Material and Energy Balance Computations

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Lecture –02
Introduction to Engineering Calculations (Contd.,)

Hello everyone, welcome back to the second lecture on the Material and Energy Balance Computations. Under the module one, we are looking into the introduction to engineering calculations processes and process variables.

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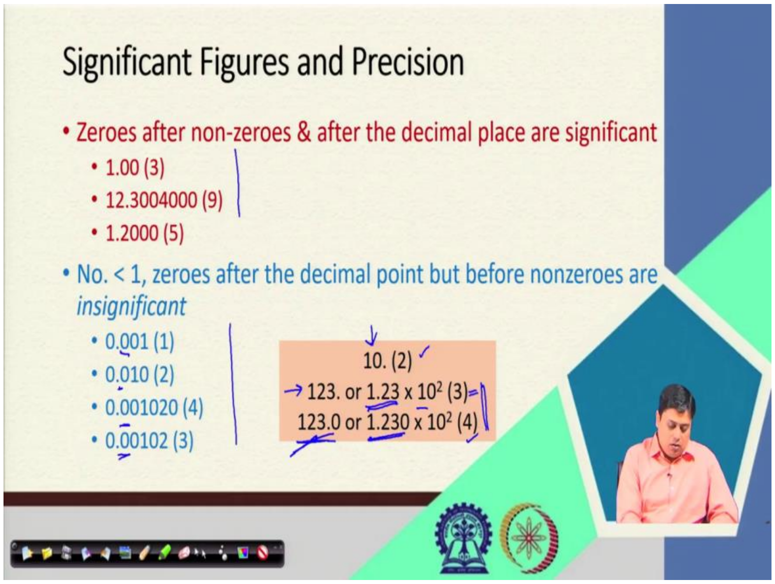

So, in the last class, we were understanding the significant figures. The necessity of understanding significant figures, the precision and we will also see how the scientific notation works. Now before I resume this part, let me tell you that why do we need these scientific figures what this kind of precision that I started in the last class. So, these are essential, particularly when we have something calculated or derived values.

Say, you did an experiment, you came up with a value, and then this value is utilized for subsequent calculations. Now say at a certain stage you reached a point where you have this kind of a number, say 3.32589 this kind of a number you reached. Now you can take this whole number with all the digits into the subsequent stage and go for the final calculation. But does it have any meaning to consider all the points from the perspective of your application.

Where say you have a calculation that involves large numbers, say in the order of thousand, say when we talk about the commercial output system we have tons per hour (t/h) or per day kind of a throughput of the product material. Now there, say such kind of number if say this comes as kg/h, how much this is significant corresponding to our desired application and whether all these numbers after the decimal place makes any sense or not.

That is why we need to understand that what are the significant figures or the significant digits in a number that is a convention. Now also say you have reported a value say the reported value is you are mentioning as say 8.7 with some necessary unit. Now that means one can argue that that means this value is essentially between 8.65 and 8.75; say, if we have 8.7, this number actually falls in between this range.

Now, whether for your calculation this is sensitive or not, if it is sensitive, then you might go for a better accuracy of reporting this value. So, then what you can do, you can possibly tell that my value is 8.70 and what does this mean, this means that, now the value is in between in this range. 8.70 is basically in between 8.695 and 8.705. So, you have narrow down the uncertainty of your reported value, or you have increased the accuracy of reporting your value if you think it in other way.

So, that is why understanding these significant figures and the precision are important. So, we have seen that zeros after non-zeros and after decimal places are significant. We have seen that when the number is less than one, then the zeros after decimal point, but before non-zeros are not significant, that means these zeros are not significant figures. In this case, when you place the decimal in order to fix the number of significant figures, say for first example, 10. is not a conventional fashion to report this number.

But still, if somebody writes in this way, that means the significant figure in this calculation should be at least 2. The easy way in order to understand the number of significant figures is to convert these numbers into scientific notation. The scientific notation means, where you write the decimal points including the 10 to the power some values. So, for example, this one 123. or the decimal place means that 1.23×10^2.

