Basics of Mechanical Engineering-3

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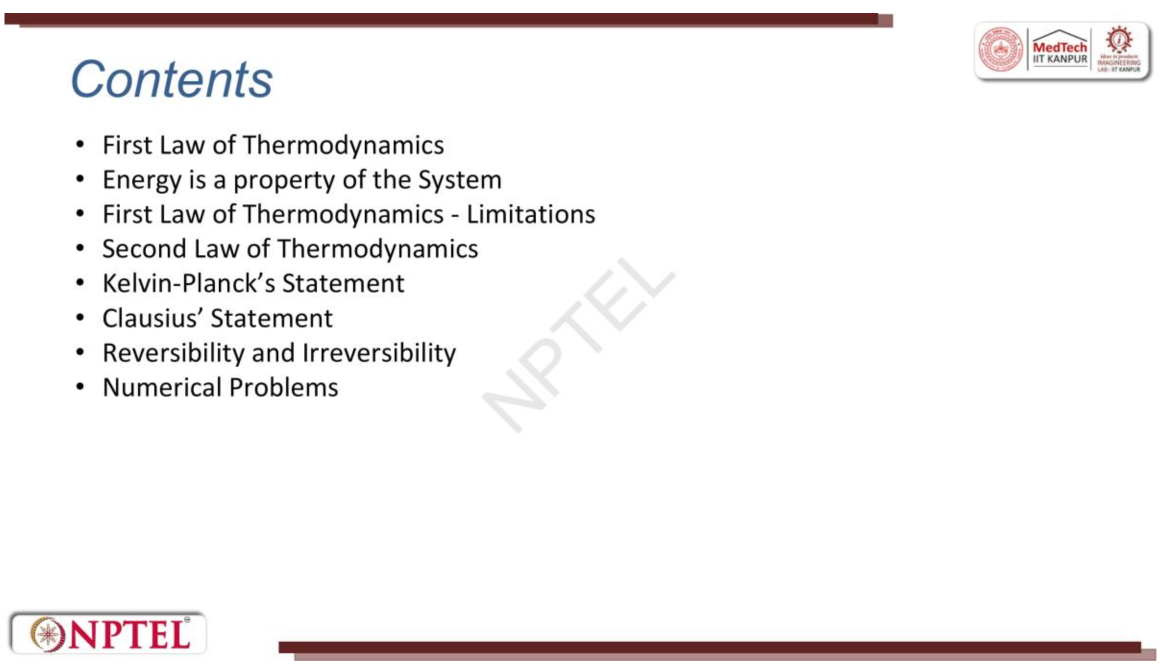
Week 02

Lecture 07: Basic Laws of Thermodynamics Part 2 of 5

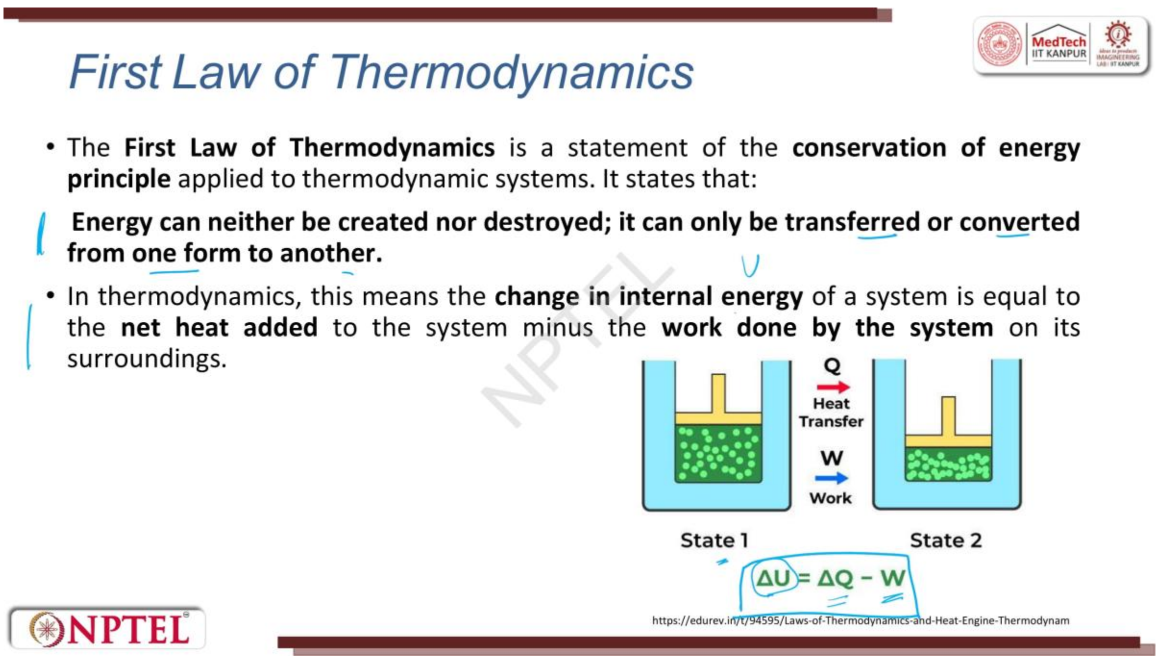
Welcome to the next lecture on Basic Laws of Thermodynamics Part 2. In Part 1, we covered Work and Heat, two topics. We looked at latent heat of vaporization, latent heat of fusion, and latent heat of sublimation. We also examined specific heat. When we discussed work, we tried to understand the formulas for Isobaric, Isochoric, Isothermal, Polytropic, and Enthalpy. So, we looked into the formulas: how do we calculate the work?



Now, let us move to the Second Law of Thermodynamics.

Before we get into the second law, we will review the first law. Then, Energy is a Property of a System. Then, First Law of Thermodynamics Limitations. Then, only then can you understand why the second law comes into play. So, the second law: Kelvin-Planck Statement, Clausius Statement.

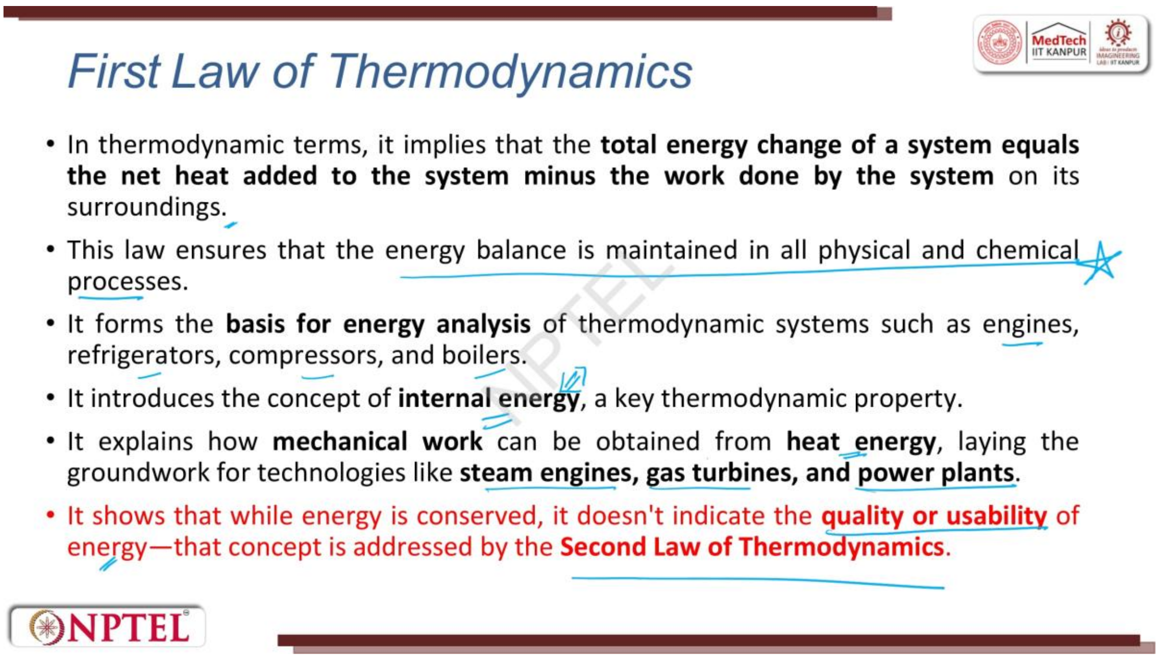
Then, we studied a little about Reversibility and Irreversibility. That we will focus on. Finally, we will try to solve Numerical Problems. Friends, all the numerical problems will be covered in the tutorial session. So, I request you to use this lecture for understanding. In the tutorials, we will solve three or four problems, which will be discussed by Dr. Amandeep.



