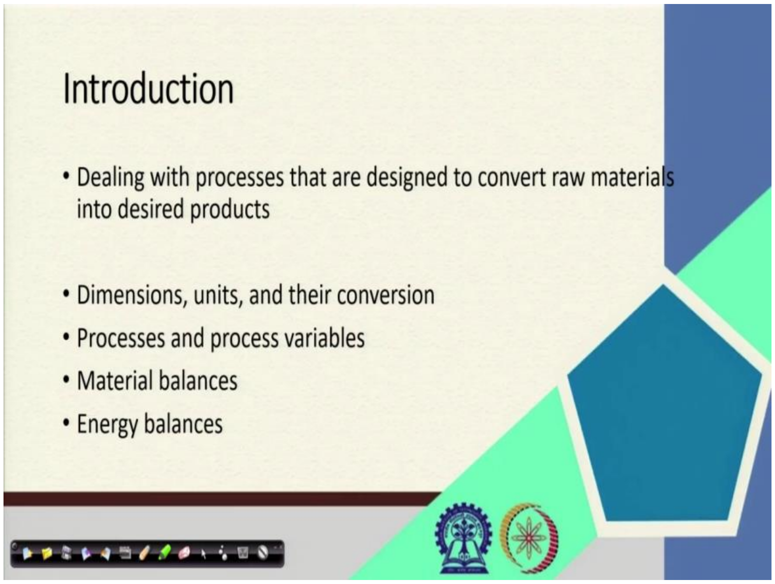
Material and Energy Balance Computations
Prof. ARNAB ATTA
Department of Chemical Engineering
Indian Institute of Technology, Kharagpur

Lecture –01
Introduction to Engineering Calculations

Hello everyone, welcome to the NPTEL online certification course on Material and Energy Balance Computations. I am Arnab Atta from the Department of Chemical Engineering, IIT Kharagpur. So, in this 12-week course, you have already seen the modules that are already given along with the course content. So, in the first module, we will have basically introductory engineering calculations.

We will understand what is meant by processes and process variables. In this first lecture, it is a pure introduction to engineering calculations. So, in this first lecture, it would serve basically a kind of refresher lecture that several things you are aware but for the sake of continuity, we will refresh those memories in the context of this material and energy balance computations.

(Refer Slide Time: 01:41)



So, to start with that, for any computation, we need to understand that for what or which process we are doing these calculations. So, there is a common thread across several engineering disciplines; it is not specifically this subject is relevant for the chemical engineers but also several other engineering disciplines because in those disciplines, some way or the other, we try to convert raw material into desired product.

And while doing so, we go through several stages of operations or several processes. Now for that, this course is relevant for a wide spectrum of disciplines. Now, as I mentioned, if we try to understand or if you try to have the first step of calculation, we have to understand the concept of dimensions, its unit and their mutual conversions when we have different units. So, in this introductory lecture, we will focus mainly on this aspect, and then we gradually move to different processes or what are the process variables that we have to understand.

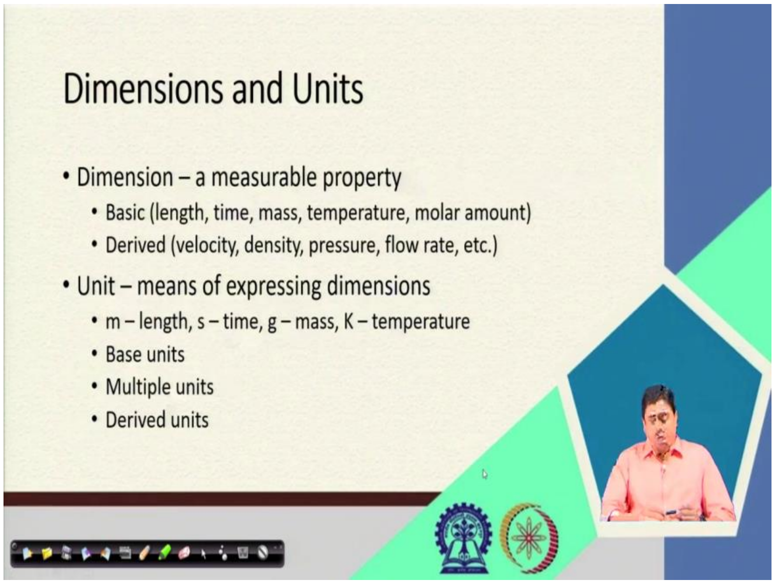
And then we go to the main crux of this course those are having two components one is the material balance other is the energy balance. So, the thing is that when we try to convert a raw material to a desired product, the mass conservation should happen. So, this is the main focus that would be given for the material balance, that for a process when we have certain raw material we are processing, and it gives some desired product, it also generates some undesired products.

