Engineering Thermodynamics
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Week-01
Lecture-4
Energy and Energy Transfer

Hello and welcome to this lecture. This is a new topic, and we will discuss Energy and Energy Transfer in this lecture. We will cover 3-4 concepts in this. First is the concept of energy and the different forms of energy. We will identify that particular and discuss it. How many different forms are there. And there will be a lot of focus in this lecture to understand about internal energy. And finally, we will understand about heat and the words associated with it and the terminology used. So, let's try to understand this with a simple example of energy conservation. Suppose you have a room and you have kept a refrigerator in it. And you sealed the room well. Which is called insulated. It means that the energy that is inside will remain. But what did you do next? You opened the refrigerator door. Now the question arises that Will the temperature of the room increases, or will it be cold? And the refrigeration system and the refrigerator? It's on. It's continuing. Intuition is sometimes thought to be a natural way to cool down the system. Because now it has a lot of space. But it is not like that. Because here we use the simple application of energy conservation. Here we will use energy conservation. And if energy conservation is used. So, the concept of the room is that since it is insulated, it means that you have no way to let your energy go out. Even if your efficiency system is open, you are continuously supplying electrical power to the room. So, when your electrical energy is going to your room, your room's energy is naturally increasing. And when the energy of the room increases, your air will keep rising. So, the simplest thing about this question is that The answer is that your temperature of the room will increase because it is insulated. So here energy conservation is useful. Now, the temperature is. If we understand what that temperature does, we will try to understand it through the means of internal energy. But first, we have to understand how many forms of energy there are. First, like thermal energy, the temperature that allows the movement of molecules to rotate rapidly, to transfer from one place to another, all that comes in the form of thermal energy. Mechanical, kinetic, potential, electrical, magnetic, chemical, etc. These are all different forms that we will try to understand. Now we can divide energy into two parts. Anybody, like your car, is also called a body. For example, if a potato is a body, then we can divide it into two parts. The first one is called a macroscopy. The motor body is attached to the whole body. If the car is moving, then you have a kinetic energy connected to this car. If you are on the mountain, then your body has potential energy. But the proteins, molecules and other things that are running inside your body are different. That comes in your microscope. So, one is your microscopic, which is a big form, which is applied to the overall system. Whether it is moving or not, if it is not moving, if it is not moving, if it is stopped, then naturally its kinetic energy is zero in that system. But if the system is above the surface of the earth, and if it is very high above the surface of the earth, then it has some potential energy. And in the same body, like water is taken, the molecules in the water, the molecules of water, oxygen, hydrogen, it has its own structure, it has its own movement, and the things connected to it, the energy, All these are microscopic forms So microscopic is molecular structure which is connected with molecules or atoms and it doesn't mean how much it is moving even if it is moving it is microscopic it has some structure inside some molecules are forming their structure It is not dependent on the outside. It is independent. We will try to understand this more. But if you consider that there are different forms of microscopy, if the whole joint is given, and the energy of the joint is obtained from different forms, like rotation, translation, molecule vibrates from one place, like your bond is there, the length of the energy is not fixed, it vibrates. Vibrational energy is also a part of microscopic energy. If we add all these parts together, we call it internal energy. And this is a very important part of any system. So, in this, we will discuss a little more about the types of energy forms in the internal energy. But first we will discuss this and discuss that the macroscopic form has two specific forms. If you do not have anything else, the only forms of energy you have are motion and gravity. The macroscopic form of energy is the motion of the body and the effect of the external field. the energy generated by that is known as the microscopic energy If there is a motion, then there is a kinetic energy So the energy of this is the relative motion from the reference frame If Earth is taken as a reference, then the car is running on it and it has a specific velocity that is the kinetic energy Gravity is an external field, so the energy of anybody depends on the elevation of the earth. If there is a magnetic field and electricity, then it will have a different form of energy, but it comes under a microscopic form. This is the kinetic energy per mass of the system.

