Indian Institute of Technology Kanpur

National Programme on Technology Enhanced Learning (NPTEL)

Course Title
Engineering Thermodynamics

Lecture – 01
Thermodynamics and its application

By
Prof. D. P. Mishra
Department of Aerospace Engineering
Indian Institute of Technology
Kanpur – 208 016
mishra@iitk.ac.in

I welcome all of you for this important and fascinating subject, that is engineering thermodynamics all of you might be aware of this thermodynamics because in your courses like +2 science and here also you might be exposed through the various concepts of thermodynamics however we will be trying to recapitulate some of the concepts in the beginning then later on we will have to look at the application parts of the thermodynamics what we will call engineering thermodynamics. So let us now look at it and what do you mean by thermodynamics.

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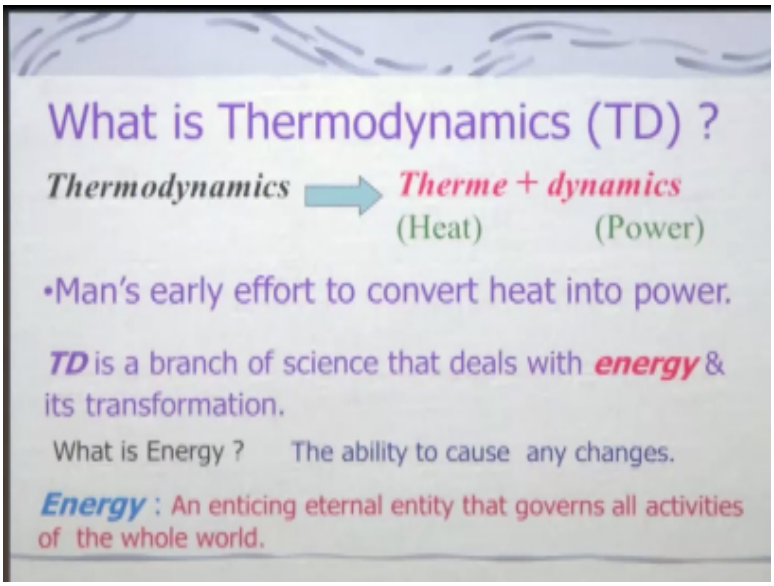

Can anybody tell me, this word if you look at the word the thermodynamics of this word then it is basically originated from two Greeks world one is the therme other is dynamics therme means it is basically the heat and dynamics means power. So if you look at one can say that basic idea of thermodynamics is to convert this heat into power but that was the old concept in earlier days people where you know concern about that how to convert this heat energy into the power why it is so.

Because to overcome the limitation of the man's physical power right and that is why if you look at this heat basically comes from the fire that is the reason why our ancestor always revered the fire and you can see of you know through these in our Vedic literature about fire till today also we always river the fire as the genesis of the life in this beautiful world.

So but later on you know earlier days it was but if you look at this is as I was telling that is the early days man's were trying to look at this how to convert this heat into power, but today the concept is little different and it has been expanded so today it is about the energy and its transformation if you look at in earlier days historically energy is a new word which was basically coined by in 1807 by unction and it was not accepted at that time you know whenever you give a new concept you know people do not you know take it what you call as it is they always resist you know.

And then you know this energy is basically accepted in the middle of the19th century earlier days people were talking about heat caloric theory you might be knowing and then force and other things so if you look at the energy we do use this term in our day today life right for example you say look I am tired I don't have energy to do the walk right, so then when I say what do you mean by energy right it is a you know very commonly used word but little subtle to define I have already given the definition what by giving that example that is basically ability to do what in the you know text book if you look at physics or something you can see that.

But it is basically ability to cause any changes that we call it as energy even if you look at all whatever we see whatever we think whatever we do it is basically manifestation of energy but example if I am moving my hand like this right is it not a manifestation of energy even if I'm sitting quietly for example you are listening to me and then are you not expending the energy or utilizing the energy yes or no how, because even though you are sitting quietly lot of thought processes are going on in your mind right?

So those things are basically due to the energy transformation for example like you know that you will be knowing that the brain consumes the large amount of energy, so also the livers of all the components of your body itself and whatever we see it is energy right why even the whatever you see in the sense like your trees, animals, birds, river, sea and all are manifestation of energy and even if you go to the cosmic levels or the you know like a star, moon, Sun right all are in motion and all are having even atom molecules all are having basically transformation of energy.

So therefore I would like to define in little different way that energy is an enticing eternal entity that governs all the activities of the whole universe so if you look at whatever we see this phenomenal universe is basically manifestation of energy and in you know like an interaction with the matter and then what we will see as we go along we will see.

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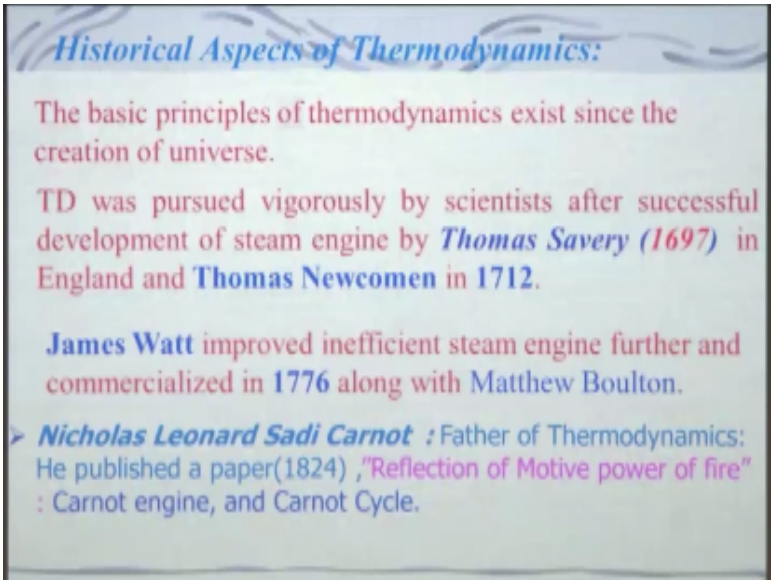

But that let us look at a very brief you know historical perspective of thermodynamics because the history is very, very, you know big and rich also a lot of people have done work if you look at the basic principle of thermodynamics exist from the stating of the universe if you look at you know Big Bang Theory then you know like the it was in the beginning very small and then expanded.

