Mass, Momentum and Energy Balances in Engineering Analysis
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Lecture - 01
Introduction

Welcome. Today, in the first lecture for this course on Mass, Momentum and Energy Balances in Engineering Analysis; we shall be getting to introduced to some very basic concepts about why we need to do this kind of balances and how these are going to be useful for us.

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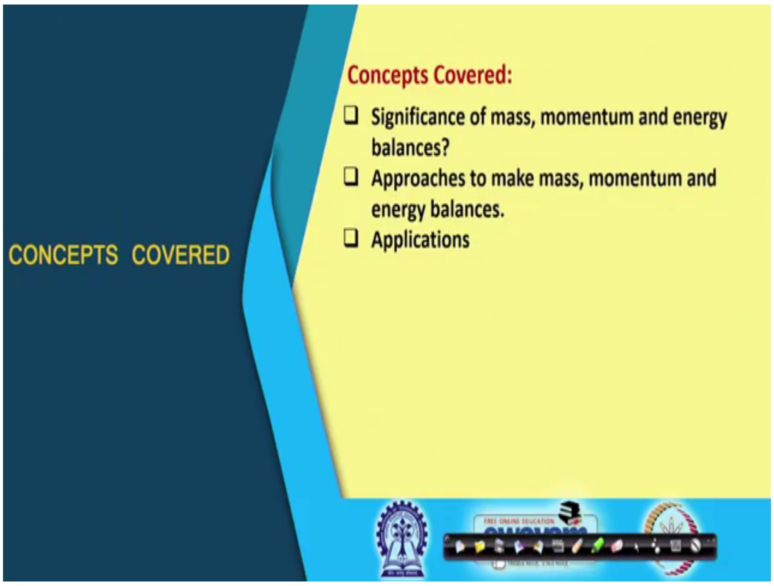

So, this particular lecture, will be giving us the significance of this Mass, Momentum and Energy Balances and the various approaches which we adopt to make these kind of balances and some applications of this mass, momentum and energy balances.

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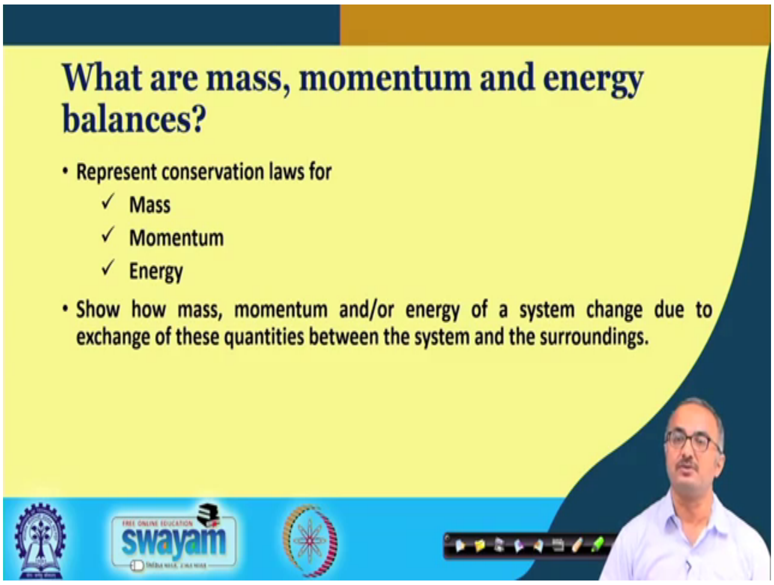

So, first let us see that what we mean by mass, momentum and energy balance? Now, all these balances they primarily represent some kind of conservation laws and as we know the conservation laws pertain to mass, momentum and energy. So, all these three things are conserved and whenever we are making any balances on any kind of system, we are basically writing these balances and when we write the balance equation, what it shows?

It shows that how these three quantities like mass, energy or momentum, they are getting exchanged between the system and our surroundings and due to this exchange of this mass, momentum and energy how the system itself is changing ok.

Now, please understand this that it is not necessary that in any particular system, all these three must exist. It may so happen that we may sometimes for ease of our calculation. We may sometime neglect one or the other conservation law assuming that particular quantity not to be changing with time or in the particular system. But in general we write the conservation laws for any kind of processes.

