Engineering Thermodynamics
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Lecture-1
Introduction: Engineering thermodynamics

Hello, my name is Jayant Kumar Singh. I am a professor in the Department of Chemical Engineering, IIT, Kanpur. Welcome to this course, Engineering Thermodynamics. This is the first lecture. In this lecture, we will review some fundamental things that we have already studied. We will focus on two things in this lecture. One is about metric standard international, and the other is about basic concept of system. But first we must know what is thermodynamics?

Thermodynamics is made up of two words. The term is therme which means heat and dynamics which is power. So, Thermodynamics is basically a subject that focuses on how to convert heat into power. extract the work and eventually convert it into useful work. So, in general, the concept of thermodynamics is basically a science of energy and its energy transformation.

That is why it is used in every normal daily life. It is used for complicated things like phone calls, engine calls, etc. In this course, we will try to understand the basic laws of foundations and how to use them in different applications. One of the applications we will consider is basically engines. Like steam, engine, etc. or car engineers typically. We will try to understand all these things. But first let's take some examples in which we try to understand thermodynamics. As I told you, thermodynamics is made up of thermo and dynamics. And it means the conversion of heat to power. The classic examples are you can see that is a simple mixer that converts electrical energy into mechanical energy. This is also a type of transformation. The second example is a heater that converts electrical energy into thermal energy.

We will try to understand its efficiency later. But in general, in thermodynamics, these examples will be understood in this course. and how to make your system or devices efficient So let's start with fundamental laws of nature which you must have studied in your 11th and 12th class. One of the most fundamental laws is the first law. The basic statement is that energy cannot be created or destroyed. It can only change its form. For example, if a stone is at a certain height, its energy is currently 10 units. We will discuss this later in this lecture. But initially, it had no kinetic energy. It means that there is no velocity. And when it is released, then eventually you will see that where the intermediate is not completely dropped, the potential energy has decreased. But the rest has been transferred into kinetic energy. And eventually, your potential energy will be zero. But the rest will be converted into kinetic energy. If the rest of the energy friction or other loss. So, this is the first law which simply says that energy cannot be destroyed, you can convert it.

Now, the second specific law deals with direction. It means that there is a particular direction in any process. And the validity of that process will be valid or not, it depends on the second law as well, which we will discuss later. As an example, if you see this, these are standard normal examples which you can see in your daily life. In general, you can see that if you order a coffee at a high temperature and room temperature is 20 degrees, then you can see that the heat flow is at a low temperature. That is decreasing temperature. This is what we call heat flow. It will never happen that from here, from this cool environment, i.e. from cold temperature, your coffee is transferred to heat, and coffee gets hot. You will never see this. So, there is no opposite direction. This is a specific direction of the natural process. Similarly, if you take an electrical circuit and if current flows in it, generate. But you can't apply heat on this circuit, then the current will flow. This will never happen. So, the process is in a certain direction, not in a reverse direction. And this specific part of this information is part of the second law. We will discuss it later. But the existence of any process. It depends on two laws. The first one is that energy cannot be created or destroyed. When this is valid, the second law is specific and deals with direction. And this should also be valid, then your process is done. For example, if we look at this case, the more energy we take out of here, the more energy your coffee will not be hot even after giving it. First law is valid, it does not mean that the process is valid. So that is something which is very important to understand. The first law is valid, so it is not necessary that the process is valid. Both laws are valid to make the process valid. So, we will talk about this. We will discuss this topic in detail in this course.

