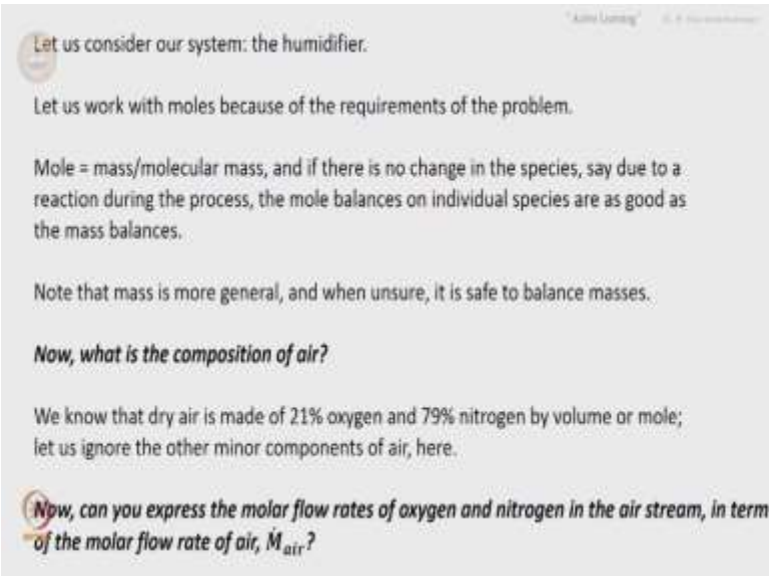

We will have to first consider the system which is the humidifier. This comes from material balance; applying material balance principles. So, let us consider the system as a humidifier here indicated by the dotted line. Let us work with moles because the requirements of the problem. Mole as we know is mass divided by the molecular mass and if there is no change in the species, say due to a reaction, during the process, the mole balances on individual species are as good as the mass balances. However, when there is a reaction, be a little careful. When in doubt always do mass balances. In this case, we know that there is no chemical reaction. Therefore, mole balances are as good as mass balances. Remember this mass by molecular mass, the mass would be the same and so on.

What is the composition of air? You ask this question to the class, give them time and then they would come up with hopefully it is made up of 21 percent oxygen and 79 percent of nitrogen by volume or mole, if we ignore the minor components such as carbon dioxide and other things in the air. For the purposes of this problem, let us consider air to consist of 21 percent oxygen and 79 percent nitrogen by mole or volume, they are the same.

Now, this is the question to pose to class. Now can you express the molar flow rates of oxygen and nitrogen in the air stream? In terms of the molar flow rate of air right. Remember, we had earlier shown or the problem statement had the molar flow rate of air, that is what we need to find. So, we need to work around that. And therefore, the need here is to express the molar flow rates of oxygen and nitrogen in the air stream in terms of the molar flow rate of air. Give them time, couple of minutes and probably walk around the class to figure out what is happening. You will have very good idea as to who is struggling, who is very enthusiastic, who is very comfortable with this and so on so forth; just by this exercise.

So, during this active learning process, there is so much information about the students learning, their abilities and so on so forth that can be gleaned by just observing.

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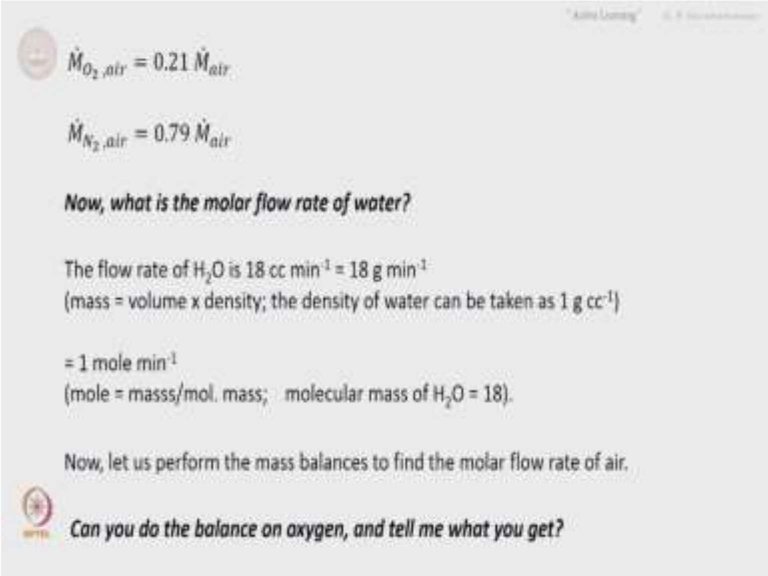