The First Law of Thermodynamics is a statement of the conversion of energy principles applied to a thermodynamic system. It is stated as: energy can neither be created nor destroyed. It can only be transformed or converted from one form to another. From mechanical to chemical, chemical to mechanical, mechanical to electrical, electrical to mechanical. See, it is something like that, right? Energy can neither be created nor destroyed; it can be transferred or converted from one form to another. In thermodynamics, this means that the change in the internal energy of a system is equal to the net heat added to the system minus the work done by the system on its surroundings.

Whatever the first one was, it was very easy: energy conversion. But if you want to put it into thermodynamic fashion, then this is very important. In thermodynamics, this means that the change in the internal energy of a system is equal to the net heat added to the system minus the work done by the system on its surroundings. So, statement 1 is Q. Q is heat transferred. Work done.

So, this is delta U is equal to delta Q minus work done. So, this is what the first law of thermodynamics states. Internal energy change is equal to the heat getting added minus the work done by the system to whom? To the surroundings.



The first law of thermodynamics—the thermodynamic term—implies that the total energy change of a system equals the net heat added to the system minus the work done by the system on the surroundings.

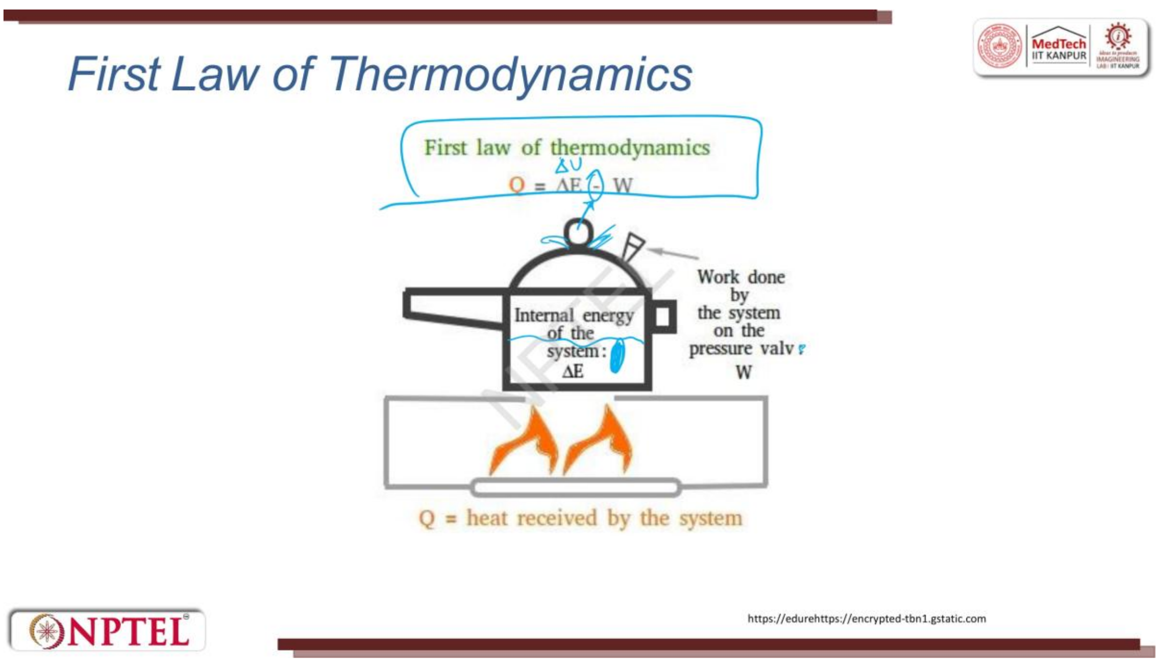
This law ensures that the energy balance is maintained in all the physical and chemical process. So, you have to understand it is not only physical, it is also for chemical. It forms the basis for energy analysis of thermodynamic system such as engines, refrigerator, compressor and boiler. So, everywhere, if you do the energy analysis of a system, we try to use the similar understanding. It introduces the concept of internal energy, a key in thermodynamic property, internal energy.

What all are the key words I have just put? So, if you don't understand, what is internal energy, you can go back to my previous lectures and get to know what is it. It explains how much work can be obtained from heat energy laying the ground work for technology of steam engine, gas turbine and power plants. So, heat energy. So, the first law explains that how mechanical work, cranking or moving of a shaft, how can mechanical work can be obtained from heat.

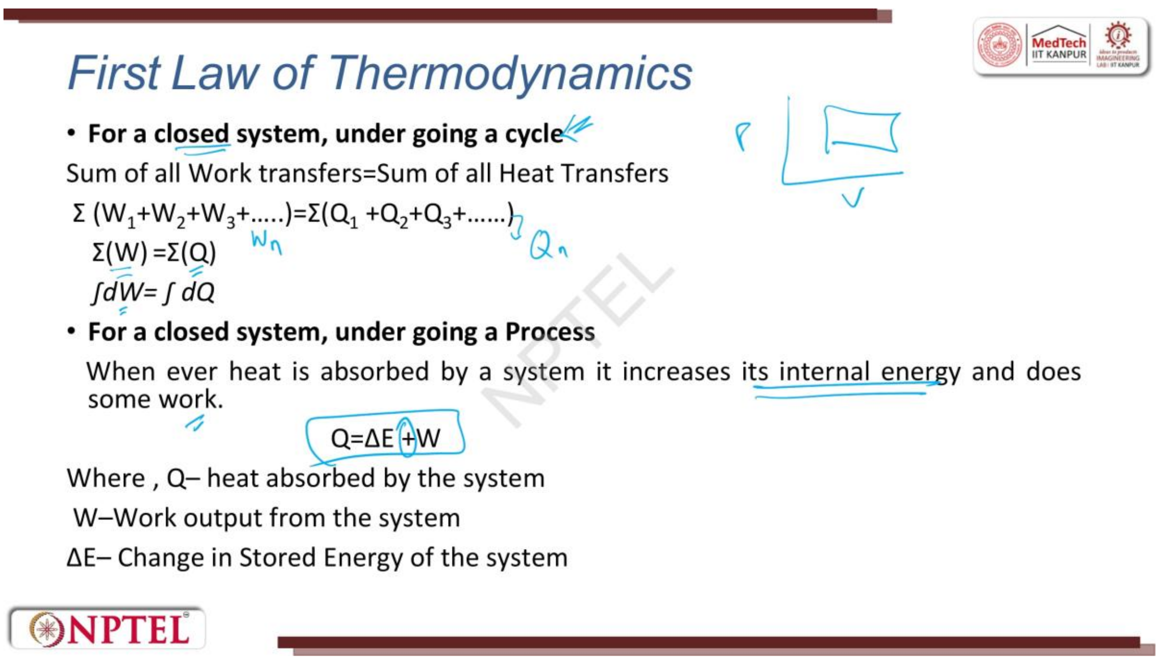
This is very important. From a boiling of an egg on a pan, lifting the lid, gave a seed for the thought of steam engine. So, which started happening at a kitchen in some scientist's house. A pan filled with water, an egg dropped inside. Water is boiled from the bottom heat. He could see there was lot of bubbling which was happening. There was lot of steam which was going.

This gentleman dropped a lid on top of it. Then, he could see the lid dancing. So, when the lid was dancing, the inference that came to him was that there is a mass which can be lifted by the steam. So, you look at it, and it explains how mechanical work can be obtained from heat energy. That came from the first law of thermodynamics, and that came from the concept of internal energy.

Everything is fine. But it did not say the last part of it. It shows that while energy is conserved, it does not indicate the quality or usability of energy. It does not say that. So, that led to the concept of, or the seed for, the second law of thermodynamics.



So, the first law of thermodynamics is very simple, whatever example I have given. Q is the heat which is added to the system. Here, there is an egg, there is water. So, the heat is transferred to the water. The water starts boiling, the egg gets boiled, or the vegetable gets boiled. So, the pressure keeps on increasing, the volume is constant. After a set period, there will be a lot of pressure increasing. The weights will be relaxed, and the extra energy will be eased out such that the system maintains the pressure for a given constant volume. So, the first law of thermodynamics says very clearly, Q = dE - W. If you go back to this formula, it is almost the same. The work done by the system on the pressure valve is W. The internal energy is E, or you can represent it as delta U.