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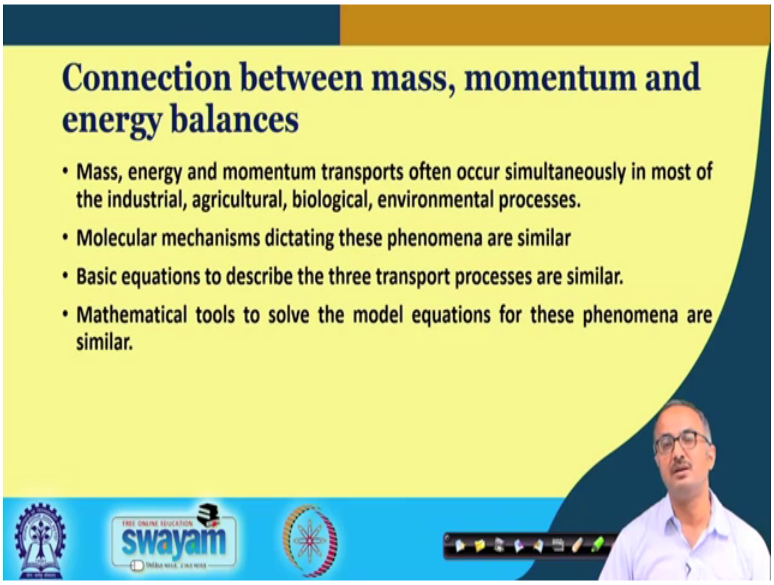

Now, let us see that how these three things are connected; this mass, energy and momentum balances. Now, we see at many a times as I was telling you that for many applications, all these three occurred together. For example, in the industrial processes, in agricultural processes, in biological and environmental processes.

So, whenever you see that in this kind of systems you find that all the three conservation laws can be applied together and for this kind of systems, we will write this conservation laws in the form of the balanced equations.

And sometimes these molecular dynamics of the system dictates these all these phenomena. Molecular dynamics means that how the constituent molecules of a particular system are interacting among themselves and these interactions are reflected in the macroscopic or the overall behavior of the system.

And we shall also find that even though this mass, momentum, energy apparently look dissimilar or different. But when you write the equations, conservation laws for these three you find that there will be some kind of similarity in their expressions and because of this similarity, what we find that the method of solution to obtain the various quantities like species concentration, the temperature, velocity, flow rate etcetera are also similar.

So, in that way we find that if we know how to solve a particular set of equations, we can also extrapolate or adopt a similar methodology to solve another type of equation. So, all these mathematical tools to solve these model equations become similar because the original balance equations are similar mathematically.

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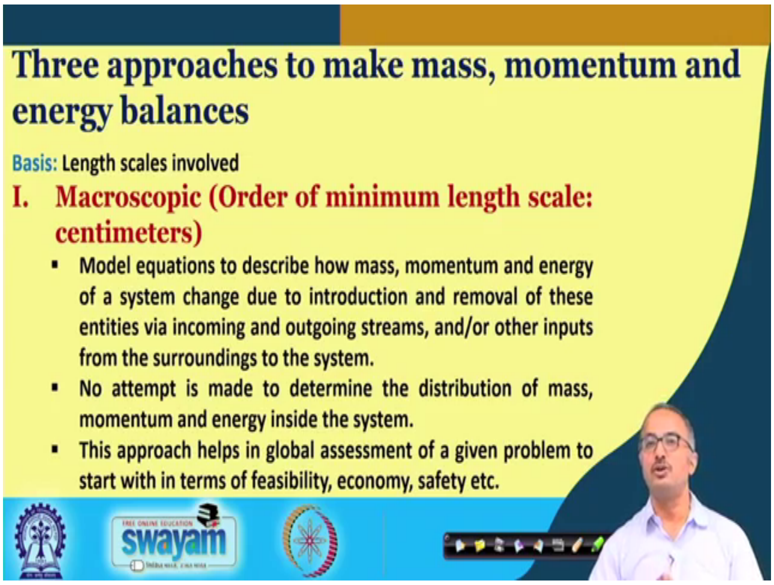

Now, before we go on to make these balance equations, we find that there are broadly three approaches for this mass, momentum and energy balances and these approaches are based on the length scale involved.