So, molar flow rate of oxygen and air is 0.21, the molar flow rate of air 21 percent by mole is oxygen and by extension the molar flow rate of nitrogen in air must be 0.791 minus 0.21; 0.79 molar flow rate of air this would come from the students mostly. Wait till the average student gets it, there will be 1 or 2 who would be very bright and come up with the answer immediately, acknowledge them definitely, do not put them down, but give time for the average student to get to it. And then when you are walking around, you could ask the students to think in various different terms to get to this answer, provide them with clues and so on so forth.

Now, ask this question. Now, what is the molar flow rate of water. It is already given in the problem, but in a form that needs to be converted. The form given in the problem is 18 cc per minute is the molar flow rate of water, the density of or it is 18 gram per minute, you can write this down and ask the students why? Some would give the answer and then you need to you might need to explain it to some. Mass is volume times density and therefore, the density of water is 1 gram per cc; 18 cc per minute would be 18 grams per minute, 18 grams per minute. Mass by molecular mass is moles, the molecular mass of water is 18, therefore, mass one gram divided by moles 18, you would get one mole per minute. That is what is given there. Mole is mass by molecular mass, molecular mass of water is 18.

Now, let us perform; the mass balance is to find out the molar flow rate of air, present this and then say, can you do the balance on oxygen and tell me what you get? See you are directing them to do a balance on oxygen, doing a balance on oxygen is straightforward thing that you are asking them to do. In the problem, they will have to figure it out themselves. Here you are directing them. So, give them some hints and they could do. This is the first time they are being exposed to the problem.

So, tell me what you get or expose to the aspect of applying material balances to a closed ended problem. So, can you do the balance on oxygen, tell me what you get. Then they would do the balance, they would focus on the system, they would write the material balance equation and figure out how the mass balance on oxygen works out. The details could be something like this; steady state process, therefore for all species the time derivative can be taken to be 0. That is,

input rate + generation rate - the output rate - the consumption rate = accumulation rate; the useful form of the material balance equation for processes.

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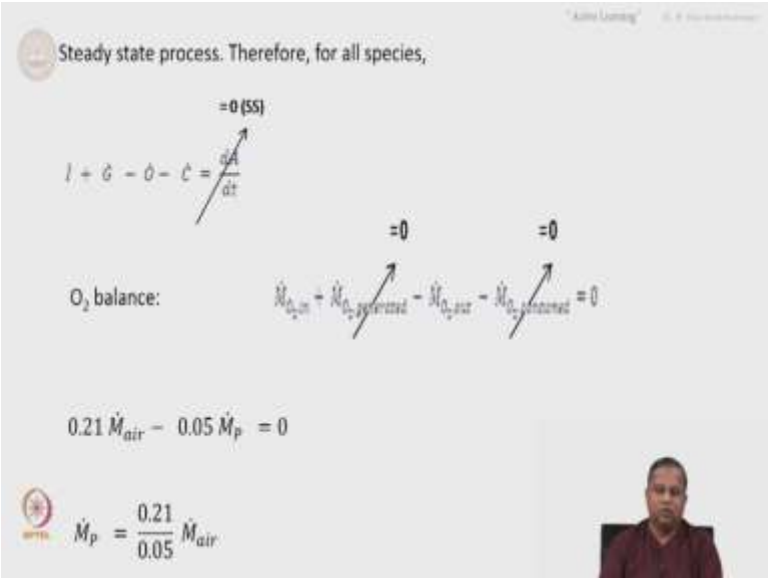

Since this is a steady state process the accumulation term goes to 0 and therefore, the oxygen balance would be the molar flow rate of oxygen in the

input + generated out - output – consumption = 0

There is no generation of oxygen in the system, therefore, that term goes to 0. There is no consumption of oxygen in the system; therefore that term goes to 0. And therefore, what remains is:

(molar flow rate of oxygen in the input stream) – (the molar flow rate of oxygen in the output stream) = 0

So that is your material balance.