Now the point is that this desired and the undesired product combinations in terms of the mass or say the in terms of different material when it is combined into the desired product these materials have to be or the mass of this have to be balanced. If we go into the very details that the atoms, molecules those are conserved and then in the energy balance what we will learn we will see that the estimation of energy in order to convert or to process these operations.

So, say, for example, a couple of questions may arise that what would be say necessary amount of steam that you need to generate in order to operate a turbine. So, how much of water we need to heat to a certain operation for a certain operations in order to generate steam. So, in those cases, the amount of energy that is being put into the system, whether that is efficiently converted or not, that we can estimate by the energy balance.

So, in today's lecture, we focus on the dimensions, units and their conversion, so, if we look into the dimension and unit this concept.

(Refer Slide Time: 05:45)



So, dimension is basically a measurable property. So, for example, there are certain basic things that we describe because without having understanding of those parameters, it is difficult to define any process or process variables. So, for example, the basic things that we need to understand or need to mention during description of a process are that the length parameter either be its diameter of the reactor or the height of the reactor that comes under the purview of the dimension.

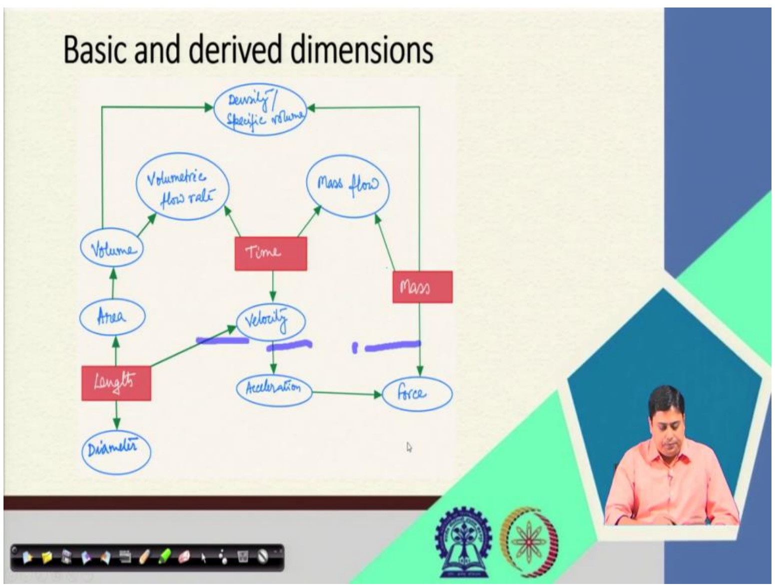
How much time it requires to convert the process or for this process to happen that is the time. The amount that you are trying to convert is the mass. What is the desired level of temperature, or what is the desired level of a process where it can efficiently work if we have a certain temperature and other conditions and also, the other basic property is the molar amount that dictates its concentration.

So, based on these basic dimensions, we have several derived or calculated dimensions as well. So, for example, the velocity and the density. So, the velocity we know it has a unit of say length per unit time. So, here the combination is the length and the time. So, that means we have the combined length per second that is the unit of velocity and these we are aware of pretty much. So, the velocity consists of the SI unit is m/s.

So, it is the length per second. So, in this case, similarly, we have several other derived quantities, which are the derived dimensions, which are the density, pressure, flow rate, etc. Now the unit is the means of expressing these dimensions. So, for example, as I mentioned, we have meter for length, we say that we have second for time, grams for mass, Kelvin for temperature these are the example.

Like we have some basic dimension and derived dimensions here; also we have some base units we have multiple units and the derived units from the base units either combining couple of base units.