So, for a closed system, we saw what is a open system, closed system, isolated system. For a closed system undergoing a cycle, the sum of all the work transfer is equal to sum of all the heat transfer. That means to say,

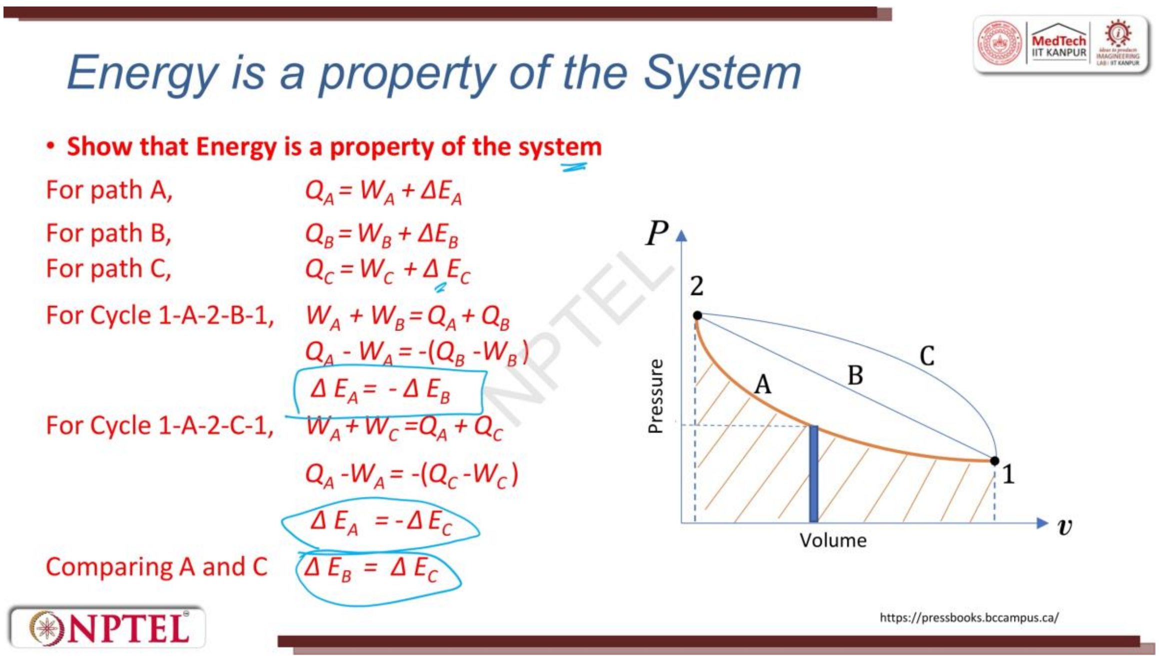
$$\Sigma\,(W_1+W_2+W_3+.....)=\Sigma(Q_1+Q_2+Q_3+......)$$
$$\Sigma(W)=\Sigma(Q)$$
$$\int dW=\int dQ$$

For a closed system undergoing a process, this is a cycle. What is a cycle? This is a cycle, right? Rankine cycle, PV diagram, Rankine cycle, Otto cycle, Diesel cycle, Brayton cycle, right?

All these cycles are cycles. For a closed system undergoing a process, right? When every heat is absorbed by the system, it increases its internal energy and does some work. So, Q

= dE + W. Whenever heat is absorbed by a system, it increases its internal energy and does some work. Where Q is the absorbed heat, W is the work output of the system and delta E is the change in the store energy of the system.

In some places, we have written minus and in some places, sorry, plus and some places we have written minus. So, please think about it and then let me know.



So, the energy is a property of a system. So, PV diagram. So, we move from 1 to 2, 2 to 1. So, it is A, B, C, right? Three paths are there. So now, Energy is a Property of a System. Show that the energy is a property of a system. So, we are just proving it.

For path A, $Q_A = W_A + \Delta E_A$

For path B, $Q_B = W_B + \Delta E_B$

For path C, $Q_C = W_C + \Delta E_C$

For Cycle 1-A-2-B-1, $W_A + W_B = Q_A + Q_B$

$Q_A - W_A = -(Q_B - W_B)$

$\Delta E_A = -\Delta E_B$

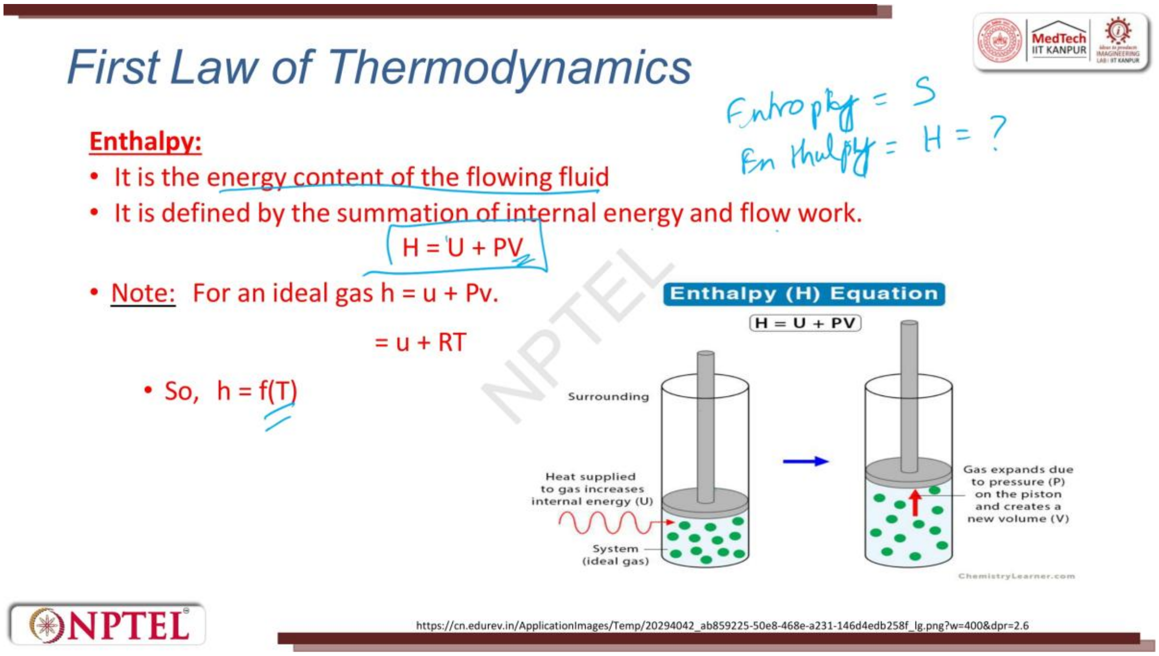
For Cycle 1-A-2-C-1, $W_A + W_C = Q_A + Q_C$

$Q_A - W_A = -(Q_C - W_C)$

$\Delta E_A = -\Delta E_C$

Comparing A and C $\Delta E_B = \Delta E_C$

Is it clear, friends? So, we are now proving that it is a property of a system. It shows the energy is a property of a system.

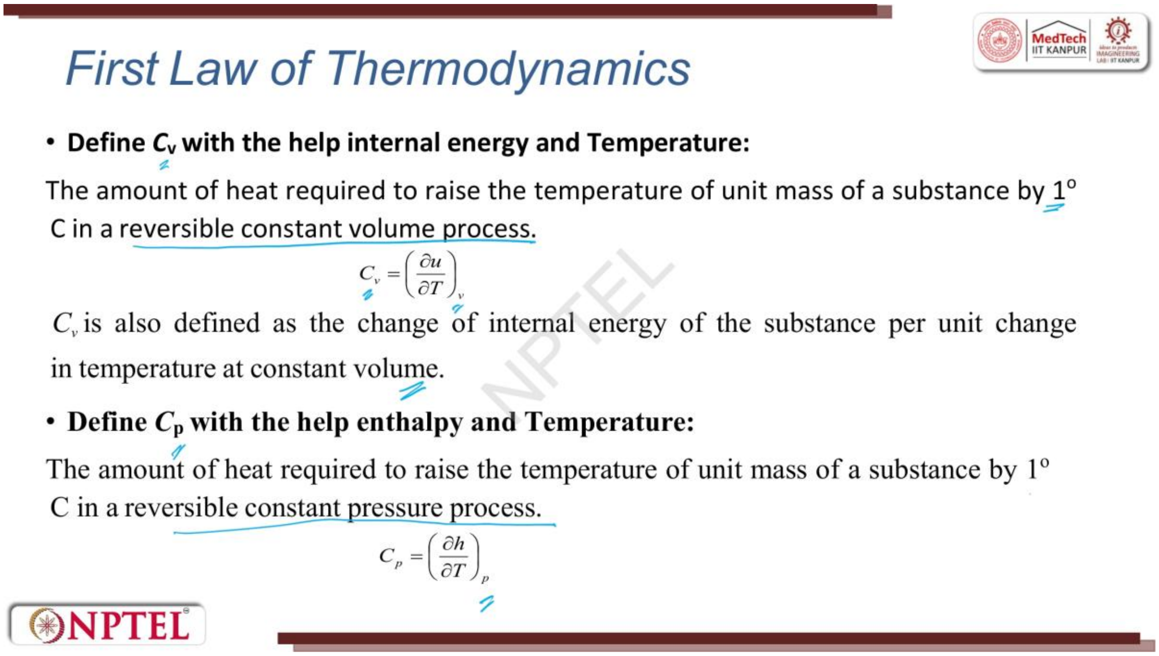


So, now let us understand the first law of thermodynamics. We will try to discuss enthalpy. It is the energy content of the fluid flow. What is enthalpy? It is the energy content of the fluid flow. It is defined by the summation of internal energy and flow work.