We will try to understand both the first law and second law. We are trying to understand it in its sub ship. But just to give you an idea how this course will expand. Thermodynamics has a big role in engineering careers. Whether it is mechanical engineering, res-project engineering, or chemical engineering. Thermodynamics works very inherently in decision making, particularly in design and development of new systems and processes. Or if there is already a process or a system that already exists with you, how to improve it, there is a very important contribution of thermodynamics in this. For example, if we see that ammonia production is a very basic ingredient of fertilizer, for this you need nitrogen, hydrogen, and if there is a reaction, then ammonia. So as an engineer you will get specific questions like First of all, where do you get the raw material from? In what form? To occur this reaction? What temperature, pressure, ratio of reactant should you have? Or how much energy you will be using? If we go into details of this process This is a gas form. We will compress it at a particular temperature and pressure. So, by compressing it, you have enhanced the pressure. And then, you increased the temperature. And, depending on the temperature, you are mixing it at a specific temperature and pressure. Okay, by mixing it, you have basically brought it to the reactor. Because the reactor will react at a specific temperature and pressure. After that, when the reaction is done, you separate it with a condenser in liquid form. This is the process. Why are we doing this? Of course, we will not be able to do a detailed analysis of this now. But in general, the concept says that you have to do this reaction on a specific temperature and pressure. And after that, because the reaction will never be complete, it will be rare. but in general it will not happen so it depends on catalysis and how much time you take and on 50 different things so it means that some reactants will remain so you have to separate them if you want to remove ammonia so if you condense in liquid then your ammonia will condense quickly and rest of the un-reacted nitrogen and hydrogen you can mix them again So, this is a simple process of ammonia synthesis. And you will get many questions in this process. Like you have these questions in your mind.

The second question is how much energy you need for a heat exchanger. Or how much energy you need for condenser to cool you. For cooling, how much amount of refrigerant you need, what kind of refrigerant you need, how much final temperature you need and eventually, you have to think about all these things as an engineer. So, in summary, thermodynamics is basically the study of energy and transformation. It enables you, empowers you, gives you enough information to answer all these questions as an engineer. One of the important elements in this is phase change. Particularly phase, liquid, gas, etc. are useful. So, thermodynamics gives you information about phase change and deeply. In industrial scale, power plants are used to generate power. In this, different units are used to design and to design the devices. Unit is also called; unit operation is also done. You will hear this word very commonly as a chemical engineer. You will also hear it as a mechanical engineer. So, if you have clear concepts of thermodynamic analysis, then you can apply it in steam drum application or turbine heat exchanger pump. So, there is a general schematic in steam power plant. In this, basically your steam water is used as a working fluid. and this is heated at a certain temperature and pressure. Finally, steam goes to the turbine. The basic function of the turbine is to use this high temperature pressure to convert it into work. And when the steam is released at low pressure, water comes out of it and the steam is recycled through heat exchanger and pump. I will try to understand this in the later part of this course. But more or less, in this whole concept, the first law and the second law are heavily used to design the unit operations.

Notice that the coal used is normally this coal power plant to make the temperature of the coal certain. When coal is heated, the gas that comes out with it is CO2, SO2 and other things. This is called Flue gas. And the CO2, SO2, NOx and other gases that come out in the Flu gas are not good for the environment. That's why, finally, a gas purifier is used, and before leaving it in the air, it is very important to clear and separate it. In fact, it is becoming more mandatory to capture carbon CO2 and then how to utilize that capture has become an important element in the industry. This is a schematic image of your power plant. This is a representative image of the proper power plant. This is how a power plant is built in large scale, it is located for many kilometers The refinery is also very large and it is located for many kilometers This is the schematic of the steam power plant and this is the real image of the power plant You can use them in many applications. In fact, you can use them in many practical applications. For example, in the concept of thermodynamics. For example, in the management of heat load. For example, if you want to install solar power collectors or panels. How much should it cost? You can do all these basic analyses. Cost versus efficiency. You can do all these things with the thermodynamics concept. Refrigeration system, refrigerator, food. Automobile or any transportation Power plant is there, and also chemical plants can be applied Thumbnail mix concept Laws of Thematics is created by many scientists. Commonly we will hear in this course is Rankine, William Rankine, Rodolfo Colossius, Lord Kelvin and William Gibbs. But there will be many other names. But these names are most famous and contributed. Your ranking cycle is based on your ranking. Clausius has contributed a lot to understanding the second law of Thumbed Amps. Kelvin scale and Gibbs have contributed a lot to introducing free energy or understanding the two-phase system.