So from the very beginning of the creation of universe these principles will be there like it is similar to that any other physical laws for example you know if you look at a small baby will be

knowing about this laws of motions or not will be experiencing certainly yes a small baby will be experiencing laws effects because these are physical laws much before the Newton could think of up you know laws of motion looking at the Apple falling from a tree there now very existing.

So similarly thermodynamics also were the basic principle of thermodynamics exist before the creation itself or before from the you know broth of the universe so if you look at but thermodynamics was basically vigorously being pursued during the industrial revolution right because the man was very much tempted by the science and its utilities to overcome its limitation that is the physical power they want to overcome the you know problems with the other animals what they are using for their movements like horses and other things right.

So at that time there are two people who have done very good work that is Thomas survey and in 1697 in England and Thomas Newcomen in 1712 and they have you know spend a lot of time to design and develop a steam engine but unfortunately those engines were not accepted by the society because of fact that it was quite inefficient and it was popping out and then making lot of noise right.

And it is not that these two guys did a lot of other people might have burned their fingers for developing an engine to have some power convert this heat into that later on the James Watt is the person who improved this inefficient steam engine and could manage to develop a little better one. So that it can be accepted he along with Matthews Boulton in 1776 you know developed a engine steam engine and commercialize if you look at today that steam engine is out of business am I right.

But I am thinking that it may come up again some of you might have seen your steam locomotives did you see or maybe in old movies you will be looking at steam locomotives you know puffing out the gases and then coming out so this engine was the turning point for the thermodynamic as a subject to evolve because of its applications, and then later on the a person who is a very, very you know famous and contributed a lot of work his name is Nicolas Léonard Sadi Carnot who wrote a book basically a reflection of motive power of fire right.

And he lived a very short life around 40years you know but his work is so phenomenal he is known as the father of thermodynamics he like your Swami Vivekananda Swami Vivekananda lead for a only 40 years but his contribution to our country and to the whole world over our

Indian culture and tradition is concerned is phenomenal, so similarly he is he has done wonderful work and he is about Carnot engine and Carnot cycle which we will be discussing and later on the Lord Kelvin you know he coined a word in 1849 as thermodynamics. Earlier there was no thermodynamics as such as award right so I mean this is the turning point if you look at the Carnot who really saw that how it can be done and there is several other people who have worked.

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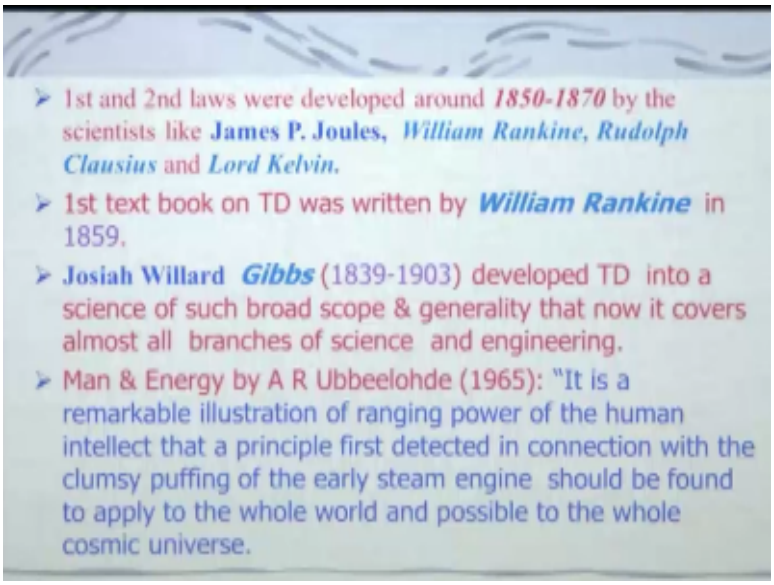

Before that if you look at the first law and second laws which were developed around 1852 1870 by scientists like jewels gems a Jules and William Rankine you might be knowing the Rankin cycles and other things he has developed and Rudolf Clausius and large Calvin were instrumental in developing the second law of thermodynamics. The first textbook was written on thermodynamics by William Rankine in 1859 just after 10years so that you know people can study and then it can be you know taught in the Universities and the new generation will come up and then contribute for the development of thermodynamics.

So if you look at there is another stalwart the Josiah Willard Gibbs who developed that thermodynamic into a science abroad you know spectrum and its scope and generality has been covered almost all branches of science and engineering so if you look at of course you might be aware of the gifts free energy and then gives equation which we will be discussing in this course so it is not that these are the people who have you know really developed this thermodynamic

subject is still a lot of people are working on that but these are the stalwarts who are the pioneers in this field and they have done.

So if you look at the thermodynamic is a very important subject and they A R Ubbeelohde in 1965 he wrote a book man and energy and he says it is a remarkable illustration of ranging power of human intellect that a principal first detected in connection with clumsy puffing of early steam engine should be found to apply the whole world and possible to the whole cosmic universe see that means you know thermodynamics is a very important subject and which is having so much of application that it can encompass whatever the science whatever the technology we can think of not only now also in future.

So if you look at there is a book I must recommend to you people you can read it that is a history of thermodynamics by ingo moola let me tell you it is not a book which you can read while travelling in a train or you know flight it is a little serious book but it gives the very good you know as what you call historical a perspective of how the thermodynamic is evolved and what are the issue that still there he has also mentioned which can be you know looked at it or investigated further.