Microscopic energy changes due to velocity and elevation. Microscopic energy contributions. So, if we look at potential energy, then potential energy is mass Acceleration due to gravity and this is elevation. So, this is your height. What is the height? And we will call this small p, which means small p, and this is potential energy per kg of the system. Kilojoule divided by kg. So sometimes we use this to divide it by its mass. Because if we apply energy conservation on one body and the mass is changing, we can also analyze the Kappa unit mass. If there is no magnetic electric or surface tension on the system, then the total energy is your microscopic energy, which is called the big one, which is kinetic energy potential, plus the internal energy, which is inside the system due to molecules. Okay, so this is total energy. So, we can expand this too. This is your kinetic energy, this is your potential energy, plus internal energy. Now we will discuss the type of energy formed in this. As I said, internal energy is the temperature given by the molecules. So, when there is a velocity, the molecules translate. The tendency is that they rotate as well. Like here we said that there is a bond. This is a molecule in which there are two atoms. And the bond is attached to it. So, there will be rotation with it. And there will not only be rotation, but there will also be vibration. So, with this, there is translation energy. With this, there is rotational kinetic energy. So, all this is the form of kinetic energy. This is the molecular kinetic energy The previous kinetic energy is effectively connected to the entire system Not only molecules, but also electrons will be translated Electrons will also rotate and spin nuclear spin All this is done in the internal energy The whole system is connected to the internal energy.

These 6 specific forms are connected to kinetic energy. Is it rotational, vibrational or translational? The word is a sensible energy. So, there is a sensible energy in the internal energy. The part that we saw. If you have a system like ice, then ice is water. Water molecules will be there. which are connected to each other through hydrogen bond. There is a kind of bond, there are strong interactions between the two, which means that they are attracting each other. And when you give energy, like you hit it, it melts, and it becomes a liquid. It means that your water is made properly. So, the energy that changed here, both had internal energy, both had sensible energy. If you see both, you have energy in the ice, the same translation motion is running. And it is also in the water with you. But now what you did by giving heat, the water is very different, the structure of the molecules around it has changed when it became liquid. So, this change is called phase change. Phase change means that you have ice and a liquid. The energy associated with phase change is called latent energy. This is basically the difference between the two. So latent energy is needed as much as the energy of ice and water. liquid or liquid to a gas. So latent energy is connected to phase change of the system. The energy connected to the phase change of the system is latent energy. Then comes your chemical energy. You have chemical bonds. When there are reactions, when something is converted, like the reactions you do in chemistry, The bond that breaks with it and something else is formed. So, the energy that is connected to these chemical bonds is called chemical energy. Similarly, the energy that is connected to the nucleus, which is connected to the atom, is your nuclear energy. So, in this course, we will not give any examples in which you need nuclear energy. but mainly we use the sensitive and latent energy to We will use that in our example. But all these parts, your latent energy, chemical energy, nuclear energy, all these parts come inside from internal energy. So, this sum of all the energy, if you add all this, then your internal energy will come. The total energy of the system can be stored in the system. If we store it, then it is called static. The energy form is static. And if we cannot store the energy connected to the system, then it is called the dynamical form. So, the static form of energy is the one that we have stored. Like internal energy is a static form. It is contained inside the system. And the dynamical form of energy is usually the interaction with the boundary. It is interacting with the outside of the system and going from here to there. So, such things are dynamic. It has not stopped. And it is always connected to the boundary. And the example is heating transfer and work. Your heat transfer and work is your dynamic form of energy. Heat transfer is only due to temperature difference. Suppose you have a system and energy is interacting with the boundary of the system. If there is no temperature difference between your system and surroundings, then heat transfer will not happen. But if there is an interaction, then it will definitely be a form of work. So, this is something to understand.

The other thing is that microscopic energy, like someone is moving your body completely. And the microscopic kinetic energy that we talked about in which molecules are moving. When molecules move, there is no direction. They move in every direction. Sometimes they collide with this, sometimes with that. So, effectively, they have no direction. That's why they are not able to do anything because it is called disorder, they are not organized. Imagine that if water goes in every direction, then water stops there. If the flow of water is from top to bottom, then there is a direction, so we can flow. And what is inside this is that if the molecule goes in every direction, then the molecule does not have any direction, which is not effective direction, that's why it. it can't work. Molecular interactions can't work like this. Like if you think that you have placed a wheel in the water and you think that the molecule is moving then it will collide with your wheel, and it will rotate. It won't happen because it is disordered. It has no organization. But there is a flow here. The water is already flowing. So, with the flow, a particular. Kinetic energy is moving So that is Microscopic Kinetic Energy It will attack the wheel and start moving from here So Microscopic Kinetic Energy is organized and Microscopic is disorganized So the organized form of energy becomes valuable for us because we can convert it into other forms which is useful work or mechanical work.