So, clearly, now we understand that here we have 3 significant figures that this number contains 3 significant figures if you place a zero after the decimal point, which now becomes a significant figure. So, that means 123.0 here, you now have 4 significant figures, and then that can easily be understood if you convert this to scientific notation, which is 1.230×10^2. So, here you now clearly see that we have 4 significant figures.

So, this is the conventional scientific notation which easily reveals the significant figures or the significant digits. So, say we have understood this thing now. Now, what is the utility that when we do the calculation, what do we do in those cases when we manipulate those?

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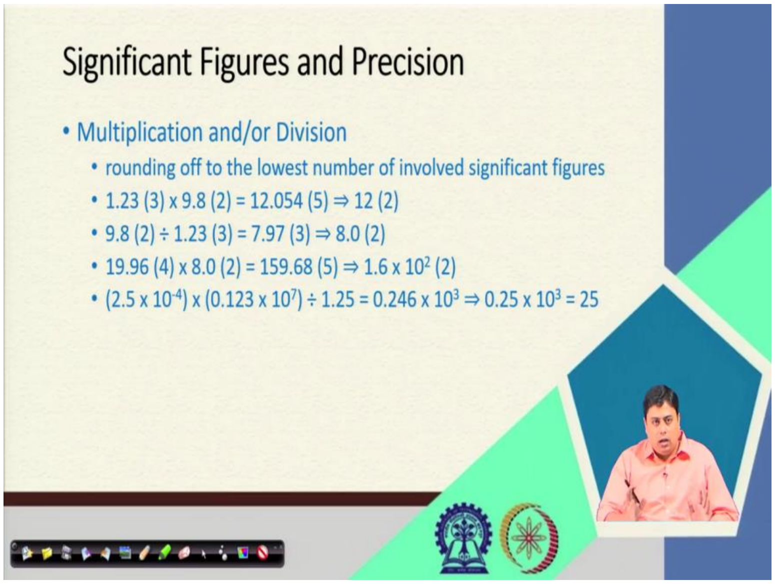

So, to start with some multiplication and division, we typically do it in a normal way like we do for any algebraic calculation; and then, the thumb rule or the convention is that we round off to the lowest number of involved significant figures. That means the lowest number in the multiplicand or division wherever you have the minimum number of significant figures, you use that to report for the final result.

So, for example, in the first case, we are having 1.23×9.8. If you do it in the calculator, the result would be 12.054 now, whether you report that or go with the convention like we are having here that for division or multiplication, we find out after the usual calculation, that in which of these values we have the minimum number of significant figures. So, 1.23 contains 3 significant digits, 9.8 contains two significant digits.

So, our final result should ideally contain two significant digits. So, in process calculations, the process engineers typically follow such convention, and if you do this, it would not be a wrong value, because in your calculation, the least significant number involved is 2. So, you can safely report your final value with the two significant figures in the final result. Similarly, the next example, where we have the division, we do the normal division as usual, and we see that by calculator or any other means if you find out the answer.

Say, we have this kind of a value 7.97 which is of 3 significant figures, but it involved a minimum or the lowest number of the significant figures here was 2. So, the final result we would report as 8.0 we will have the 2 significant figures. Now, remember here one point that all the things that we are mentioning here are for the derived or the estimated or say the measured values.

When you are given with the integer, integers typically have an infinite number of significant values, which means all the digits would be significant that are involved there is no rounding off. So, 8.0 we have here say 2 significant digits. So, now similarly, when we have consecutive calculations, say in the last example or even in the third case where we have the multiplication and we found that we have a number that is coming out containing 5 significant figures.

In this case, 8.0 was of 2 significant numbers. So, we have to report this value in terms of 2 significant numbers. Now it is easier now to convert this to the scientific notation and report it as 1.6×10^2. When we have stages of operations or calculations. So, what we have here, in this case, we have the value significant value 2, in this case we have 4, here we have 3.

So, our final result that we will report if it contains 2 significant digits that would be sufficient or as per our desired precision. So I hope the operations or the manipulations of these significant figures when it comes to multiplication or division is clear to you.