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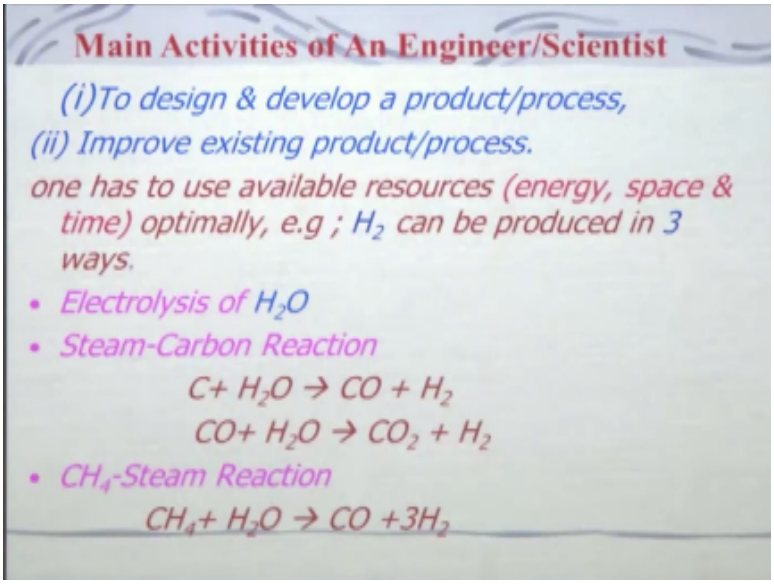

So as an engineer or a scientist some of you might be from the physics and other things so we need to understand what are the activities we need to undertake for our professional life can anybody tell me? Let me put another question what are the differences between an engineer and

a scientist can anybody tell me? You have toiled hard to come to engineering by you know like these vertical entrance examinations and working hard for two years what are what are the differences is there any difference?

Basically let me just tell you as all of you are not you know trying to or attempting to answer my question so engineer is basically try to find out whatever we are not ingesting earlier days for example like your pen ballpoint pen or your any other point pen was it there and let us say 2000 years back or 3000 years back no but let us say your fan your mobile phone and other things were not there that was been designed by the man to improve the quality of life right.

But whereas the Newton's law the laws of thermodynamics were existing before the man could they want to find out what it is and right to recognize what are the physical laws that govern the activities of the nature and then try to understand utilize it for the development of engineering product or the technology so if you look at the main activities of an engineer is basically to design and develop a product and process right what for to improve the quality of life.

And when you are doing that you will have to look at also the nature right and when you do that you will also need to find out how to improve the a product or a project process which is already just always there is a scope of improving it and then when you do that these activities then you will have to use the available resources and what are the available resources the available resources are energy that is very important what we will be dealing with in this course.

And the space and the time suppose you want to design a product it has to be done quickly otherwise the market will not look at it you may take some many years to develop a product but it may not be accepted and it has been happen it has happened in the history also. So if you look at all those things have to be you know optimally use that means an engineer has to work under a lot of constraints right.

So I will not develop on about the engineering aspect but I will tell you that it is very important let us take an example you know like hydrogen is a very benign fuel today am I right, because of fossil fuel is getting depleted and not only that it is affecting the environment adversely there for like you know hydrogen is considered as a very benign fuel and it has to be used that people are propagating it so that the we can avoid the pollution or the environmental pollution right.

So for that we may need to use hydrogen because we know hydrogen will be reacting with oxygen going through the what product water and also little bit a no X may be produced in the process of during combustion at the burning of hydrogen but hydrogen is not available with us in the natural form so there has to be produce now if we want to produce how you can produce hydrogen what are the way that means you people might be aware am I right.

Let us say we can make it electrolysis of water right we can split the hydrogen and water we can speed the water into hydrogen oxygen it has to be separated so that you know you can collect it and there is another way of steam carbon reaction like we are having carbon lot of carbons are there right informs of fuel and coal and the several other things like carbon can be reacting with water going to the carbon monoxide and hydrogen.

So carbon monoxide is reacting with water going to the carbon dioxide and hydrogen right so if you look at these are endothermic reactions we need to supply certain amount of energy and means to elevate its temperature otherwise it would not work beside this will be using catalyst right for that to enhance the reaction rate and the reaction can go forward it can go backward and then we will have to see what extent it can go and so also.

So also there is another way of doing like you can use the methane steam reactants similarly methane will be reacting with water and it is going to the product of carbon monoxide and three moles of hydrogen and again this shift water shift reaction like carbon monoxide reacting with the water going to the carbon dioxide and hydrogen. Now if you look at this process already existing and then are we may have to develop because there are several other things are coming up in the process of developing producing hydrogen like your gasoline can be used or methanol some several other things. Now you need to look at like this you know ways of producing hydrogen.

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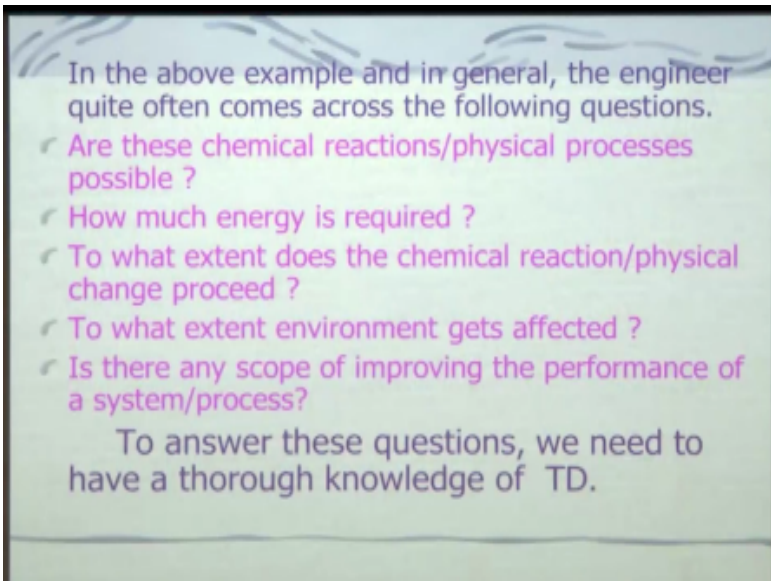

But however from the thermodynamic point of view you need to look at you know often ask certain questions in these reactions whether it is possible you know are these chemical reactions or physical processes are possible and even if it is possible then we will have to say how much energy is required to sustain this work because as I told these are endothermic if we gazelle more amount of energy what it can produce by the burning of hydrogen then it would not be accepted.