So,

$$0.21\,\dot{M}_{air} - 0.05\,\dot{M}_P = 0$$

0.21 molar flow rate of oxygen, molar flow rate of air is the molar flow rate of oxygen in the input stream. 0.05 $\dot{M}_P$ is the molar flow rate of oxygen in the output stream in terms of the variables that we have defined for ourselves. Therefore, input minus output equals 0, rates that is. And therefore, we have $\dot{M}_P$ in terms of the molar flow rate of air and then it is straightforward. Tell them see here, there are 2 variables molar flow rate of the product which is unknown and the molar flow rate of air that is unknown we need the molar flow rate of air. Therefore, we need to have another equation in terms of these variables or related variables and we need to solve this.

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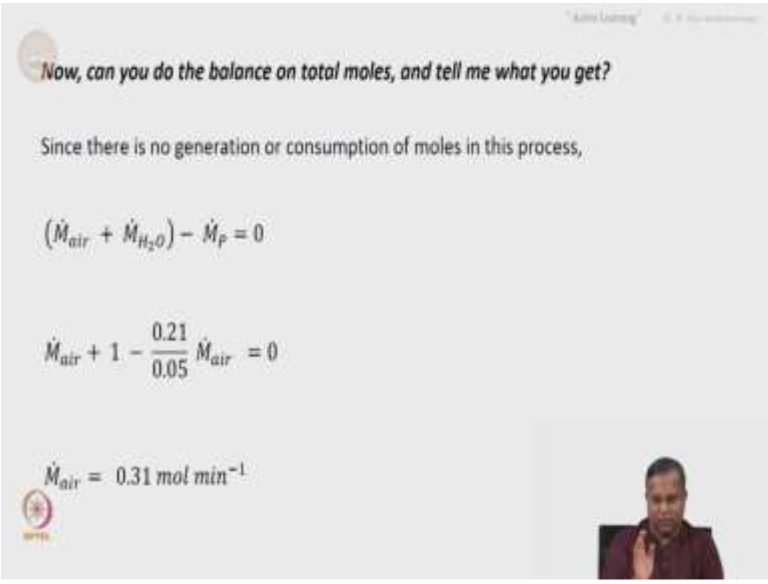

So, to provide that equation tell them can you now do a balance on the total moles and tell me what you get, total moles is very straightforward. Then they will start doing it, you go around, first time you might need to give them more time. Give them hints as you go along since there is no generation or consumption of moles in this process. This is the solution to it. The molar flow rate of air plus the molar flow rate of water. This is the input minus the molar flow rate of the product, that is the output with the system in focus is 0.

Therefore, you substitute the terms in terms of whatever we have found out in the previous parts of the problem, you will get:

$$\dot{M}_{air} + 1 - \frac{0.21}{0.05}\dot{M}_{air} = 0$$

Molar flow rate of air is $\dot{M}_{air}$, molar, flow rate of water is one and

$\dot{M}_P$ is $\frac{0.21}{0.05}\dot{M}_{air}$.

And if you solve this it is all in terms of molar flow rate of air, we get 0.31 mole per minute and this is our answer. So, this is active learning. We pose the problem, then we give them the principles and then we guide them through solving the problem. The learning is far far better for an average student compared to we just telling them what it is; they have processed this and therefore, the learning is that much better.

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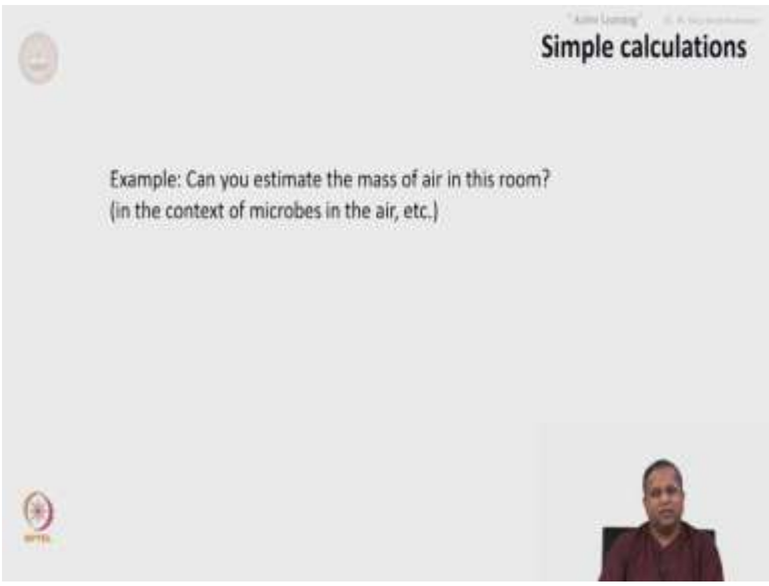

The second way by which, I am going to give you a few examples by which active learning can be done, this is by no means exhaustive. There are so many other different methods by which one can implement active learning. I am just giving you some examples so that you would know. The second example, you could ask them, ask the class to do simple calculations and give them time and wait. Waiting is something that is very difficult for inexperienced people in this particular strategy, but wait, go around the class help the class and then it will be far far better learning.