So, now we have studied two terms which are called entropy and enthalpy. So, entropy P Y enthalpy is P Y, right? So, entropy and enthalpy. So, entropy we know is S, and enthalpy is H. Now, we will try to understand what enthalpy is. So, it is the energy content of a flowing fluid, enthalpy.

It is defined by the summation of internal energy plus flow work. Internal energy plus flow work, that is H. For an ideal gas, H = U + PV. PV is nothing but RT. So, H is a function of T. So, if you look at this figure, enthalpy H is nothing but H = U + PV.

So, here is a system surrounding; heat is applied to an ideal gas to increase the internal energy. So, you can see the gas expands to pressure on the piston and creates a new volume.



So, defining Cv with the help of internal energy and temperature. What is Cv? Cv is the change in the internal energy, right?

The amount of heat, Cv, the amount of heat required to raise the temperature of a unit mass of a substance by 1 degree Celsius in a reversible constant volume process is Cv. C is defined as a change in the internal energy of a substance per unit change in the temperature at a constant volume is Cv. $C_v = \left(\frac{\partial u}{\partial T}\right)_v$

For Cp, which is a constant pressure process, the amount of heat required to raise the temperature of a unit mass of a substance by 1 degree Celsius in a reversible constant pressure process. $C_p = \left(\frac{\partial h}{\partial T}\right)_p$

First Law of Thermodynamics

C_p is also defined as the change of internal energy of the substance per unit change in temperature at constant pressure.

Process	Index=n	Q	W = ∫PdV	P-V-T Relation
Rev. Const. Vol.	∞	$Q = \Delta U = mC_v(T_2 - T_1)$	W = 0	$P_1/T_1 = P_2/T_2$
Rev. Const. Pressure	n = 0	$Q = H = mC_p(T_2 - T_1)$	$W = P(V_2 - V_1) = mR(T_2 - T_1)$	$V_1/T_1 = V_2/T_2$
Rev. Isothermal	n = 1	$Q = W = PV\ln(V_2/V_1)$	$W = PV\ln(V_2/V_1)$	$P_1V_1 = P_2V_2$
Rev. Adiabatic	n = γ	$Q = 0$	$W = (P_1V_1 - P_2V_2)/(\gamma - 1)$	$P_1V_1^{\gamma} = P_2V_2^{\gamma}$
Rev. Polytropic	n	$Q = \Delta U + W$	$W = (P_1V_1 - P_2V_2)/(n - 1)$	$P_1V_1^{n} = P_2V_2^{n}$

So, the first law of thermodynamics, Cp is also defined as the change of internal energy of a substance per unit change in temperature at a constant pressure, Cp. $\gamma = Cp/Cv$.

Process	Index=n	Q	W = ∫PdV	P-V-T Relation
Rev. Const. Vol.	∞	$Q = \Delta U = mC_v(T_2 - T_1)$	W = 0	$P_1/T_1 = P_2/T_2$
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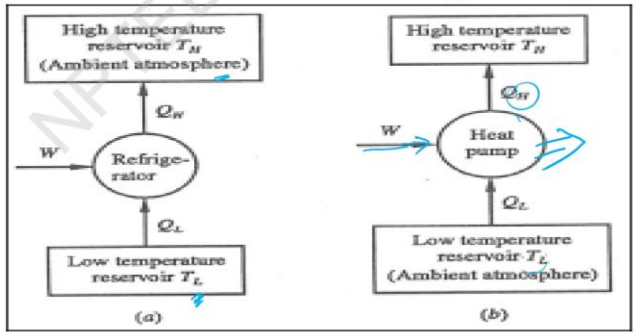
Rev. Adiabatic	n = γ	$Q = 0$	$W = (P_1V_1 - P_2V_2)/(\gamma - 1)$	$P_1V_1^{\gamma} = P_2V_2^{\gamma}$
Rev. Polytropic	n	$Q = \Delta U + W$	$W = (P_1V_1 - P_2V_2)/(n - 1)$	$P_1V_1^{n} = P_2V_2^{n}$

First Law of Thermodynamics

- The First Law highlights that energy can enter or leave a system only through heat transfer or work interactions.
- It is a universal law that applies to all types of systems—whether open or closed—and it underpins the design and analysis of machines such as engines, turbines, refrigerators, and power plants.



https://www.vaia.com/en-us/explanations/physics/particle-model-of-matter/internal-energy/

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So, this you have to keep it in mind, so that you can solve problems. The first law highlights the energy can enter or leave the system only through a heat transfer or work interaction. It is a universal law that applies to all types of systems, whether it is an open or a closed loop, and we underpin the design and analysis of a machine such as engines, turbines, refrigerator and power plants. So, we have higher temperature reservoir TH. So, you have a refrigerator.

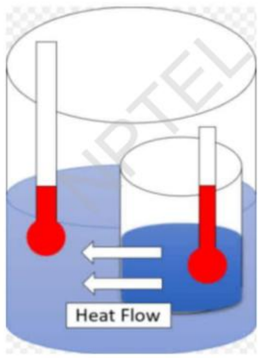
We have a lower temperature reservoir TL. So, Q is the energy QL TH. Here is the work done. Higher temperature reservoir which is the ambient temperature. Here, it is the low temperature.

So, Q goes here. Work is done on the system. So, when you try to take heat pumps, high temperature reservoir, TH, is in the top; and here you will have low temperature reservoir, TL, which again follows QH, TL and work is done to the system. So, you will have a heat. Let it be a heat pump. Let us be a refractor, sorry, refrigerator. So, you will try to have a similar system.

So, this applies the first law of thermodynamics. Friends, it would be nice if you could spend a little time and see what a heat pump is. Heat pumps are energy-efficient pumps that are used extensively today. If you are not able to understand, in the tutorial, we will try to cover what heat pumps are.

First Law of Thermodynamics

- Ultimately, the First Law serves as the **fundamental energy balance equation** and is essential for understanding and designing any thermodynamic process or system.



https://www.vaia.com/en-us/explanations/physics/particle-model-of-matter/internal-energy/

Ultimately, the first law serves as a fundamental energy balance equation and is essential for understanding and designing any thermodynamic system or process. So, this is the first law of thermodynamics.

First Law of Thermodynamics

- For any system and in any process, the first law can be written as

$$Q=\Delta E+W$$

Where E represents all forms of energy stored in the system.