And to what extent does the chemical reaction physical change proceed that also we need to look at it we and what extent environment gets affected earlier days people are not bother about an environment but today it is very important otherwise you know survival of human being itself will be at stake. So is there any scope of improving performance of a system or a process because always we want to improve what extent what is the limit of that.

Whether or will be spending lot of time and finding out you know like this thing and then we later on we find look it is not the well posed problem right it is not possible to go beyond right and which will be you know be answered with the help of thermodynamic laws. So therefore you know you need to have a thorough knowledge of thermodynamic otherwise it is very difficult to look at these processes.

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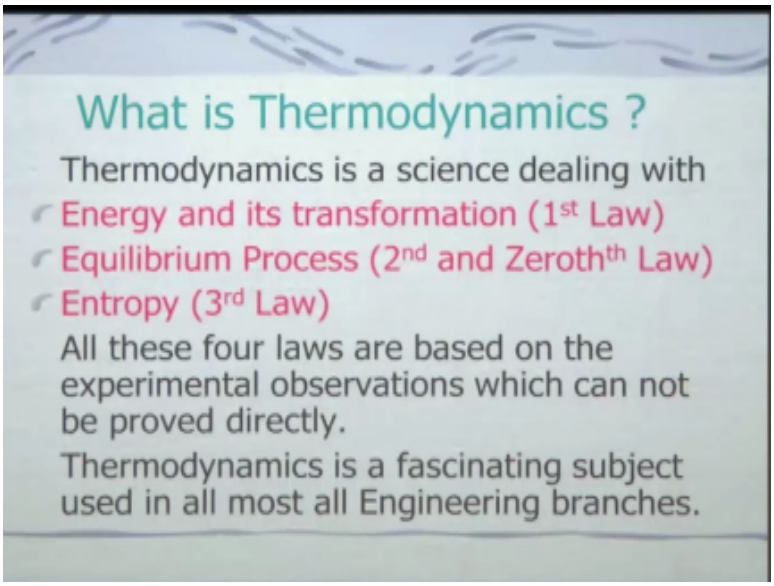

And if I summarize what is thermodynamic whenever we are dealing with thermodynamic will be basically looking at the first law of thermodynamics which is energy and its transformation you might be knowing that you know energy can neither be created or be destroyed it can be converted from one form to other right, is in it that is the law which you might have heard but what is this implication what is the limitation that you need to understand right.

And we will be discussing elaborately about the first law of thermodynamics and we will be applying it to for analyzing certain problems related to you know engineering aspects of that and the another thing is very important which is the second law of thermodynamics which we will be talking about equilibrium process that means what is the equilibrium and all those things we will be discussing but it will be also telling you what extent the a chemical reaction can proceed or a process can proceed and whether it will be feasible or not to have a process or a product you know like kind of things.

So that will be give you the direction and zeroth law of thermodynamics of course all of you know and it is basically they are talking about thermal equilibrium which we will be discussing

and will be mostly applying this first law and second law and will be taking care of zeroth law sometime and we will be defining a term which is known as entropy and entropy is very important it is not only applied for the thermodynamics or the engineering applications nowadays people are applying for economics and other things.

So that is the third law which is defining the entropy but we would not be using much but what we will be using in our course is the first law and second law of thermodynamics and 0th law to some extent, so all these four laws are based on experimental observations right which cannot be proved directly like your annoy you people are very much gaga about mathematics of course the mathematics is very important because it is the language of science but however you know these are all based on experimental if some of you could prove that these experimental observations based on which these laws are being you know put forward and being utilized are wrong.

Then you know you will definitely be contributing a lot so there is therefore lot of you know scope will be there to relook at it of course. You know one has to have that courage to challenge these laws and prove that it is wrong so if you look at thermodynamics a very fascinating subject used in almost all engineering branches so I will sum it up saying that what thermodynamic we will be looking at in this course is basically a energy and entropy and equilibrium.

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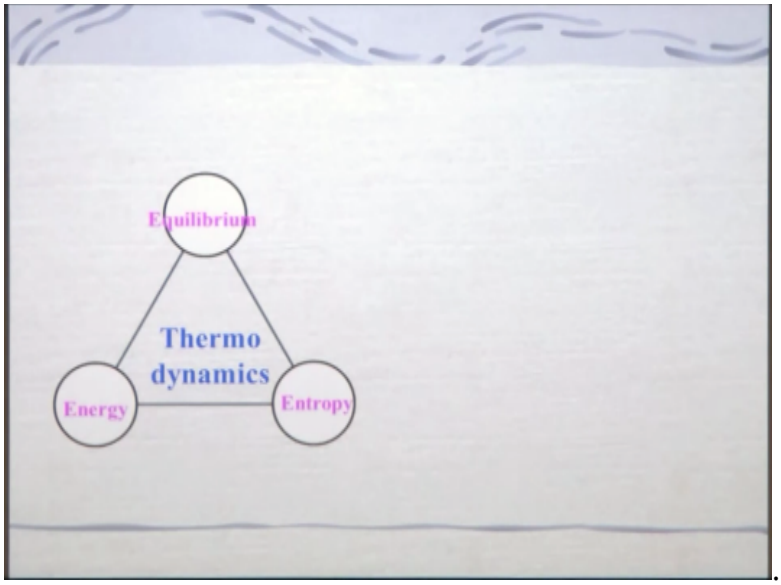

This is like a triangle you know but a question arises whether it is related to the human life when you talk about his human life is basically is having body and you are having a mind and there is a

spirit and this would be in balance right so their question arises whether you can say that thermodynamics is can be related to the human life and one can explain of course that I had I always believed that lot of your emotion and your happiness sorrow other things can be explained using the thermodynamic law.