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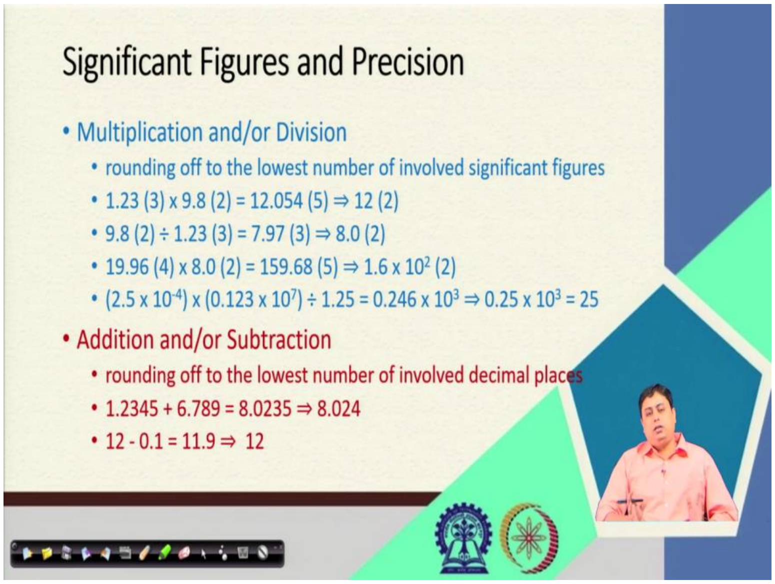

Now, when it comes to the addition or subtraction, we do the normal addition of the subtraction process, but then we find out in order to round off the final result what is the lowest number of involved decimal place, here we look into the lowest number of involved decimal place. So, for example, in the first case that we have here, we see that this addition. So, here we have 5 significant figures here we have 4.

The reasons I have not mentioned here are the significant figures in bracket is to avoid any confusion, because here we will find out that where in or which number we have the lowest number of decimal place. So, when you find out this answer. Now here, after the decimal place we see here, we have 3 decimal places. So, we round off the value to the 3 decimal places. The last example here we have 12 – 0.1 which will be 11.9 but here there was no decimal place or the point here this number is kind of insignificant to the final or the final result is kind of insensitive towards whatever you are subtracting from that number.

So, these are the things that we typically follow in the process calculation in the material and energy balance computations.

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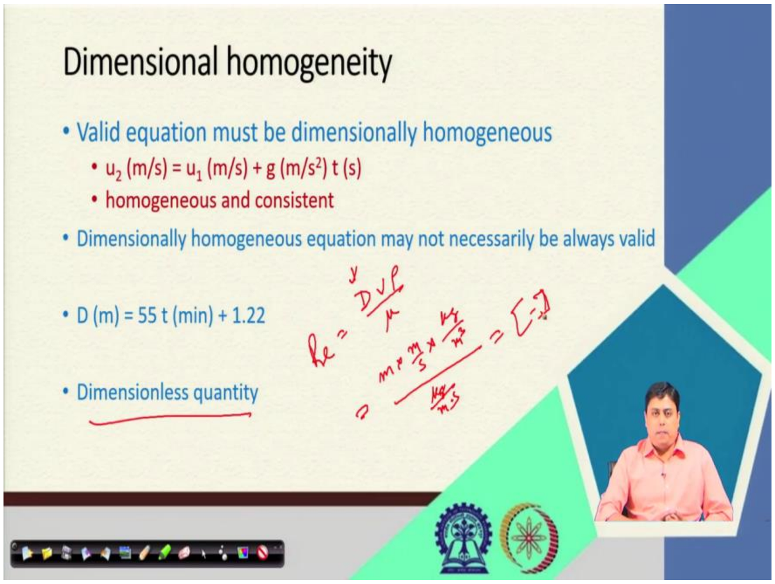

Now, I mentioned earlier that in order to have a division or multiplication, we need not look into the unit consistency, but when it comes to the addition or subtraction, the units have to be similar. The dimensions have to be of same category and the units have to be consistent, say in other word we call the dimensional homogeneity when it comes to a equation. So, any valid governing equation or any valid equation must be dimensionally homogeneous.

So, for example, say you are calculating the value of velocity with a previous or known velocity at a different time, or it has this kind of expression where u_2 is equal to u_1 + gt. Now here, this equation is valid because it is dimensionally homogeneous. What we have here is the velocity unit m/s. Similarly, here on the right-hand side, when it comes to the calculation of gt, we have this as $m/s^2 \times s$, which is m/s. So, that we can safely add u + gt in order to have a new u value.