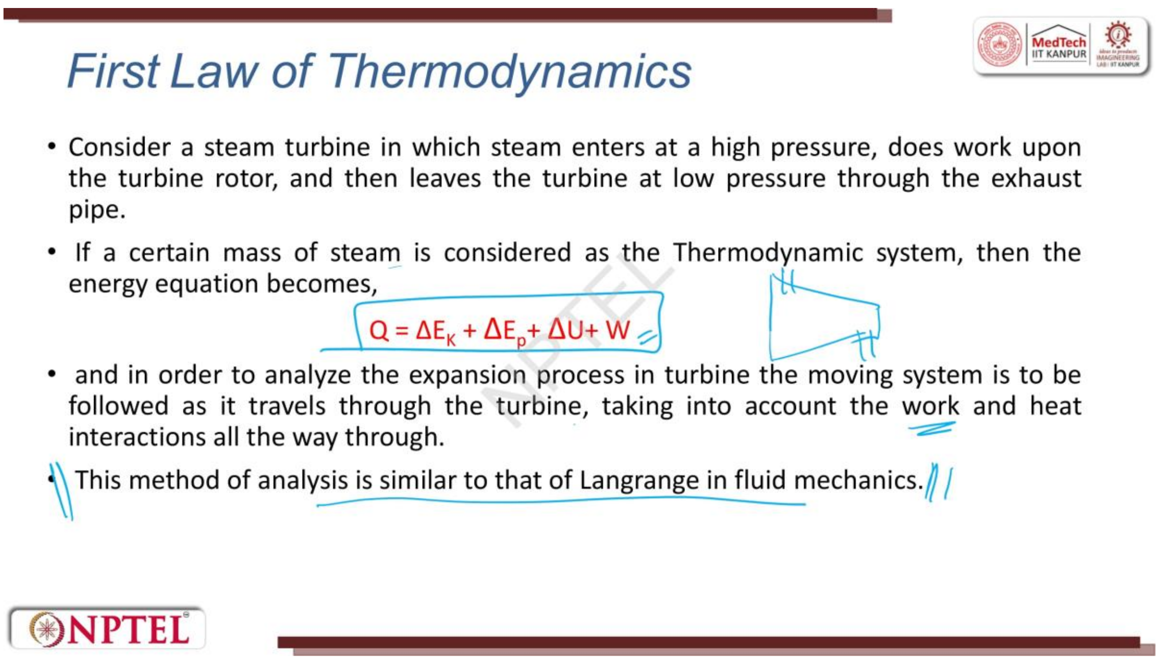
- For a pure substance,

$$E=E_K+E_p+U$$

where E_K is the K.E., E_p the P.E., and U the residual energy stored in the molecular structure of the substance.

So, for any system and in any process, the first law can be written as Q equals delta E plus W. For a pure substance, it will become E equals KE plus PE plus U. What are KE and PE? Kinetic energy and potential energy. So, KE is the kinetic energy, PE is the potential energy, of what? Of a pure substance, and U is the residual energy stored in the molecular structure of a system. So, this is how you try to bring the first law of thermodynamics for mathematical solving.

So, here, Q = dE + W. Now, we are talking about E. E = Ek + Ep + U. So, now, you take it there and then you substitute it.



So, considering a steam turbine in which steam enters at a high pressure, thus works upon the turbine rotor, and then leaves the turbine at a low pressure through the exhaust pipe. If a certain mass of steam is considered as a thermodynamic system, then

$$Q = \Delta E_K + \Delta E_p + \Delta U + W$$

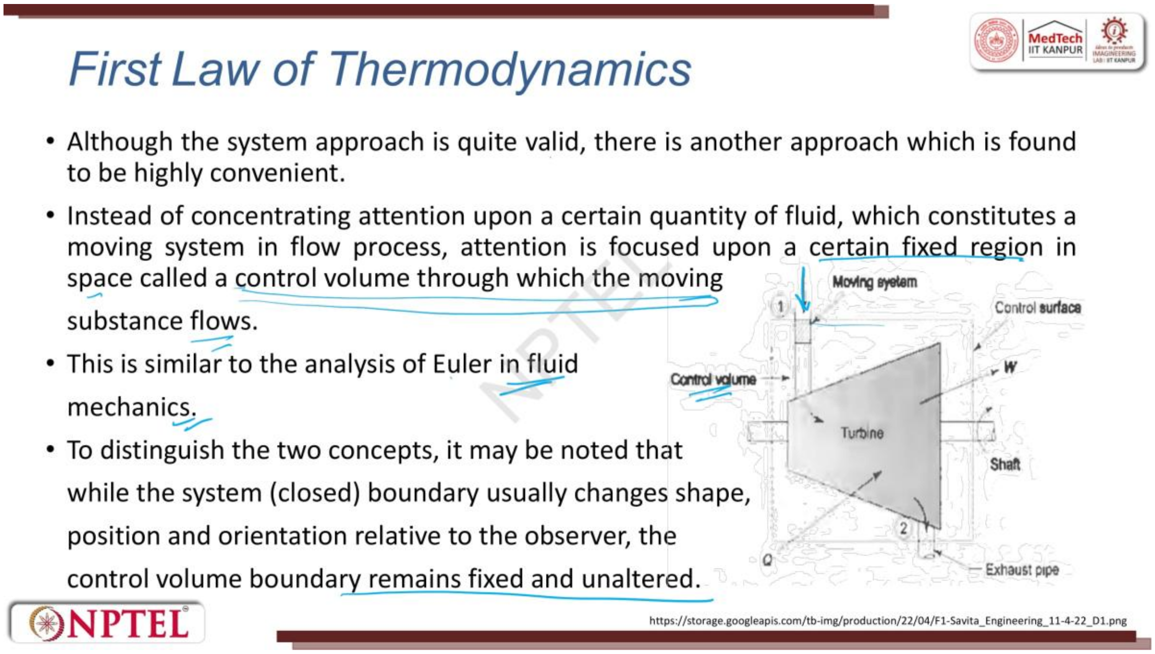
So, this work is nothing but when you open a water tap. The water gushes from the tap, and you have a very small turbine blade. So, it hits the turbine blade and the turbine blade rotates or you blow air and then you have a paper windmill when you blow it, this is a force which is on a tangent and it rotates. So, this rotation is nothing but the work. If you are blowing a steam of very high energy and rotating a turbine. So, then what happens when the turbine rotates there is a shaft, from this shaft you tap out an output. So, that is called the work.

So, that is what we say, here in a certain mass of steam is considered as a thermodynamic system, then the energy equation can be written like this. And, in order to analyze the expansion process. Why is called as expansion? Because in a steam in a turbine, what happens, they come with high energy and leave with low energy because they have done the work there.

So, in order to analyze the expansion process in turbine, the moving system is to be followed as it travels through the turbine, taking into account the work and the heat whatever is given to the system. This method of analysis is similar to Lagrangian in fluid mechanics. So, it is almost the same.

If people want to make an analogy, they can try to make it with Lagrangian in fluid mechanics. Although, the system approach is quite valid, there is another approach which is found to be highly convenient. Instead of concentrating attention upon a certain quantity of fluid which constitutes a moving system in flow process, attention is focused on a certain fixed region in space called as controlled volume through which the moving of a substance happens. So, what we are trying to say is, here is a moving mass, here is a controlled surface, this dabba is a controlled surface and what you have in a controlled surface is a controlled volume. So, now in order to make it little more easier, we try to always consider a controlled volume through which the moving is happening.

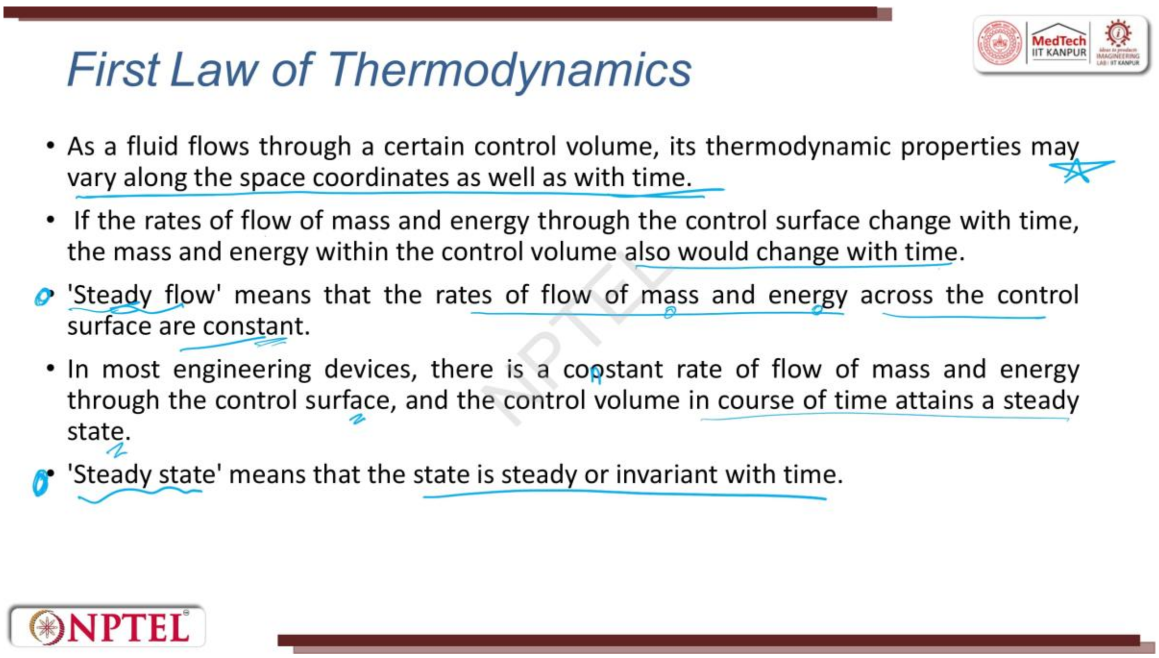
Why is it? Because you know the formulas, whatever we saw here, constant volume. So, you can use it for problem-solving from reality to a little bit of idealistic condition and try to get the answer. So, this is similar to the analysis of Euler's in fluid mechanics. So, this course is also a combination of thermodynamics and fluid mechanics. So, you will have fluid mechanics where similar concepts are also used to distinguish the two concepts. What are the two concepts?