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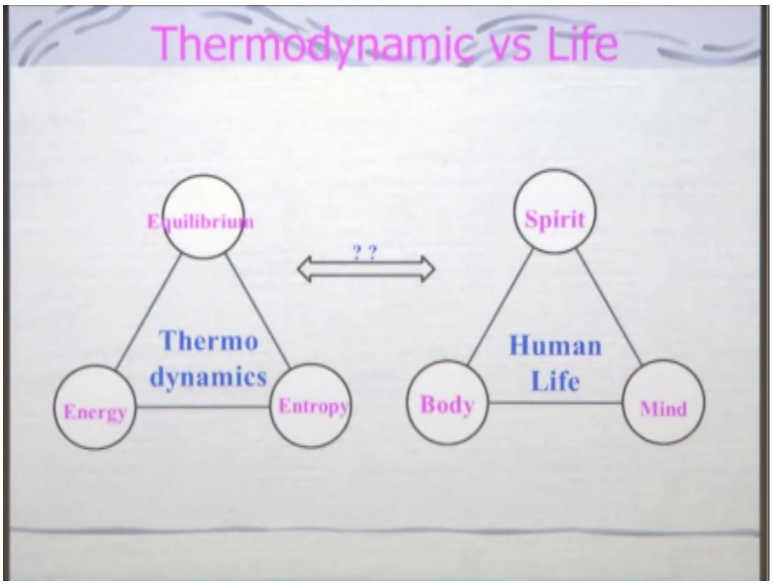

Provided you know you can think about It so we may not dealing with those things but I will be dealing with the general thing let us look at applications of thermodynamics right what are the application can anybody tell me what are the application you are aware so you can look at your household even right now in this room right you are having let us say camera you are having light right so these are all or you are having air condition in this room.

So these are all thermo dynamically you know systems which can be analyzed with the help of thermodynamic laws so just to give you some example like as almost all engineering activity involves the energy and its interaction with the matter so let us take for a few examples of them for example we use in our modern day life to have a better quality life what we call that is you know air conditioner and refrigerators.

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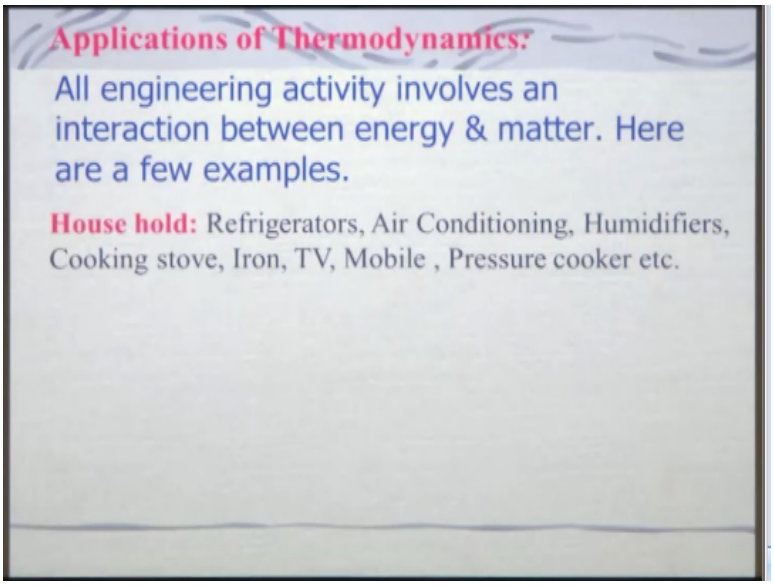

Most of the houses in urban areas we are having of course you should have enough money to purchase those product and humidifiers cooking stove of course cooking stout most of people have to use you know because they will have to cook food without put what you will do so I don t be mobile pressure cooker and so on so forth.

You can think of lot of things right and the if you look at industrial application enormous I have given few of them like your power pants right we get this you know energy whatever the electrical energy or any other form of energy we get you know like electricity we get that is being you know developed or that is being produced in power plants we had having coal power plant hydraulic power plant thermal power plant gas phase power plant right which will be discussing about and even your automobiles.

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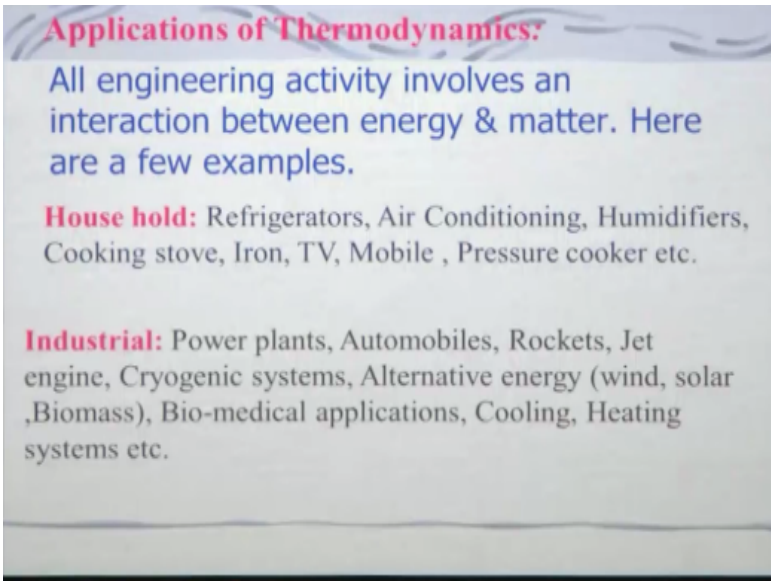

Rocket engines jet engines cryogenic systems right and of course nowadays people are very much concerned about how to develop the power using the alternative energy sources like solar Queen biomass and medical applications you know like we there are several products which can and cooling and heating systems and so on so forth there are several of them one can think of application wise.