So, first let us go to the very popular one or which is the more easiest you can say that is the macroscopic and in this case the minimum order of the length is in centimeters; that means, centimeter or kilometer or meter, this kind of order is of the system dimension ok. For you when you have this kind of bigger systems in that case you may go for this macroscopic balance.

And here we find that the model equations describe how mass, momentum and energy of a system change due to some introduction and removal of these entities via incoming and out coming streams or other inputs from or to the surroundings. So, basically what we are looking for is this that if there is a system, if there are some inputs, there are some outputs and if there is any kind of interaction between the system and the surroundings; then what would be the change in the system properties?

So, here we are not trying to figure out how the system is behaving from inside. It is a just overall picture we want to have and so, there is no attempt to know the distribution of the mass or energy or the momentum within the system.

And this is the most what you call the first the approach anybody would make and this kind of approaches are not only for our process engineering; but they are also applied to economics for safety reasons. So, all these things we can assess by making this overall or Macroscopic balance.

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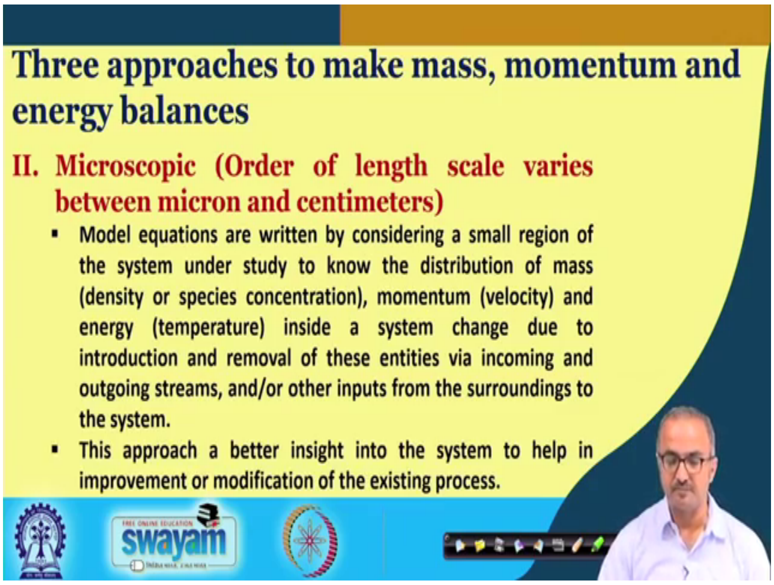

Next we come to a lower scale and when you go to lower scale, it means that if the system size becomes a bit smaller or rather we consider a system size which is smaller than what we considered for the macroscopic scale and in this case the order is between say centimeters to up to micron.

So, in this case the model equations are written by considering a small region of the system under study to know that how this mass and energy and the momentum are distributed. When I say mass, mass here means that suppose a particular system has many species in a mixture form. So, we want to know how the various species are distributed within the system. That means how the concentration of each species varies within the system.

Similarly, we can also know from the momentum equation how the velocity varies from the energy equation. We can know how the temperature varies within the system and again, all these things are varying due to the influence from the input streams, the output streams and any kind of interactions between the system and the surroundings.

So, this kind of approach is used when we want to have a better insight into the existing process and why this insight; what we gain? We can modify the process because if we find that a process is not working or is not performing as desired; then we need to take some corrective actions, we need to do some modifications or rectification. So, for this we need to know how the process is behaving and what are the distributions or mechanisms within the thing that are need to be considered so that we can bring about any kind of modifications.