Simple calculations such as these can be given for example, can you estimate the mass of air in this room? This I normally dowhen I teach principles of biology to engineers and they need numbers and so on to work with. Therefore, I give them this problem, but with an idea of getting them to appreciate that microbes are present in the air all the time at reasonable concentrations. So, I ask them, can you estimate the mass of air in this room and then wait for the answers, walk around. So, how do you find the, the mass of air is what is needed? What is known? You can figure out the dimensions of the room and you know the density of air is 1.29 kilogram per meter cubed. And therefore, volume times density is going to be mass, as simple as that.

So, if you look at this particular room, the quick thing to fix is the height which would be typically about 10 feet here, about 10 feet here and then the width this is pretty much a square room. The width if I go by the benches, the benches would at least be 5 feet, 3 of them with about 3 feet in between. So, 15 plus 6 that is 21 feet. So, about 7 meters. So, 7 meters by 7 meters; 49; 49 times 3 or let us say 50 times 3; 150 meter cubed is the volume of this room.

So, the volume is known the density is 1.29. So, 150 times 1.29 is the mass of air that is present in this room in kilograms. So, that is a little startling to people at times to figure out there are hundreds of kilograms of air in a typical room. So, this causes the students to participate in the process of learning and give them simple calculations in the context of whatever you are doing to come up with better learning. You could even ask them to do derivations in part. And then they are involved in the process of the derivation itself, the basal principle and how to use that principle to get maybe a useful form of an equation. They can be a part of, let me illustrate it by this example. This in the context of transport. I am going to derive one of the fundamental useful equations in transport. Let us consider a fixed volume in space. The volume $\Delta V = \Delta x \, \Delta y \, \Delta z$

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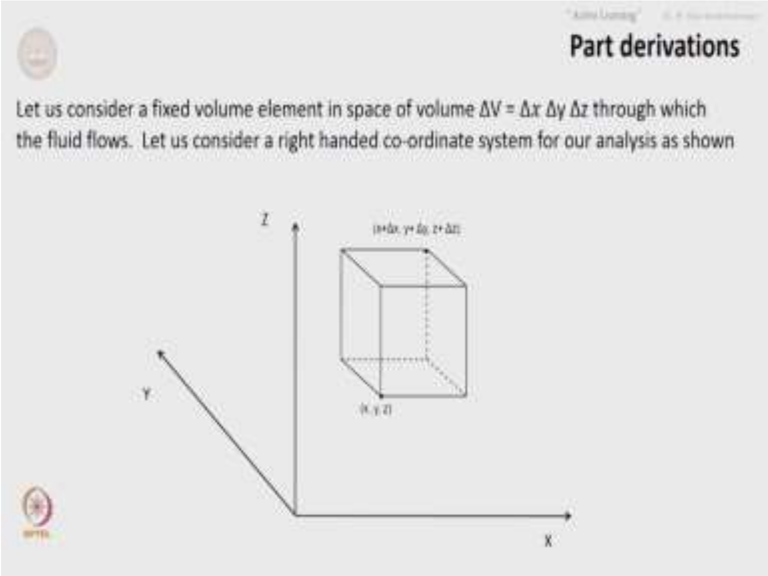

This is a cuboid through which the fluid flows. Let us consider the right handed coordinate system for our analysis. If x is this and y is this, when you go from x to y, the direction of the right handed screw should be z. You go from x, you turn x to y, z is like this. So, if you write x like this and y like this, x to y is like this, your z will be like this.

So, let us choose a right handed system in this case. I have given our x is like this our y is into the board or into the space here. And therefore, x cross y your right handed screw comes up like this. Therefore, your z axis should be like this. Here we have drawn a cuboid, the length here is Δ x, the length here is Δ y, the length here is Δ, z the coordinates of this point, therefore, the coordinates of this point are $(x+\Delta x, y+ \Delta y, z+ \Delta z)$. So, this is a very general kind of a thing which we use to derive some very fundamental equations, which can be applied to anything. Here I am going to do something about material balance for in a flow situation.