So, now let's talk about mechanical work. So, this is the work which is very valuable for us. Like, if there is a pump, what the pump does is increase your pressure. And what the turbine does is that it uses the same high-pressure fluid, the fluid is called water, and converts it into energy. And when its exit is basically low pressure. So, pressure difference matters a lot. So, Mechanical energy is the form which we can convert into mechanical work. Like your pump is done and turbine is talking. We will do something about this example. If we convert the mechanical energy connected to it into mechanical work, then the device for that, the device you are talking about, like you are talking about the turbine, what is in the turbine, the water coming from above, that will be at high pressure, and that is connected to you, you are generating energy from it, and when it comes out later, it will be at low pressure. We will assume that there is no loss in it, that is why it is called an ideal turbine. So, this type of device is called the ideal mechanical device. So, this flow, like this flow that we are showing in this flow, has three things connected with it. First, if this flow has a potential energy above, there is a potential energy. If there is an elevation, if it is above the earth, then there is potential energy. and they said it per unit mass then if your flow is flowing then it is a kinetic energy, right? Other than this your pressure is very important when pressure is moving then your pressure is connected If there is pressure and velocity, then it is specifically a work which is called flow work. flow work is specifically associated with this. Okay. If the flow work is considered as flow energy, then if pressure into volume or pressure divided by density is a flow energy, if this pressure is flowing in the whole system, then a specific pressure will be at one point. flow energy will be different from pressure then your velocity is kinetic energy and its energy is different than your elevation is its energy is different so these three parts are we call it mechanical energy if we take two points in this system and we want to find the difference the difference of mechanical energy any point can be here, this point can be here ok So what we will do is If per unit mask because there is no change in the mask So your Suppose this is 2 and this is 1 So P2-P1 plus V2 square minus V1 square plus g Z2 minus Z1 So this is the mechanical energy change and this change will be converted into mechanical work So let's try to understand this as an example So it is important that in this particular slide it is important that you have flow energy which is an important element of mechanical energy of the water that you have, you cannot ignore it. There is no potential energy of kinetic energy, because pressure is also an element.

The unit of pressure, if you pay attention, is Newton per meter squared, which is called the pressure unit. Okay, and if we show it, we cannot call it that, because you can convert Newton. and when you convert it, it will be joule per meter cube. This means that the pressure is only energy per unit volume. That's why it's called P by roh. So, if you think of it this way, if you take out a product with volume, then it comes in a loop. Alright, so I will write it again. That the pressure is Newton per meter square. We can write it as joule per meter cube. This means that it is energy per meter volume. And that is why PV, pressure into volume, comes in joules, in energy. If we write this in energy per unit mass, then it will be P by rho. Because 1 by density is nothing but 1 by density is in molar volume. So, P times small v, which is molar volume, will be P by rho. So, this part is pressure. part of the system. Hope you understood it. Now let's apply it. Suppose you have a turbine and this fluid which has an edge at a particular height, and it is being used to convert it into work. Water is coming from here and finally the wheels are running. Imagine that this generator is finally being generated and being converted into specific work.