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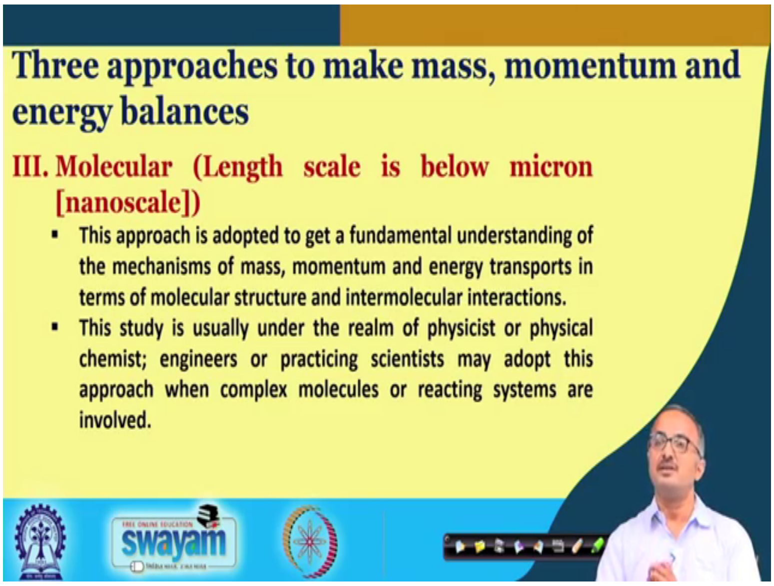

And the last approach is the Molecular approach. In this the scale is very very small and very small means it is bellow say micro scale; that means, it is we are going almost towards nano scale. And in this case, the approach is to get a fundamental understanding of the mass, momentum and energy transports in terms of molecular structure and intermolecular interactions.

So, this is in contrast to what is done in the microscopic or macroscopic approaches. So, here we are trying to look at the various molecules and their interactions between themselves. And generally, it is under the study this are studied under the physics or those scientists or who are even in engineering, there are many scientists who look into such kind of nano scale. So, this kind of approach is more for the scientific work rather than for the industrial work.

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So, we see that all these approaches are adopted as per the requirement. So, all these approaches are interrelated. Even though apparently they may look different, but they are all interrelated and the information flows from the one approach to the other. For example, that you see that transport properties like viscosity, thermal conductivity, diffusivity are determined from the molecular description of the system. And once you determine this, from the molecular description and those values of these properties are again taken to the microscopic or for the macroscopic approaches.

And then, these profiles of the specific concentration, temperature, velocity obtained via the microscopic balance may be needed for the macroscopic study. In the sense, that whatever profile we are getting for the temperature, velocity or the species concentration, those profiles may be again integrated over the whole system to get some kind of average values and these average values may again be used in the macroscopic balances. So, we see that all these three approaches are interrelated and information flows from one approach to the other.

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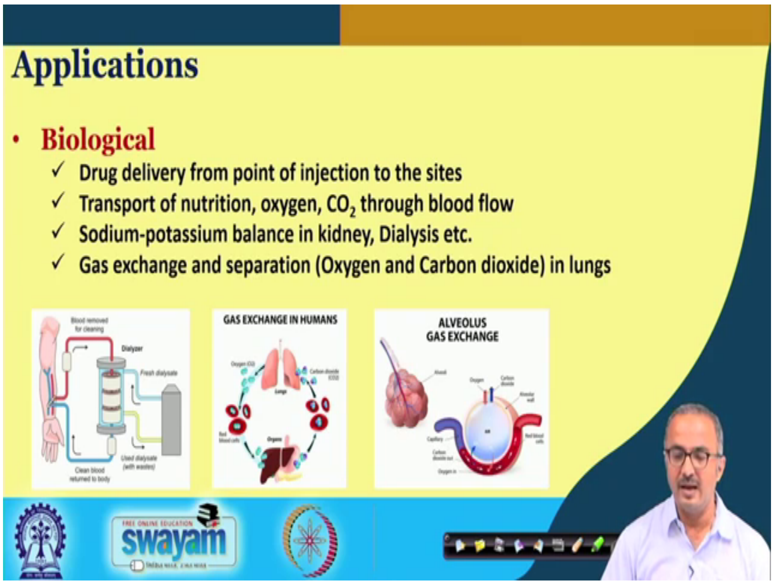

Now, after understanding about these three approaches of balances. Now, let us come to see some applications where these balances will be required and these applications you will find that they pertain to various types of engineering and scientific fields. I have just shown you some representative applications and this is not at all exhaustive.