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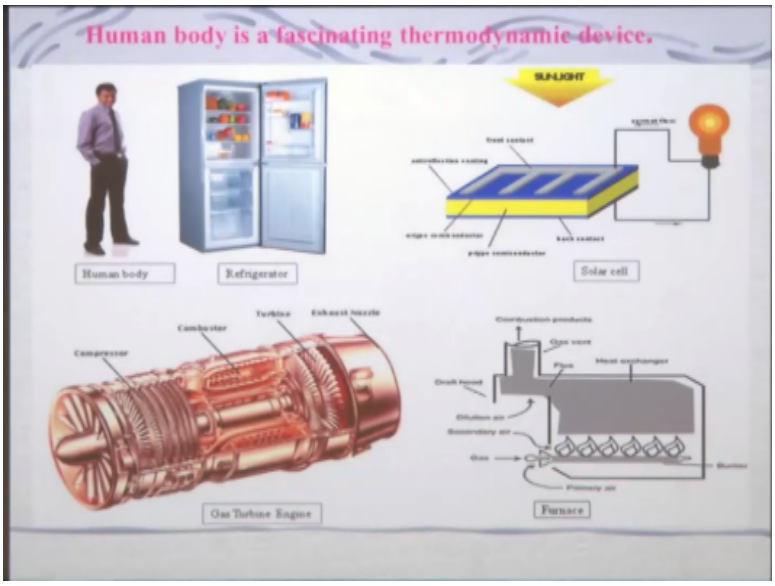

So if you look at the human body itself why human body even animal okay is a very fascinating thermodynamic device we do a lot of you know like what you call things in the body itself can be analyzed using the thermodynamic laws for example if you look at energy like if you take more food what will happen if you would not do exercise what will I when you we can move fast right it became to be so that you know one has to also talk about that so.

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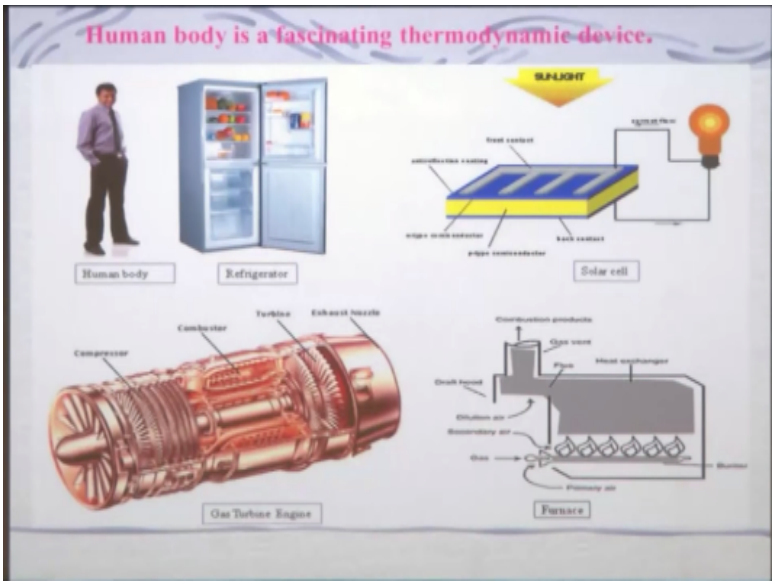

If you look at refrigerator and we are having solar cell nowadays lot of effort are being made to utilize the solar energy or country because we are getting a lot large amount of solar energy right and that can be utilized we are having gas turbine engines and your furnace which are being used for process industries like producing iron copper and there are several other places like we use this furnaces.

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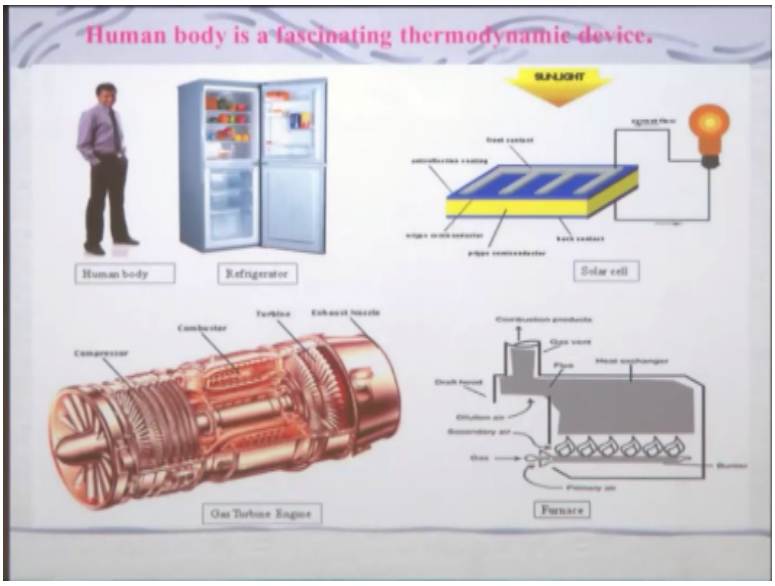

And if you look at we are having a very good you know ambitious space programs like spacecraft we are very good at this moment in the entire wall and it is quite cheaper to produce indigenous spacecraft and that those components can be analyzed by using the laws of thermodynamics as I told the coal power plants like if you look at you can get this coal and then you are having a boiler and it can be having a steam you know it can be paned in a turbine.