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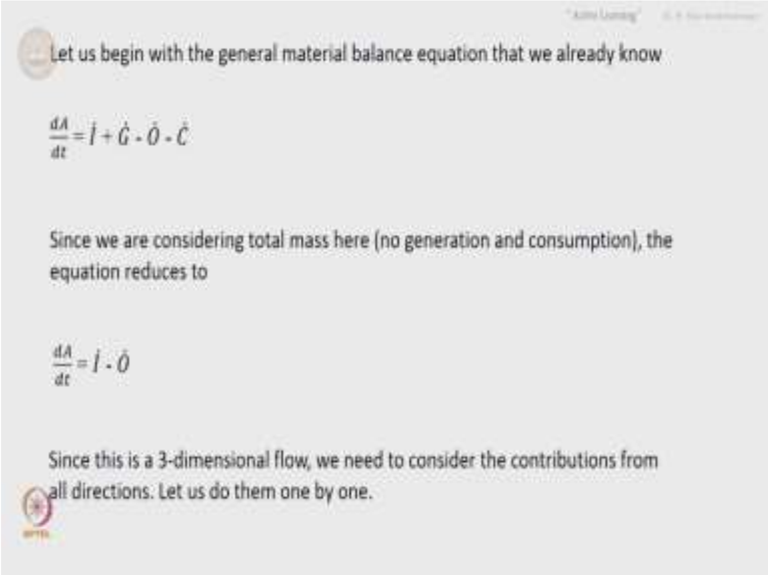
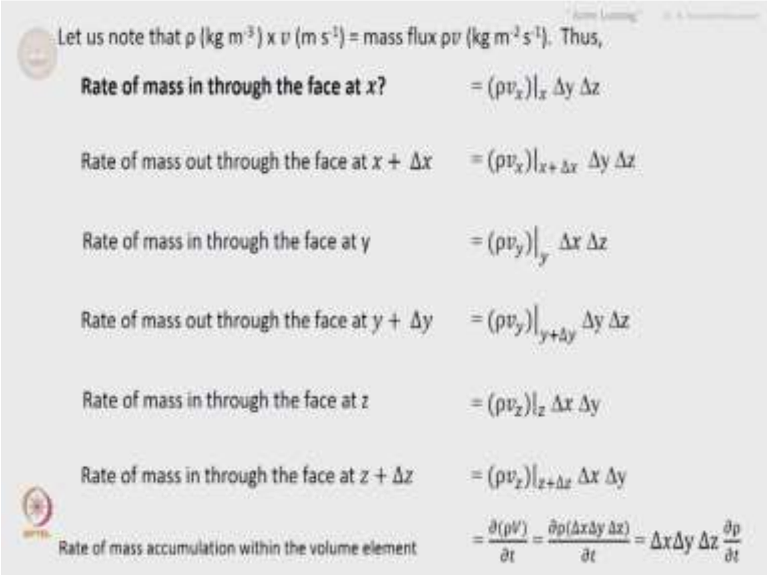


So, let us begin the general material balance equation that we already know. The accumulation rate is input rate plus generation rate minus output rate minus consumption rate. This has to be valid over any system. In this case, we are going to concentrate on the cuboid that we have defined. And let us apply this equation there. We are considering total mass. Here we are going to do a total mass balance. Therefore, there is no question of any generation or consumption. And therefore, the equation will reduce to the accumulation rate is input rate minus output rate. And since this is a 3 dimensional flow we need to consider the contributions from all the directions x, y and z.

And, let us consider them one by one, all this you can state right in the beginning, because this is too early to bring them in. You need to bring them in a guided fashion.

Especially, this is something that they have not seen at all.



Before we go forward, let us note that density times velocity would be the mass flux. You know ρv_x, ρ is kilogram per meter cubed, velocity is meter per second, even in terms of units kilogram per meter square per second which is nothing but amount of mass transferred per unit area perpendicular to the direction of motion per unit time or the rate of mass transferred per unit area perpendicular to the direction of transfer. Therefore, which is nothing but flux of mass, flux of that quantity, flux of mass and therefore:

ρ (kg m^{-3}) x v (m s^{-1}) = mass flux ρv (kg m^{-2} s^{-1})

So, what is going to be the rate of mass through the face at x in other words this particular thing? So, this is the x axis, this is the face at x. So, what is going to be the flux of mass or the rate of mass, in order to do balance, we need rates. The rate of mass through the face at x, this is the question that I am posing to class, might be difficult for anybody in class to answer in the beginning. And therefore, let us give the answer after waiting maybe for a short while, that would be ρv_x, this is the flux at x, at that x times the area of that face which would be $\Delta y \, \Delta z$; you point out the area at that face as, but this is the area that we are interested in, what is that area this is the area of the rectangle here this is $\Delta y \, \Delta z$.