(Refer Slide Time: 09:28)



So, in this case, if we look at this diagram, this schematic would basically show you that what I am trying to convey by saying that there are base and the derived quantities. So, these red blocks that are mentioned here are basically the base dimension that is the mass length and the time. Now combining any of these or all of these, we can have different major dimensions, and so, as to express those dimensions, we have derived units.

So, for example, in this schematic, if you look at it carefully, say we have mass here. Mass and time these two combinations gives us a measurable dimension is the mass flow rate. From time we basically get the velocity with the combination of length. So, if you follow these arrows, you would see that time and length these two arrows converges on velocity because velocity is the meter per second that involves the length and the time.

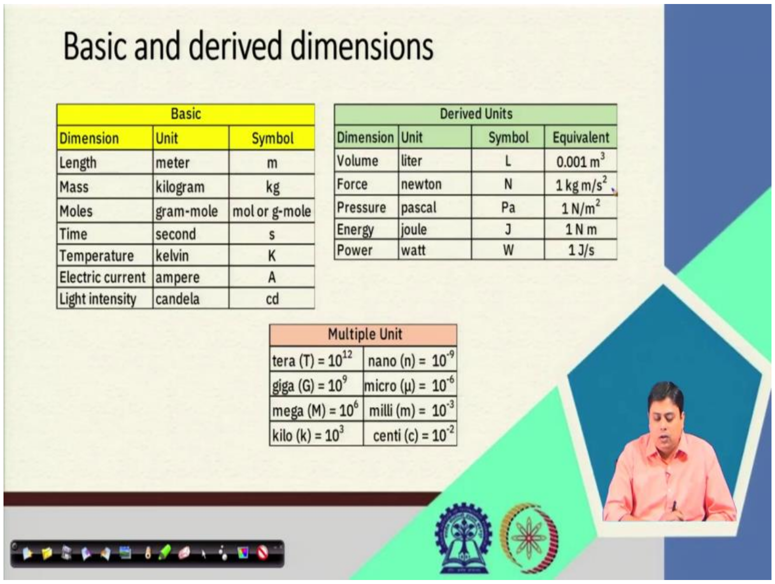
Similarly, from velocity, the other derived unit is the acceleration; from there, we have the dimension force. But for that, mass and acceleration are combined to give or to have the calculation of force. Similarly, the example of length is, say the diameter from length, the length is the dimension we have or say that the unit we have meter, area is L^2 further we can have the volume from the dimension of length which is the L^3.

Now this volume and the time; so, here it is not only the combination of two base dimensions or multiple base dimensions, but also the derived dimension and the base dimension that gives us another measurable or calculated or derived dimension which is the volumetric flow rate, it requires the dimension of volume and time. For example, the volumetric flow rate is m^3/s. Similarly, the volume and mass these two combinations gives us the information of density, or in other words, we say that also specific volume.

So, this network shows that if we have the understanding of several base dimensions from there, how the flow of measured or derived dimensions can happen. So, similar to this dimension understanding now, if we understand that based on these base dimensions, we have derived dimensions. So, now since unit is merely a representation of the dimension, we can have in some similar to the base unit like for mass we have the base unit is the kg or gram we have several derived units.

So, in this case if we look at this diagram this schematic would basically show you that what I am trying to convey by saying that there are base and the derived quantities. So, this red blocks that are mentioned here is basically the base dimension that is the mass length and the time. Now combining any of these or all of these we can have different major dimensions and so, as to express those dimensions we have derived units.

(Refer Slide Time: 14:25)



So, here is the example. So, these are the basic dimension of their unit and the way to express those units called the symbol. Now, this symbol has also importance in the calculation because we cannot arbitrarily write any symbol in order to represent kg or gram, and there are several conventional errors also that happen while representing those units.

For example, we have seen in several cases people represent gram by writing gm while in the calculation, which is not right. The convention is that we write only g. So, we have the importance of symbol as well, and that is why it is clearly shown here, or I have mentioned it here that for length is the dimension its unit is meter and the symbol is small m not even capital M, this is the point we must note that we cannot arbitrarily write or designate the unit meter as capital M that is unconventional.

So, the basic dimension or the base dimensions are length, mass, mole, time, temperature, electric current, light intensity, and the respective basic units are meter, kilogram, gram mole or mole, for time we have second and for temperature it is Kelvin. Again remember the difference is that it is capital K not small k. In kg, the k is never capital Kg it is small kg, ampere it is capital A candela which is the unit of light intensity is cd.