Let's start with dimensions. Dimension is very important in thermodynamics because if you introduce physical quantity without units, it doesn't make any sense. So, any physical quantity, whether it is force, mass or energy, you should have magnitude and unit. Without units, magnitude doesn't make any sense. There are two types of dimensions. One is called primary or fundamental dimensions. In which mass, length, time, temperature are defined. The other is secondary dimensions which are derived from primary dimensions. Like velocity which depends on length and time. Energy, volume which depends on length and so forth. So, this dependence can be presented in many systems. If we define the basic, primary, fundamental dimensions, like if we call the mass as gram, then a fundamental or metric system will emerge. And some other system will emerge. If we call the length as meter, the mass as kg, Time is called S, temperature is called Kelvin, ampere is A, Candela is the representation of amount of light and mole. So, these forms, these fundamental dimensions, we call them SI units. These are standard international units. In this, we call the length meter, mass, kilogram, time, second and so on. Similarly, CGS unit, English unit, these are different units. Different countries have different systems. But commonly, the ones used across different countries, the acceptable ones are basically SI units. In SI units, you have standard prefix as well. Like your Tera, Giga, Y, and so forth. In Kilo, you just have to remember that K is small in k. Sometimes, people even write Kilo Gram by mistake. K is the capital of the unit. But K represents Kelvin. One important thing is the homogeneity of dimensionality. For example, you have an equation A plus B equals C. So, A and B should have the same unit. Because you are adding. Similarly, C should have the same unit. So, this is homogenous. Every term should be the same. Our interest in applying in thermodynamics is in the system. The system is anything you can apply, whether it is an engine or a house. There will be a region in which you apply thermodynamics, which we will call the system. The system is basically a quantity of matter and the region in space is chosen for study.

The boundary that separates the system and the surrounding This can be imaginary too. The boundary can be fixed, movable, and the thickness of the boundary is negligible. And the mass is zero. For example, the system of interest can be a reactor, a soft drink can, an engine, an earth atmosphere, an auto engine, or any interest in applying the laws. Fundamental laws. There are three types of mass. One is a closed system, in which mass is not allowed. Neither the mass can go to the surrounding nor to the surrounding. So mass is constant. Mass is not allowed. This is a closed system. Volume can be changed. If this is a piston, it can come up and down. So, the volume can be changed. For example, if you put some heat here, then this piston can go up. So, the volume can be changed. So, the second important thing is that the energy can be transferred in the closed system. Like I did. Energy can be transferred from your surroundings and can also be transferred from the system. In a closed system, mass is not allowed, but energy can be allowed, and your volume can be changed. It has a subset, the Isolated System. If your energy is not allowed, then it is called the Isolated System. That means in the Isolated System, your mass cannot be exchanged, you cannot change the system and energy cannot be changed. So, this is your specific case, isolated system. Then comes the open system. In the open system, your mass can cross the boundary, energy can cross the boundary. So, to understand this, let's take an example, a nozzle that is normally used to change pressure. So, this is your flow, in this dotted line, this is your system, open system. For example, we use control mass in closed systems. And this black line in the nozzle is your real boundary. This dotted part is your imaginary. Because it separates the flow. and it is going inside this region, so separate it.

This is your normal control volume. Control volume doesn't have to be fixed. For example, if you have a piston cylinder with an inlet, then this control volume boundary can move. Because your flow is coming here, so it can go up. So, the boundary that is visible is a movable boundary in this particular case. Then comes the example of a water heater where the inlet and outlet are fixed. So, the boundary is also fixed and there is a specific region of the control volume. This is an example of an open system with one inlet and one exit.

The important thing is that in an open system, both mass and energy can be exchanged. There are some practical examples like a coffee cup. It has mass and energy, so it is an open system. This is the specific can, the surrounding will be at a higher temperature, so heat transfers from a higher temperature to a lower temperature. So, assuming that this can is cold, so this is specifically a closed system. And assuming that in a short duration, the thermals maintain the temperature inside, it means that it is isolated. In general, this is a representation that an open system can exchange energy and matter from surroundings and close system can exchange energy and nothing is isolated. So, this was all we had to cover in this lecture. In which we discussed about metric system and learned about system. In the next lecture, we will discuss the state postulate equilibrium process. So, I hope that you liked the lecture and I hope to see you again in the next lecture. Till then See you in the next one.