So, the flux times the area is going to give us mass. And therefore,

Rate of mass in through the face at x = $(\rho v_x)|_x \, \Delta y \, \Delta z$

This is flux ρv_x at x, times relevant area perpendicular to the direction of transfer Δy Δz. Now what is the rate of mass with the face at $x + \Delta x$ in this particular thing, it is going to be $(\rho v_x)|_{x+\Delta x}$ Δy Δz.

So, once we have given them this, then students are able to relate to what we need for this particular derivation. Then pose the question. Now can you tell me what the rate of mass through the face at y is this direction. Therefore, what is the rate of mass through n and then they would work it out. Many would get it with this, some might need help and then after waiting for some time write this out on the board. ρv_y at y and the relevant face area is Δx Δz and we can play this game till we finish up all these terms.

So, rate of mass in and rate of mass out through the various relevant faces are given. The only term that remains in the material balance is the rate of mass accumulation within the volume element and that can be represented, as this again might the students might need help based on experience. $\frac{\partial(\rho V)}{\partial t}$ is mass.

v can be written as Δx Δy Δz, that is a small volume that we are considering there, the volume of the system of the control volume

Therefore, it can be written as

$$\frac{\partial(\rho V)}{\partial t} = \frac{\partial \rho(\Delta x \Delta y\, \Delta z)}{\partial t} = \Delta x \Delta y\, \Delta z\, \frac{\partial \rho}{\partial t}$$

(Since $\Delta x \Delta y\, \Delta z$ are not functions of t we can take them out)

Now, that we set up all these terms.

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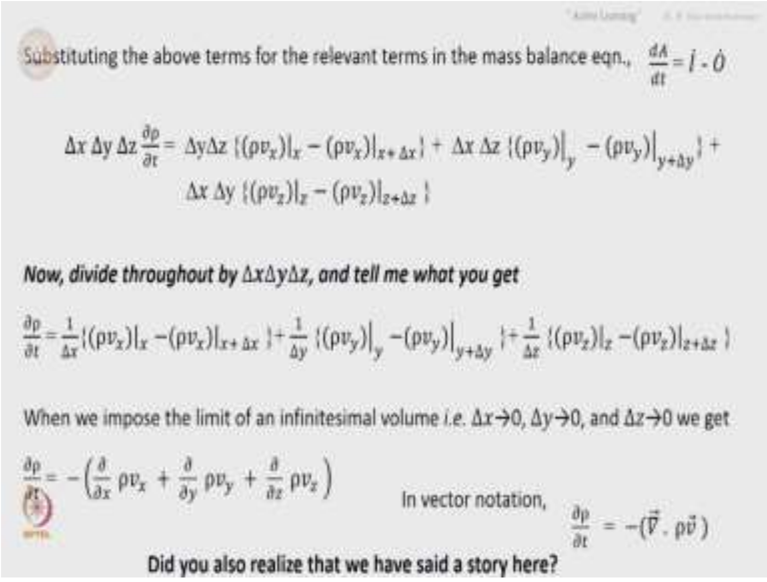

Now, can you substitute the above terms in the relevant terms in the mass balance equation tell me what you get it, is a question that can be posed. So, they will work it out, give them time, they will work it out. So, you are essentially bringing them into the derivation process itself, they put this all together, wait for some time and then you could write this down on the board. And then you tell them, now divide throughout by $\Delta x \Delta y\, \Delta z$ and tell me what you get or you could, or if you feel that it is a little too much for first timers, then you write down the earlier expression and then say- now divide by $\Delta x \Delta y\, \Delta z$ and tell me what you get. That is straight forward.