Now, so, these are the basic dimensions of their respective unit and the symbol. So, we have now the derived units that are derived based on the combination of basic units and the basic plus some of the derived units. So, here these are the variations of unit of these derived dimensions, and we have their respective unit their symbol and the equivalent that if we try to find the relation that from where it came from.

So, for volume, if we can see that it is basically the m^3. Now clearly, this part shows that these are derived units from the base units, and we also have to understand what are the conventional symbols of these dimensions. So force that comes from mass, length and time. So, I hope Now you have understood the difference between the base and the derived units of the basic and the derived units.

So, similarly, we have also multiple units. So, the multiple units example say when we say millisecond, microsecond, millimeter, nanometer, micrometer these are the examples of multiple units say it is the unit of length, the length is the dimension, unit is the meter and then there is variation of this unit that is your millimeter, centimeter, kilometer. So, these are basically the adjectives that or the prefix that is added to the units, and it becomes a multiple unit.

So, it is the tera means 10^{12}, giga is 10^9, mega is 10^6, kilo is 10^3. Now we can understand if we say kilometer that means 10^3 meter, nanometer is 10^{-9}, micrometer is 10^{-6}, millimeter is 10^{-3} and centimeter or centi is basically 10^{-2} and if we add meter after that it becomes the centimeter. So, we have basic units, derived units and multiple units.

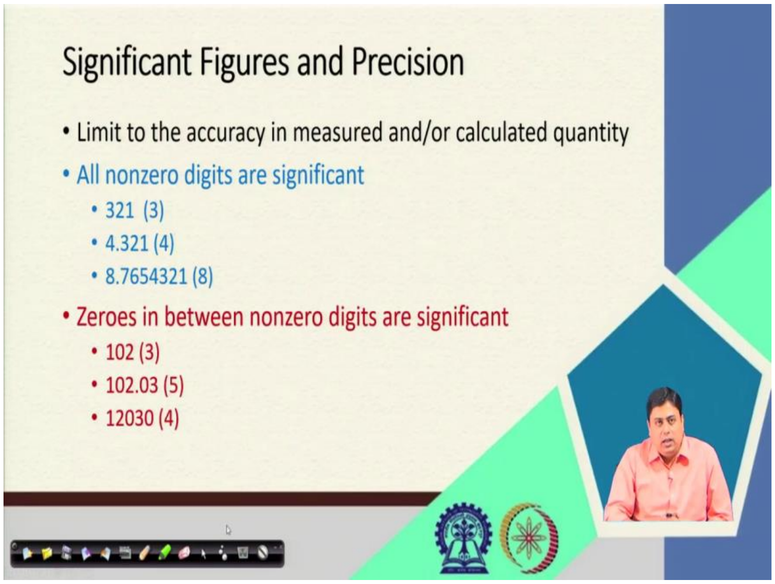
Now the point is that these units can be treated as, say as some algebraic parameter that we treat. The addition and subtraction of this unit can happen if those are of the same category that means the dimensions have to be identical or similar in order to add or subtract two values. For example, say when we talk about 2 cm – 1 cm, we write that as 1 cm. But 2 cm – 1 s does not mean anything, or even if you in case of this negative or the subtraction if you add it, it is 3cm.

But this addition of centimeter with time does not mean anything. So, the dimensions have to be consistent and say even what I am not mentioning particularly the unit is because say you can subtract 2 m – 0.5 cm this subtraction can happen and for that, you have to either convert this centimeter to meter or this meter to centimeter to make it uniform or consistent in unit and then do the subtraction or the addition whatever requires.

So, we have to be careful while manipulating these units and the dimensions because addition and subtraction requires the consistency, but multiplication or the division can easily be done even those are not consistent, and by that, only we achieved, say the dimension of velocity m/s. So, that means 1 m can be multiplied or divided by 1 s in order to get 1 m/s.

So, multiplication and division can be done even without checking the consistency of the units. But while doing the addition and subtraction, we have to be careful that we need to convert. Now those units into the consistent form and the dimensions must be homogeneous; otherwise, the addition or subtraction cannot be done. Now coming to the point that we will do several calculations.