So, let us first look at the biological applications and in this case a very common thing is that drug delivery that we want that whenever we are taking any drug, that drug should be going to the particular destination wherever our system is affected. So, this drug delivery is happening through the blood flow; how the blood is carrying the particular drug; how the drug is interacting with the various systems in a particular body. So, all these things are studied may be studied with these balances.

Then, transport of the nutrition oxygen carbon dioxide through blood flow and here in this particular picture you can see that how the lungs where this oxygen and carbon dioxide get exchanged; that how this particular lungs is performing that here the oxygen is glowing through the blood cell and again, through the various organs it is passing through. And it is carrying the all the excretory components and ultimately, the carbon dioxide is getting into the blood and oxygen is going to our body and ultimately, it is going to the lungs and it is being exhale out. So, you see that this is a particular biological systems and in this case we find all the three things will come into picture like the momentum balance, the mass balance and the energy balance.

Similarly, you know that we have to maintain certain sodium potassium balance in our body and the kidney is the organ which performs this balancing act. So, in this kidney some we find that this sodium potassium are getting exchanged and they are exchanged through some semi permeable barrier and this kidney is basically filtering out. So, if somebody's kidney is failing, then you know that we need some kind of dialyzer or something.

So, similarly you know that blood transfusions are also done and this blood transfusion occurs that if somebody has some kind of cancerous thing disease, then we need this blood transfusion. So, all these things are systems which may be studied with these balances and then, gas exchange and separation in the lungs as I just told you.

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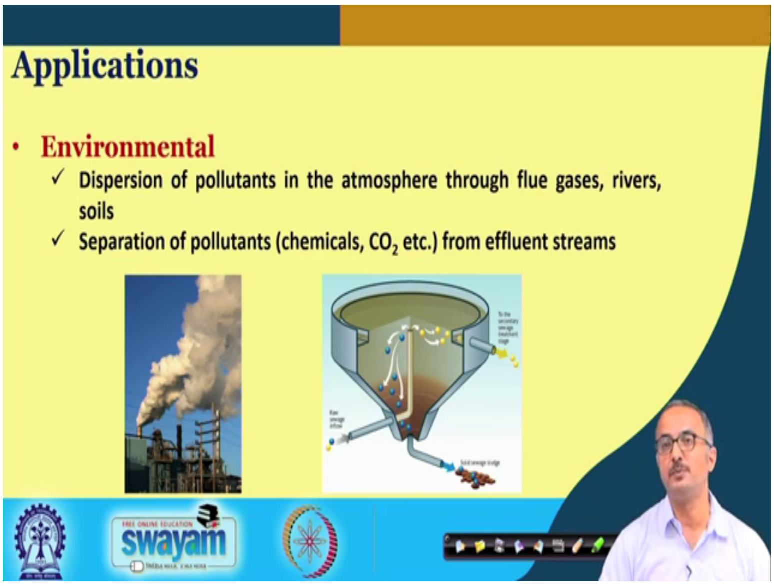

Now, next come to the Environmental effect. Here, you see that in the atmosphere how the emissions are coming out from some industry and with these emissions, we find there are many gases like carbon dioxide H2S and nitrogen oxides, they are also going into the atmosphere. And by writing the balanced equations, we can know that how these components are as getting spread into the atmosphere.

Similarly, we have the various types of chemical pollutants from the industries which are going into the rivers or some other water bodies and we can know that how these pollutants will get spread into the surrounding areas.