So,

$$\frac{\partial \rho}{\partial t} = \frac{1}{\Delta x}\{(\rho v_x)|_x - (\rho v_x)|_{x+\Delta x}\} + \frac{1}{\Delta y}\{(\rho v_y)\big|_y - (\rho v_y)\big|_{y+\Delta y}\} + \frac{1}{\Delta z}\{(\rho v_z)|_z - (\rho v_z)|_{z+\Delta z}\}$$

and so on. And then you ask them can you see something familiar there some definition of something math relevant when, especially when we impose a limit of $\Delta x \to 0$, $\Delta y \to 0$, and $\Delta z \to 0$, many would be able to see that they are all definitions of the derivative some might need help, but this is only you know directing them. Therefore, you do not have to worry about the entire class in this particular case, entire class getting it in this particular case, ultimately they will get it.

And therefore, when you apply the limits you get the differential equation

$$\frac{\partial \rho}{\partial t} = -\left(\frac{\partial}{\partial x}\rho v_x + \frac{\partial}{\partial y}\rho v_y + \frac{\partial}{\partial z}\rho v_z\right)$$

Which can be written as

$$\frac{\partial \rho}{\partial t} = -(\vec{\nabla} . \rho\vec{v})$$

You could explain the vector notation little more; I am not going to do it here.

And this process, we have brought the students into the actual derivation. They are participating in the derivation and thereby their involvement with the learning process is from ground zero and that is something very powerful. Also did you realize that we have told a story here. Remember, earlier I had mentioned that you know even math related things can be presented in a story form and this is a story here, a logical development of the process a derivation in this case with the backgrounds given, with the details given and so on so forth to help students, is what would engage the students much better and it is a story right. That is what I meant.

Another, I think this is the last example that I am going to give here. There are very many examples. You could read books on these, papers on these and employ your own means. This is a popular thing - think pair share that was put forward by Lyman and it is one of the popular things. Therefore, I thought I will include this as one of the examples of active learning.

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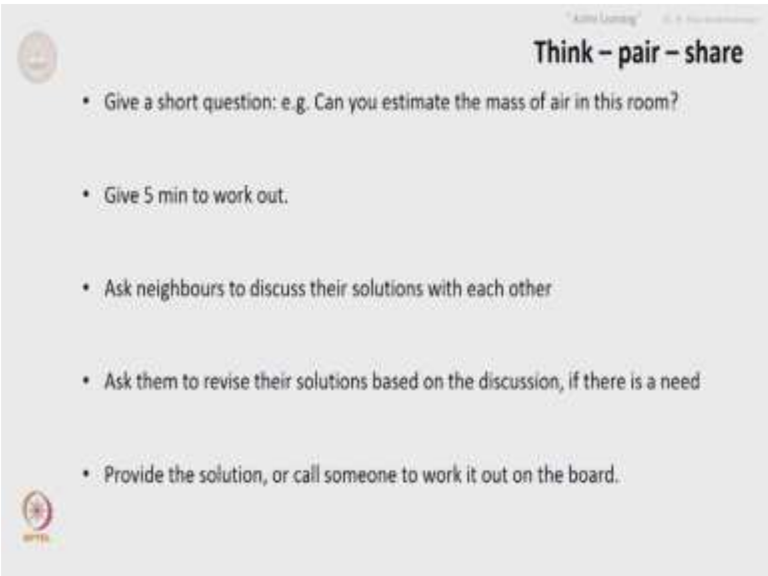

Think pair share works something like this, give a short question, it could be can you estimate the mass of air in this room right. Give 5 minutes for students to work it out individually; individual students to work it out, the regular classroom. Then after 5 minutes ask neighbors to discuss the solutions with each other right, if you have clicker possibilities and so on; you could monitor the progress as things go along, but this itself is good enough. Ask neighbors to discuss their solutions with each other and then ask them to revise solutions based on the discussion.

That itself is good enough. The neighbors can since they are in the process this very relevant, the conversations begin quite quickly they are already tuned to the conversation they begin quite quickly. They know where they are confused, so they could ask their neighbors and that discussion can go on. Ask them to revise the solution based on the discussions if there is a need. And finally, you could either provide the solution or call someone to work it out on the board or discuss the solution to the class, with the entire class and so on. There are variants of this that people have done which are more effective than just this, you can look it up later. So, this is the other example.

So, the above techniques are some means by which active learning can be implemented. There are many many more. I think that is all I have in terms of active learning for you. Active learning is essentially getting their students engaged in the learning process and making them do activities to improve their own learning. And this is a significant improvement from the traditional lecture. Initially problem based learning and then now active learning along with learning outcomes and so on so forth. We are slowly going to more and more effective means of learning, different strategies to improve that.

Let us stop here, and let us meet again later.