Although the system approach is quite valid. So, what is the first approach? The first approach is, we try to take a system wherein we try to put everything in reality. The second thing is, we try to consider a dabba.

Inside a dabba, there is a constant volume. Still, the same thing is going on. To distinguish the two concepts, it may be noted that while the system boundaries usually change shape, position, and orientation relative to the observer, the control volume boundaries remain fixed and unaltered. Though there is rotation happening, the boundary which is fixed for the turbine is constant. So, to distinguish the two concepts, the first concept and the second concept.

What is the second concept? We have a turbine which is put inside a constant surface. Instead of constant surface, constant volume, it rotates. To distinguish the two concepts, it may be noted that while the system boundaries usually changes the shape, position and orientation relative to the observer, the control volume boundaries are fixed and unaltered.



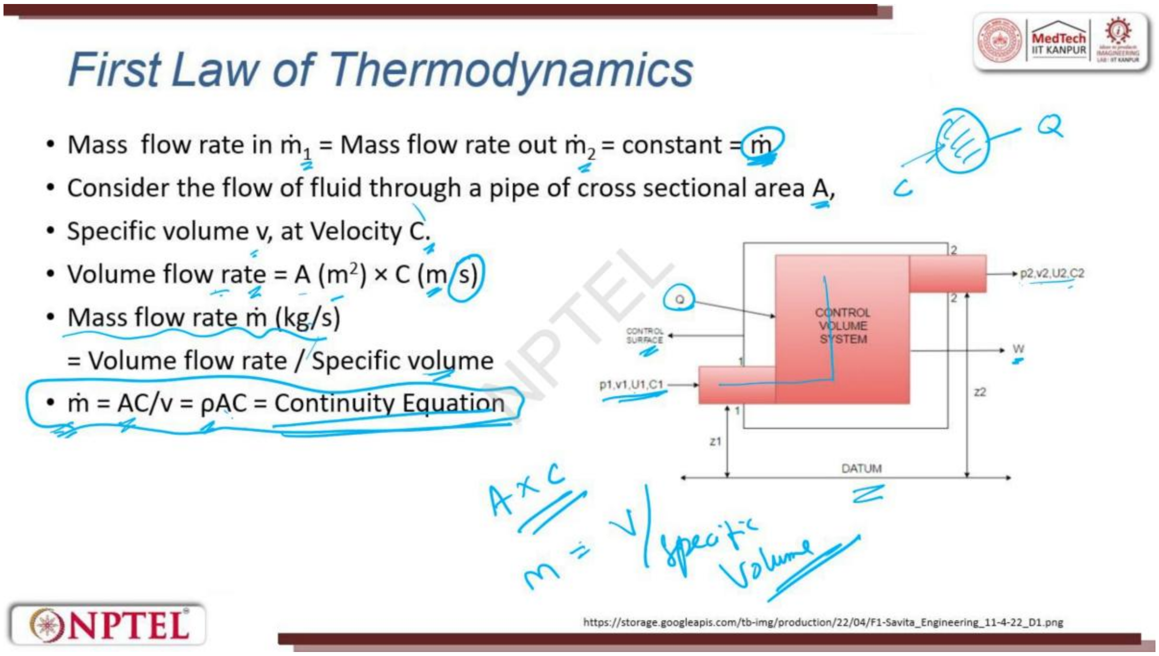
So, as a fluid flow through a control volume, its thermodynamic properties may vary along the space coordinates as well as with respect to time, which is known.

This is an important point, please make a note. So, vary with the space coordinate and varies with time. If the rate of flow of mass and energy through the constant surface changes with time, the mass and energy with the control volume also changes with time. The rate of flow of mass. Whatever steam, mass and energy through the control surface change with time.

What is control surface? The external Dabba which is drawn here, control surface, right? So, control surface with time, the mass and energy within the control volume also would change with time. There is always a steady flow, the steady flow means the rate of flow of mass and energy across the control surface is constant. In most engineering devices, there is a constant rate of flow of mass and energy through the control surface, and the control volume in course of time attains a steady state.

Please try to understand what steady flow is and what steady state is. Steady state means the state is steady or invariant with time; this is steady state. Do you know what a state is? Steady flow is when the rate of flow of mass and energy across the control surface is constant. So, now you know two new concepts: steady flow and steady state.

So, steady state means the state is steady or invariant with time; this is steady state. State—go back to the first few lectures; I have defined what a state is. Flow is the rate of flow of mass and energy across the control surface.



So, the mass flow rate is m1, and the mass flow rate is m2, which is a constant; we call it m. Consider the fluid flowing through a pipe with a cross-sectional area of A. The specific volume at a velocity c. So, I am trying to explain the flow with which a fluid is moving.

So, I have given the cross-sectional area of a pipe. I have told you what the discharge Q is. I have also told you the velocity with which it is flowing, c. And now, I want to find out the flow rate. Flow rate is nothing but area multiplied by velocity. Rate—when you say flow rate, it has to be something with respect to seconds.

So, that is what comes from here. Right. And then, I say flow. Flow means there has to be a mass, and then there has to be a length scale. So, it is M, and the length scale is also added. So, this is the volume flow rate. Volume flow rate is A x C. And the mass flow rate is M, which is nothing but volume flow rate divided by specific volume. Okay. That is the mass flow rate. So, from here, if we indirectly want to find out M, M is nothing but AC by V, which is equal to rho AC, which is nothing but the continuity equation.

So, here it is P1, V1, U1, C1 flowing through this pipe. Then there is a control system where its entry is P1, V1, U1, C1, and exit is P2, V2, U2, C2, right? This is the exit. So, then there is a Q, which happens inside the system. There is a constant surface, which is a control surface that is there, right. So, here is W, and then this is there. So, the datum is the base, right.

So, what are we trying to find out? What is this M? So, M = AC/v, and the mass flow rate is found out by volume flow rate divided by specific volume. Specific volume is per unit volume, you are saying, right?

First Law of Thermodynamics

Notations	At Inlet	At Exit	Units
PRESSURE	P_1	P_2	Pa → MPa; GPa
SPECIFIC VOLUME	v_1	v_2	m^3/kg
SPECIFIC INTERNAL ENERGY	u_1	u_2	J/kg
VELOCITY	c_1	c_2	m/s
ELEVATION FROM ARBITRARY DATUM	z_1	z_2	m
MASS FLOW RATE	$\dot{m}_1 = \dot{m}$	$\dot{m}_2 = \dot{m}$	kg/s
CROSS-SECTION OF STREAM	A_1	A_2	m^2
SPECIFIC ENTHALPY	h_1	h_2	J/kg

- Heat transfer rate to the system = Q [J/s]
- Work transfer rate from the system = W [J/s]

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So, now, the first law of thermodynamics—further, if you want to take the notations—at inlet, at exit, and what are the units?

Notations	At Inlet	At Exit	Units
PRESSURE	P_1	P_2	Pa → MPa; GPa
SPECIFIC VOLUME	v_1	v_2	m^3/kg
SPECIFIC INTERNAL ENERGY	u_1	u_2	J/kg
VELOCITY	c_1	c_2	m/s
ELEVATION FROM ARBITRARY DATUM	z_1	z_2	m
MASS FLOW RATE	$\dot{m}_1 = \dot{m}$	$\dot{m}_2 = \dot{m}$	kg/s
CROSS-SECTION OF STREAM	A_1	A_2	m^2
SPECIFIC ENTHALPY	h_1	h_2	J/kg

First Law of Thermodynamics

Assumptions-

- There is no accumulation or decrease of mass in the control volume at any time.
- The rate of mass transfers at inlet and exit are equal.
- The state and energy of the fluid at inlet, exit and in the control volume do not vary with time.
- The rate of heat and work transfers across the control volume are constant.