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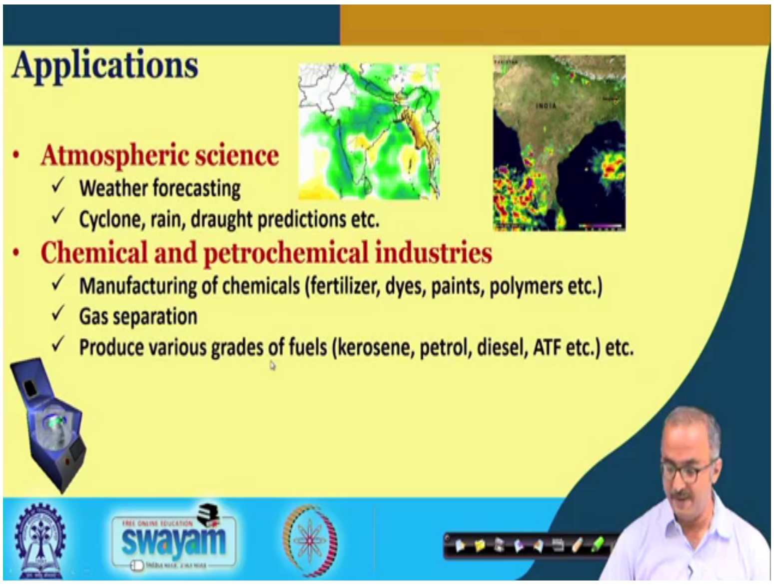

Next come the Atmospheric science. In Atmospheric science, it is very very usual that we are doing the weather forecasting. So, this weather forecasting is basically to know how the wind is flowing and do the wind; how the clouds are getting formed; how the clouds are going from one place to the other; when the monsoon would come; how the temperature would vary; whether they will be storm or not? All these things are information can be obtained by solving this basically there is kind of mass, momentum and energy balance equations.

And then, in the Chemical and petrochemical industries, we have a very big use of these kind of balances like for example, in manufacturing of the various types of chemicals like fertilizer, dyes, planes, polymers etcetera or the gas separation or to produce various types of fuels from the petroleum ok. So, every place, we find that there will be some or the other applications of this balance equations.

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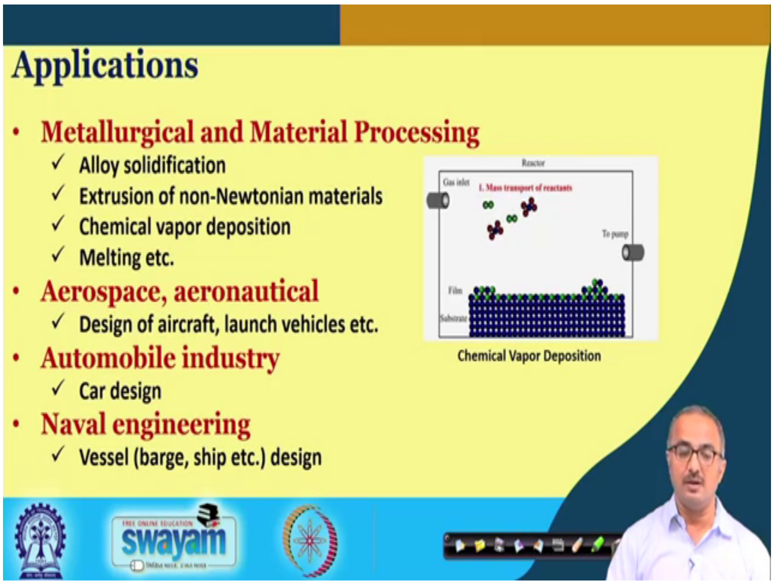

Then, come to Metallurgical applications, we have the Alloy solidification; then, Extrusion of non-Newtonian materials; then, Chemical vapor deposition about which we have just shown this particular figure that we there is a substrate on which we are trying to deposit some kind of molecules to get a very thin layer. So, this is used in the semiconductor industries.

Similarly, in Melting; how the melting takes place, how during the melting, how the various components are getting distributed inside the system? All these things can be studied using the balanced equation. Then, we have the Aerospace or Aeronautical applications, where we are designing all the space vehicles or the aircrafts using this balanced equation.

Automobile industry or the car designs you can see that there is so many types of car designs available in the market. So, all the designs are taking place in some kind of wind tunnel and there we study that when a car or some other thing like aircraft they move, how they are getting affected by the surrounding air; what kind of drug is they are experiencing? So, because the drug is correlated with the fuel consumption. So, everything are correlated. So, we need this kind of balanced equations.

In Naval engineering also similar to automobile or in the aero this aerospace or the aeronautical, here the all the ships and the barges are designed based on this kind of balanced equations.

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So, more you can learn about these systems and their applications from these following references. These are not exhaustive, but some representative references you can look into some more books.

Thank you.