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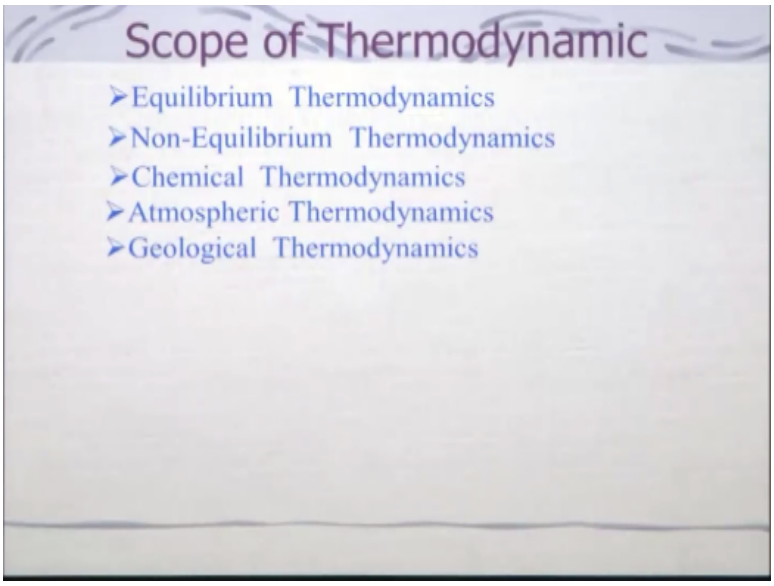

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And then you can get connected this turbine to the what you call generators and you can get this power to the transmission and then you will get power so most of in India a major chunk of power produced by the burning of coal and recent time you can get converted directly the what you call chemical energy into the directly to the electricity that is the fuel cell and lot of research is going on at this moment on the fuel cell development not only in our country in outside country also so if you look at the scope of thermodynamics is quite enormous.

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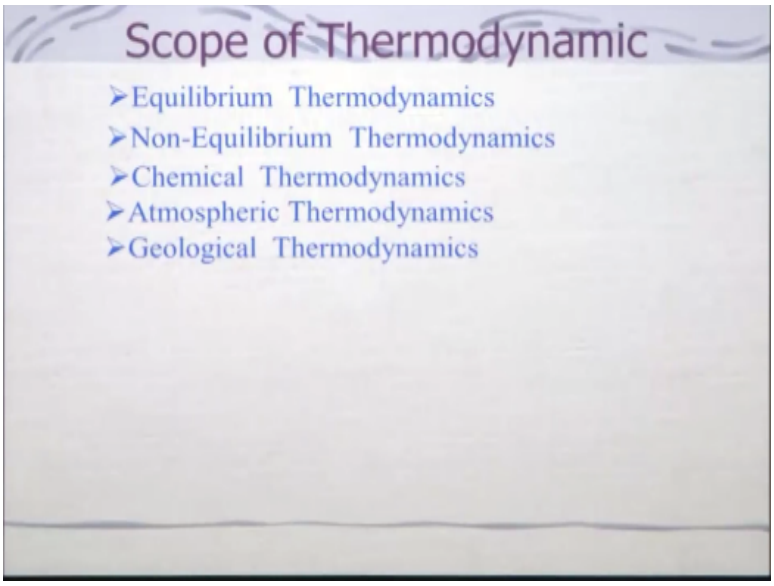

I will be giving you some of them like you can think of equilibrium thermodynamic which will be discussing basically in this course there is a non equilibrium thermodynamics which we won't be looking at and chemical thermodynamics those people from the chemical engineering hey will have to take this course chemical thermodynamics and atmosphere sermon which is quite important you know i n the global warming.

People are try in to understand what are the reasons and other things so it is quite important nowadays and geological thermal dynamics you can pick up Industrial ecology today ecology is in trouble and therefore lot of in handy through the Industrial Development and then we are spoiling the environment and we need to understand what is happening and how to talk about it so there is a thermal and statistical physics which is quite you know important in looking at the things and then that is also a thermodynamic comes into picture quantum thermodynamics to look at the quantum physics and statistical thermodynamics which we would not be discussing about.

Maybe I will just give a glimpses of it and there is a black hole thermodynamics knowledge is very important in talking about black holes and biological thermodynamics if some of you are from maybe biology you can look at there is a very interesting book is there or you know which You can study if you are interested I can tell you later on and the psychometric will be discussing little bit in your course whenever we are talking about refrigeration and air conditioning and the thermo economics this is a relatively you know new subject.

But however you know it is speaking of you can talk about economics and then apply the law of thermodynamic so therefore these are very important you know like this thing one can think of let me tell you that what Alber Einstein you know perceive the thermodynamic as a subject how does he perceive and he is one of the greatest you know scientist of the 21st century and is the best one of the best minds whatever human race has produced and he says that it is like a theory is impressive the greater the simplicity of its premises is the more the different kinds of things it relates the more extended it is its area of applicability.

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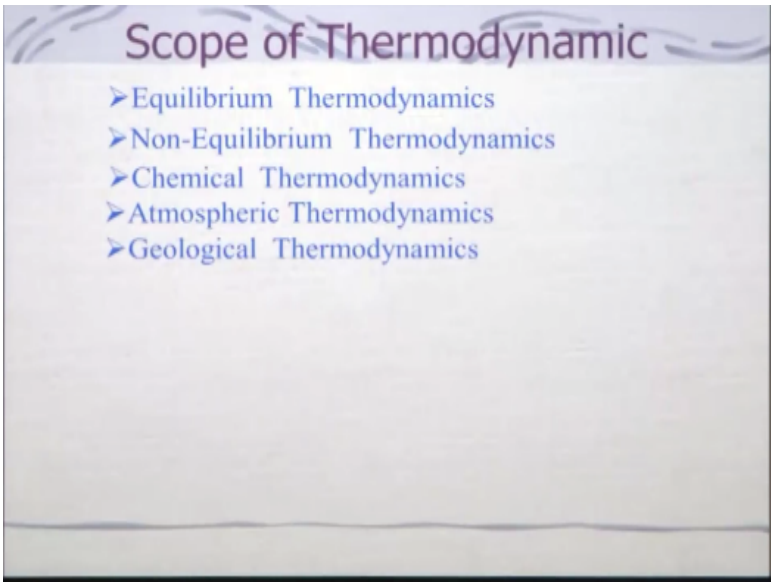

And therefore the deep impression that new dynamics made upon me see you was impressed by this term autonomy because it is a very simple and also very leg ant in nature and it is the only physical theory of universal content which I am convinced that within the framework of the applicability of the basic concept sit will never be overthrown see he as you know given so much of emphasize the importance of thermodynamics therefore it is very important for you to look at some more dynamic whatever the field you take whether engineering whether it is science whether economics whatever it may thermodynamic plays a very important role I hope and with that you will study thermodynamic more seriously and try to understand and apply in your profession and your professional and personal life.