S.F.E.E. on unit time basis –

Total energy flow rate into the control volume = total energy flow rate out of control volume.

So, when we wrote this first law of thermodynamics, it was not fully straightforward. There were a lot of assumptions made. Why do you want to know these assumptions?

Because these assumptions will give you a lead for the second law. The assumption is that there is no accumulation or decrease of mass in the control volume at any given time, which never happens. There is no accumulation or decrease of mass. So, the mass changes. That's what they say—in the control volume at any given time.

So, that is an assumption. The rate of mass transfer in the inlet and the outlet are equal, which never will happen. There will be losses and there will be friction. The state and the energy of the fluid at inlet and the exit and in the control volume do not vary with time, which is also not true, which varies with time. The state and the energy of the fluid at inlet and exit varies in a constant volume, varies with respect to time.

Then, the rate of heat and work transfer across the control volume is a constant which is never happens, right. So, the SFE on unit time basis total energy flow rate into the control is equal to total energy flow rate out of the control volume. So, here, it is into the control volume, volume is missing. Total energy flow rate into the control volume is equal to total energy flow rate of the constant control flow rate in flow out, right. So, this is the same.

First Law of Thermodynamics

$$Q + m\left[U_1 + P_1V_1 + \frac{C_1^2}{2} + g \cdot z_1\right] = W + m\left[U_2 + P_2V_2 + \frac{C_2^2}{2} + g \cdot z_2\right]$$

$$Q - W = \left[(U_2 + P_2V_2) - (U_1 + P_1V_1) + \frac{(C_2^2 - C_1^2)}{2} + g(z_2 - z_1)\right]$$

Enthalpy – $h = U + PV$

$$Q - W = m\left[(h_2 - h_1) + \frac{(C_2^2 - C_1^2)}{2} + g(z_2 - z_1)\right]$$

$$Q - W = m\left[\Delta h + \Delta K.E. + \Delta P.E.\right]$$

So, now, these are the formulas which are derived out of the first law of thermodynamics. So, where did you get this? Let us see where did we get this?

$$Q + m\left[U_1 + P_1V_1 + \frac{C_1^2}{2} + g \cdot z_1\right] = W + m\left[U_2 + P_2V_2 + \frac{C_2^2}{2} + g \cdot z_2\right]$$

$$Q - W = \left[(U_2 + P_2V_2) - (U_1 + P_1V_1) + \frac{(C_2^2 - C_1^2)}{2} + g(z_2 - z_1)\right]$$

Enthalpy – $h = U + PV$

$$Q - W = m\left[(h_2 - h_1) + \frac{(C_2^2 - C_1^2)}{2} + g(z_2 - z_1)\right]$$

$$Q - W = m\left[\Delta h + \Delta K.E. + \Delta P.E.\right]$$

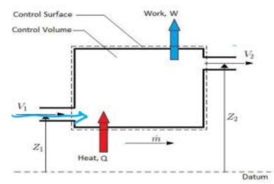
So, please remember this formula. We just went around the formulas.

First Law of Thermodynamics

Boiler:

- A boiler is a steady flow device used in power plants to convert liquid water into high-pressure steam by supplying external heat.
- It is a key component in steam power cycles (like the Rankine cycle).
- Working Principle: Water enters the boiler as a compressed liquid and exits as saturated or superheated steam.
- Heat is added, but no work is done by the system (neglecting pump work and assuming negligible changes in kinetic and potential energy).
- For a boiler - W =0, ΔK.E.=0 and Δ P.E.=0
- On using these conditions S.F.E.E. Equation,

$$Q = m\,(h_2 - h_1)$$



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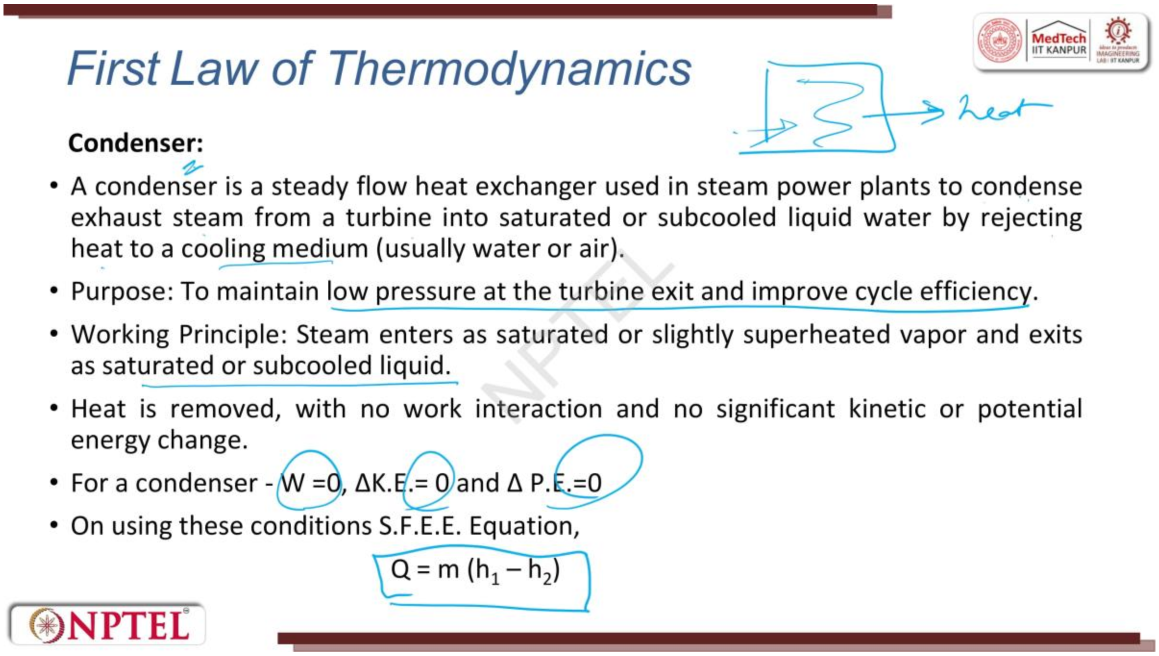
Let us take a boiler. A boiler is a steady flow device used in power plant to convert liquid water into high pressure steam by supplying external heat. So, this is boiler, you give at some velocity you send water into the boiler. So, you keep on applying heat to the to the water. So, then, what happens at a elevated time or at a elevated temperature with a long time all this water is converted into steam and this steam is ejected out through this. So, the boiler is a steady flow device used in power plant to convert liquid water into high pressure steam by supplying heat into the system.

So, when it leaves the system, the work is done, and then it the heat is lost. So, then, it comes back, and then you again apply heat. It is a key component in the steam power cycle like in Rankine cycle. The working principle is, water enters the boiler as a compressed liquid and exits as a saturated or a super saturated steam. So, it is nothing but take an example of a pressure cooker. You pour water into the pressure cooker and start heating.

There is a flow inside or you pour it inside a standard volume, and over a period of time when you start heating, the water gets converted into steam. That is what we say, the water enters the boiler as a compressed liquid and exits as a saturated or a superheated steam. The heat is added, but no work is done. Heat is only added, but no work is done in a system. So, neglecting pump work and assuming negligible change in the kinetic and potential energy for a boiler. W = 0, dKE = 0, dPE = 0.

In this situation, the SFE equation can be written as Q = m (h2 - h1). Which is nothing but change in enthalpy.