(Refer Slide Time: 25:13)



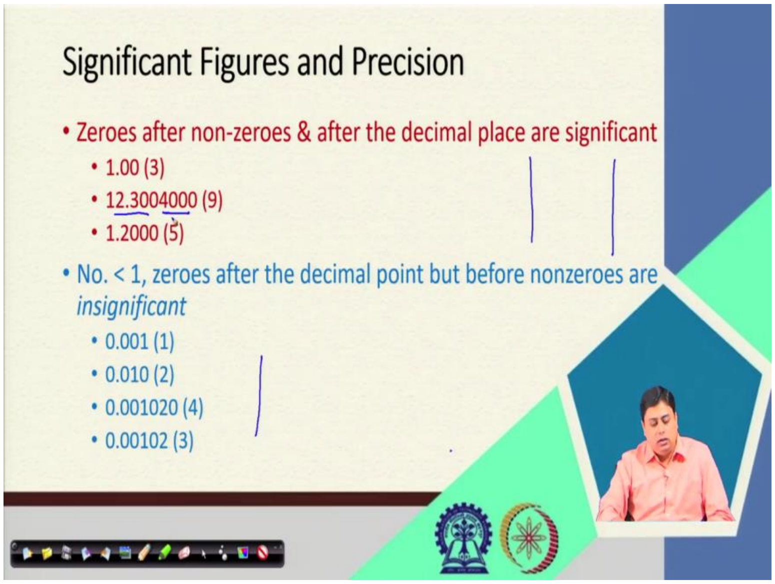
But then what is our number that we will round off that we typically do, so that comes under the consideration of significant figures and precision. By defining that, we basically understand that how much or what should be the limit till which we address the final calculation with the desired level of accuracy. So, significant figures and the precision is basically the limit to express the measured or the calculated quantity to a certain level of accuracy.

So, for that means we have to understand what are the significant figures? The significant figures say in this I have written here three numbers. So, here all the non-zero digits are significant, that means here in this 321 in this number, we have 3 significant figures or digits. In 4.321 we have 4 significant digits. Similarly, in the last number, we have 8 significant figures or the digits. Now, if the zeros come in between non-zero digits, then those are significant, and others are not.

So, here again, so let us look at the example 102, the zero comes in between 1 and 2. So, that makes that we have significant digits or the significant figures as 3 like we have seen in the last case. In this case the second one here also we see that the value is 102.03 although here we have zeros. But all are within the non-zero digits it comes in between the non-zero digits, so that means we have here 5 significant digits or figures.

In the last case here, the value is 12030. Now apparently, those who are not aware would say that we have here 5 numbers. So, it must be 5 significant digits or 5 significant figures. But by this understanding that we are mentioning here, here the zeros that comes after the non-zero digits it is not in between the last zero is not in between two non-zero digits. So, that means here this is we have 4 significant figures.

(Refer Slide Time: 29:14)



So, like this, the other cases that we have when zeros comes after the non-zeros and after the decimal place that are significant. So, for example, 1.00, we have 3 significant figures the second number that is shown here we have 9 significant figures. So, here we have 4, and here we have 5. So, total nine significant figures, although the zeros comes at the end of the non-zero digit, but it comes after the decimal places. So, that is why we have here 9 significant figures. Similarly in this case we have 5 significant figures.

Now when this number is less than 1 then the zeros that comes after the decimal point but before non-zeros are not significant. So, here the examples that I have mentioned all the numbers are < 1 in this case, although the zeros are coming after the decimal places here in the first example, the number of significant figures is 1. So, in this case here we have the number of significant figure as 2.

So, whatever comes immediately after the decimal points in case of a number < 1, if those are zeros, those are not significant numbers or figures in this case. So, by the same logic, the last example that we have is 0.00102. Here we have 3 significant figures. So, we will continue this discussion in the next lecture. So, what in this lecture we have covered or we have understood is the concept of dimension, unit.

The basic dimension, the basic unit, the derived dimension and derived units and the introduction to the significant figures because we need those to have a certain level of accuracy and the final result. So, we will continue this discussion in the next lecture, till then, thank you for your attention.

Keywords: Basic dimension, Basic unit, Derived dimension, Derived unit, Symbol, Significant Figures.