So let me just tell you that let us learn about thermodynamic amateur engineering science topic that deal switch all the terms of energy and whose manifestation propels the society an essential curriculum of Engineering needs a proper and perform understanding.

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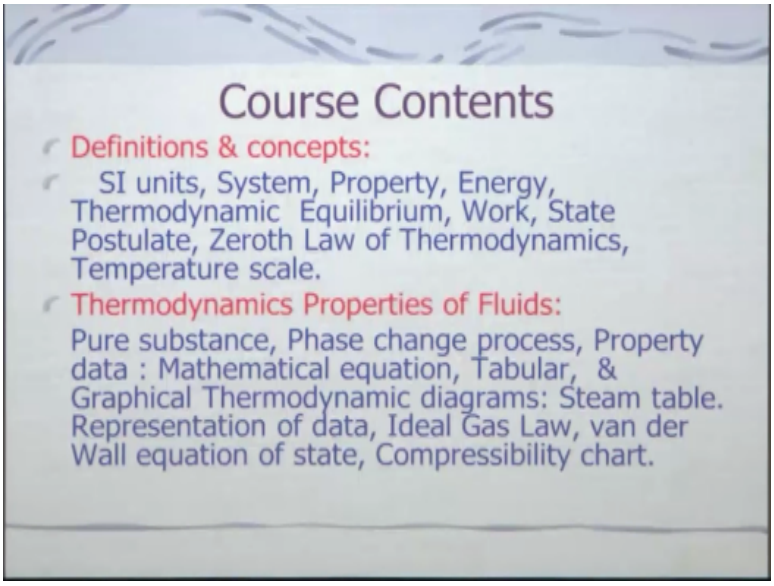

So this is very important thing and then one has to study and what will be dealing with this course is basically to start with the few definitions and concepts which are quite important and will be mostly discussing about SI units system and properties energy and we will be talking about thermodynamic equilibrium the concept of thermal thank you then we will be discussing at work and you know various forms of work which you might be knowing but we will recapitulate it and state postulate which is important for the kind of thermodynamics which we will be dealing with in this course.

And we will be looking at zero law of thermodynamics later on will be also a dwelling upon temperature scale which is quite important as the you know thermodynamic we will be dealing with the matter because it is basically energy will be interacting with the matter so we will be looking at you know properties concerned with the thermodynamic they are like pure substance and phase change processes property data like mathematical equations tabular form and you know graphical thermodynamic data diagrams which we will be looking at to look at the data because data is important and we will be looking at steam table.

And you will be using the steam table and in your exam and representation of data how we can represent the data is very important and we will be looking at ideal gas law equation of situation and also few of the what you call a real gas laws or the law gas laws mean for the real gases we will be discussing and we will be looking at compressibility chart and in the first law of thermodynamic we which will be applying for the non flow processes and we will be taking several applications both covering both the steady state and unsteady States and throttling processes kind of things and we will be looking at charging and discharging of tanks or the pressure tanks.

And several other examples we will be considering then we will move to the first law of thermodynamics for the non flow process to the reacting chemical reacting systems chemically reacting systems and we will be also looking at fuel and combustion these some of you will be knowing this thing like theoretical air fuel ratio heat of reactions and adiabatic flame temperatures and other things so then we will be moving to the second law of thermodynamics its application and before really looking at thermodynamics second law of thermodynamic we need to understand.

What the limitation of first law of thermodynamics heat engines and heat pumps and a refrigerator a few of the examples will be taking how to analyze them and then we will be looking at the second law of thermodynamics in that Kelvin - Planck and the classiest statements and their equivalences will be discussing and reversible irreversible processes will be enumerate them and then of course as I mentioned that Carnot cycle and Carnot principles which we will be discussing and this you know second law of thermodynamics beside this there is a concept known as availability which is very important for analyzing and then we will be talking about exercise.

I think you may not beware like your entropy energy is another terminology are this thing will be using this availability and later one will be moving to the power plants and various power cycles thermodynamic cycles which we will be discussing ranking cycle ideal and read cycles regenerative cycles all those things under this Rankin cycle you know various persons which you will be looking at and then we will be looking at gas power cycles in that auto cycle, diesel cycle, dual cycle, baryton cycle all those things we will be looking at how tousle it for the analyzing.

The various power producing devices and then we will move moving to the refrigeration cycle in which we will be talking about vapor compression refrigeration and gas refrigeration cycles and if the time will permit we will look at that thermodynamic potential in Maxwell relations which will be important to find out properties and then also lot of applications like you know which you can use you know relate the measurable property the immeasurable properties and that will be doing so what I would suggest.

That you can refer this book textbook in thermodynamics and by D. B. Mishra and the references book you can do you can you know refer this thing like is a very good book like an engineering approach by Wylen and bolts and fundamental thermodynamics by Stonntag and Bognkke is the first is the in author who made this book and later on these two authors have been added to that and this is a quite old book and very interesting book so beside this you can refer any other book but I would suggest that not only we attend the lectures but also the reads the book because it is very important all the things I may not tell you but it will be written in the book I think we will stopover here then we will resume the next lecture.

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