So, a valid equation must be dimensionally homogeneous as well as consistent in units. Otherwise, if it is inconsistent, there is a requirement of unit conversion, say from meter, centimeter or kilometer to meter like this. So, centimeter, meter, kilometer all basically are the units of length. But any equation can contain any of these units. But if that happens, then it becomes inconsistent, unit wise inconsistent.

So, you have to convert it to a consistent unit and then do the addition subtraction, etc. But the other point is that, even if a equation is dimensionally homogenous, that does not mean it is a valid one. So, the dimensionally homogeneous equations are not necessarily always valid. So, for example, say, you mention that the mass m = 4(m) + 5, this kind of an equation, this means nothing.

A dimension of mass ≠ 4(m) + 5 or some numbers, except it cannot be for in any situation, without 5 we can have it only for one case which is for the zeroth case. But this is kind of an invalid expression. So, now say if we try to look at this example that we are having here say d = 55t + 1.22. So, now in this equation if I ask you that what is the unit of 55 and 1.22?

Because we have seen that all these should have some unit. So, in this case, what would be the units of 55 or say should start with the dimension and then consequently what would be the units. So, what is the dimension of 55 and 1.22 its quite simple because if it is a valid equation then the dimensions have to be homogeneous on both the sides that is the left-hand side and the right-hand side. So, on the left-hand side, we see it is of length, the dimension is of length.

So, 55 and we have t that is of minute, which is the unit of time. So, 55, that means it must be length per time, because t already have the dimension of time. In order to be consistent with the left-hand side that is of length the 55 should be of dimension length per time and 1.22 quite easily be understandable that it should have the dimension of length, then only this equation would be valid.

And now if we ask that what is the unit of 55 and 1.22, the answer would be pretty simple that in this case, we have m for the length and min for the time. So, 55 will have a unit of m/min, and 1.22 will have the unit as m. If now we have to convert this equation in order to have an equation in the form of say we need in feet and here we have say t in terms of seconds.

So, what would be these coefficients? Because this would eventually then change. So, if we try to convert this expression or this equation from meter to feet and say from minute to second, what should we do? The situation is again pretty simple in this case because what we do in this case then we try to write on the left-hand side that we convert this into feet and then this, from feet what we write is that multiplied by the conversion factor from feet to meter and we know that one meter is approximately 3.28 feet.

So, one meter we have approximately 3.28 feet. We use this conversion value to replace here on the left-hand side and the minute to seconds. We all know 1 min = 60 s, we replace this as well, and we then convert both the sides to feet and seconds, and then we find out what are these coefficients that now it would change from 55 to some different value because of these conversion factors and it would change from 1.22 some other value because of this same reason.

So, then what we have is an expression called dimensionless quantity. In several places, we will see that using the combination of base units and the base dimensions, we derive a value or a quantity which are dimensionless. One of the very popular examples that you have read already possibly is the say Reynolds number. $\frac{D\, v\, \rho}{\mu}$, where D is the dimension of length, v is the velocity, ρ is the density, μ is the viscosity.

So, each and every parameter if I write here so, D we have in terms of length with unit m, say I write in SI unit, v is m/s, ρ we have kg/m^3, μ we have kg/m-s after eliminating the variables you would see that it is basically a dimensionless quantity. So, this dimensionless quantity, we will encounter in a couple of cases and that are also useful because that eliminates this conversion of different units and it also scales our different processes.

So, that means in this class what we have understood is the importance of significant figures or significant digits, its manipulation either it is multiplication or division or say if we do addition or subtraction, how do we report those values, what is the scientific notation and the necessity of dimensional homogeneity. For the calculations, these are the vital step to check. If we do not have dimensional homogeneity, that equation is not valid.

In order to have an equation valid, it should be dimensionally homogeneous and preferably consistent in the unit; if not, we do the conversion like we have seen an example. So, with this, I thank you for this class, and in the next class, we take up a different subsection that will be dealt in say data interpretation, that when we have several data points how do we interpret that, how do we have a relation in between different data points, till then thank you for your attention.