Now if you want to get maximum output in how much work, then you can do it in two ways. First, assume that this ceiling is taken from one point to another because there is only water. Water is coming here and going here later. So, you can also do that you took out total max. So, your total mechanical energy has been converted. So, total change in mechanical energy is ideal. So, all the mechanical energy changes will be converted into work. So, W max. is the rate. The mass is continuously flowing. So, this is the rate. This is equal to multiplied by delta E. And this is the change in mechanical energy. So, if you look at this, then at this point and at this point, both are in the atmosphere. Okay? And no matter how big the H is, the change in the pressure due to air is very less. So, in pressure, we can say that P1 and P4 are approximately in the atmosphere. Then The flow of the river is not flowing. The velocity is 0 in 1 and 2. This means that the flow energy is 0 in 1 and 2. The velocity is 0 in kinetic energy. So, what is delta E? and this is only Z1-Z4 which is your simple H so this is your Wmax Mg so you can do this analysis in one way you can solve it like this second way is that you see here because the pressure is not in 1 and 4 but the pressure which will be in the inlet of the turbine it will be very effective in this ok and this So if there is a difference, then we take delta e mac and here we took this system and this is the control volume and we are talking about this in this both the velocities are assuming that they are equal ok because the distance is very less they are assuming that the velocities are equal and this is approximation understand this second is that There is no difference in elevation in 2 or 3. If you apply this approximation, then your Wmax is delta E mechanical, this is only your change in the flow energy and which is P2 by rho minus P3 by rho. So, this is dot delta P by rho. So, you can also do analysis from one side like this. So, this was the case of internal energy. After that, we used mechanical energy and how it is used in 100% ideal conditions. This is completely converted. I showed you an example of that.

Now finally we will discuss on this that energy transfer by heat. So, heat is, as we said, the heat that is normally transferred is only due to the difference of temperature. If the closed system is being transferred, then the temperature difference between the surrounding and the boundary is there. The rest of the work is also due to the boundary interactions. If there is no temperature difference and there is a specific change in the work, then it will definitely be due to the work. But now we are talking about heat. So, heat is caused by temperature difference. So, there should be a difference in temperature between system and surrounding. For example, if we take soda can, and room temperature is 25 degrees, then there will be no heat transfer. But if it is 15 degrees, then there will be heat transfer. If it is 5 degrees, then there will be heat transfer. But the difference is that if the 5 degree one has more difference, then there will be more heat transfer. So, here it is written as 16 joules per second. This is more than 8. joules per second. So, the larger the temperature difference, the higher is the rate of transfer. The higher the temperature difference in the system and surroundings, the higher the rate of heat transfer. So, another important thing is that heat transfer is understood by energy. We can't call that energy heat. For example, if you take a potato and heat it, and you analyze it, that this is the surrounding air, this is your system boundary, and some parts of the heat that is transferred from the surrounding air, suppose 2 kJ is its thermal energy, the energy that is connected to it is transferred. So, some parts have gone from here. and when it went to the boundary, it was identified as heat and this heat went back to the air back to the air and when it went to the air, it went in the form of air's thermal energy so it means that this energy is only recognized in the heat when it crosses the boundary why can we call it Q? or we call it q, Q is in kilo joules and q is in kilo joules per kg and many times heat is continuously transferring from a rate to a time so in such cases we use q dot so when we integrate q dot from t1 to t2 time then the total amount of heat transfer comes out Next important thing is that if this system is insulated, then your energy will definitely be zero. Why? Because you are insulating completely, you cannot interact. surrounding in terms of heat. So, the insulated system we will call adiabatic system because Q is zero, there can be no heat transfer. The heat forms are historically the heat in 1900-1900 it was believed that if we attach a cold body to a hot body then some invisible liquid comes from a hot body to a cold body This was believed So we called it caloric That is why your unit comes in caloric form Another important thing is that heat is also considered as kinetic theory. If molecules are like small balls and they are moving, they process energy. And the energy that heat gives to the atom and molecule is random. It is not controlled in any direction. The heat in the system is not controlled. The molecule is moving. So, it cannot control the direction of heat in the system. There are many types of heat, if the heat is transferred from one body to another body, then it can be transferred in three ways, one is called conduction, convection and radiation. Conduction is the one that your more energetic particle If there is a low energy particle in the middle, then the interaction between them is transferred. The energy goes from high energy particles to low energy particles. So, in that form we call it convection. Which is connected to each other. Convection is a solid surface and if there is a wave moving next to it, then the interactions between them are and the transfer of energy is called convection. Both concepts are used in this. First, the fluid motion, which is moving at the bottom, and the conduction which we have studied in this. And radiation is only in which the energy transfer is emitted from the emission of electromagnetic waves, that is, it is coming out, because of that, the photon, which is photon transfer of energy The form of radiation is called as the form of the electromagnetic wave, which we also call photons. So, this was a brief discussion about sheets. In the next lecture, we will discuss work specifically and different forms of mechanical work. So, I hope to see you in the next lecture.