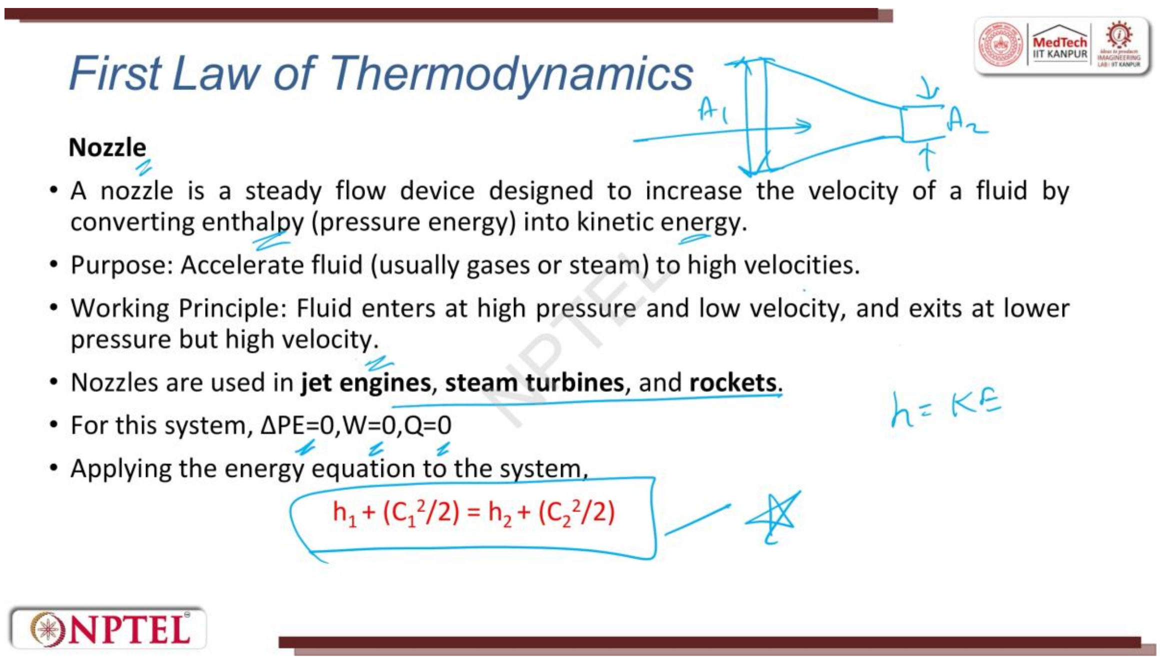
When you try to talk about the condenser, this is for a boiler. When you try to talk about a condenser, a condenser is again a steady-flow heat exchanger used in steam power plants to condense exhaust steam from the turbine into saturated or supercooled liquid water by ejecting heat to a cooling medium. So, the condenser is condensing.

Here, what happens? You have a dabba. So, there is a lot of heat. You eject the heat out. That's what they are saying.

A condenser is a steady-flow heat exchanger used in steam power plants to condense exhaust steam. So, you get steam coming inside. Steam from the turbine into saturated or supercooled liquid water by ejecting heat to a cooling medium. So, the cooling medium can be air or anything. The purpose is to obtain low pressure at the turbine exit and improve the cycle efficiency.

So, whatever water comes, you eject the water out and then you use it. The working principle is the steam enters as a saturated or slightly supersaturated vapor and exits as a saturated or subcooled liquid. So, here the heat is removed. There is no work done. So, work is 0, KE is 0, PE is 0.

So, here, Q = m (h1 - h2). So, if you see the previous one, it is h2 minus h1. If you see 1 here, h1 minus h2. But for the rest, the only difference is heat is added or heat is rejected.



Let us try to take a nozzle. A nozzle is primarily used to increase the pressure. When the area reduces, when you are trying to flow fluid through this, when you try to reduce the area, the velocity increases because continuity must be maintained. The nozzle is a steady-flow device designed to increase the velocity of a fluid by converting enthalpy into kinetic energy, h into kinetic energy. So, the purpose is to accelerate the fluid to a very high velocity. So, the working fluid is: the fluid enters at a high pressure and low velocity and exits at a low pressure and high velocity.

So, it is used in jet test steam turbines etc., where W = 0, Q = 0, PE = 0. So, the system equation can be written as $h_1 + (C_1^2/2) = h_2 + (C_2^2/2)$. So, this is the formula for a nozzle which is very important.

First Law of Thermodynamics

Turbine :

- A turbine is a steady flow device that extracts work from a high-pressure fluid (steam, gas, or water) by expanding it through a series of blades.
- Purpose: To convert enthalpy (internal energy + flow work) into mechanical work.
- Working Principle: Fluid enters at high pressure and enthalpy, expands through the turbine, and exits at lower pressure and enthalpy.
- Common in power plants, aircraft engines, and hydroelectric stations.
- Applying energy equation to the system,

Here, $Z_1 = Z_2$

$$h_1 + (C_1^2/2) - Q = h_2 + (C_2^2/2) + W$$

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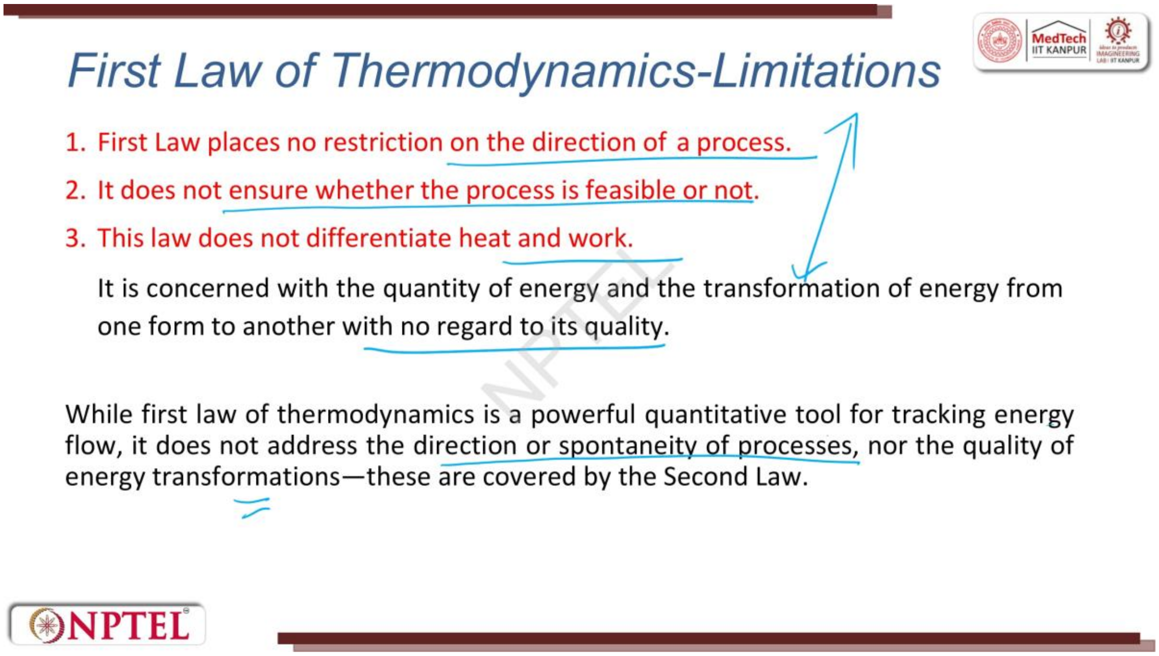
So, when we try to talk about a turbine itself as a full system, turbine is a steady flow device that extracts work from the high pressure fluid by expanding through a series of blades. So, turbine is a steady flow device that extracts work. Turbine itself, something rotates from a high pressure fluid. The fluid which comes inside is high pressure and high temperature.

So, steam comes, high pressure fluid by expanding it through a series of blades. So, to convert the enthalpy, internal energy plus flow enthalpy, which we saw earlier into a mechanical work is the purpose. The fluid enters at the high pressure and enthalpy expands through the turbine and exits at a low pressure and enthalpy. So, the fluid enters at high pressure and exits with a low pressure and enthalpy, enthalpy is there. It is commonly used in aircrafts, hydroelectric stations.

So, the formula is nothing but Z1 = Z2. This is how we represent Z1 and Z2. So, enthalpy, whatever it is. So, it is derived from the previous formula. So, it is only differences see you see here Q = 0. So, here what happens Q is minus and you add W in the previous one. You never had both the equations.



So, the first law has its own limitations. The first law places no restriction on the direction of the process; it does not ensure whether the process is feasible or not, it just describes everything. This law does not differentiate between heat and work. So, these are the problems with the first law. And, the first law also has so many assumptions. So, these are the assumptions it has.

So, I assume this. I assume the fluid is Newtonian. I assume the fluid is ideal. So, all these things were there. Mass flow rate is uniform. So, the rate of mass transfer at the entry and exit is equal. The state of the fluid at the inlet and outlet is the same.

The rate of heat and work transfer across the control volume is constant. So, all these things are assumptions. But based on these assumptions, then what is this? We have also found certain limitations. It is concerned with the quantity of energy and the transformation of energy from one form to another with no regard to its quality, which is one of the biggest limitations.

While the first law of thermodynamics is a powerful quantitative tool for tracking energy flow, it does not address the direction and spontaneity of the process, nor the quality of the energy transformed. So, it demands going for the second law of thermodynamics. And thank you so much.