Fundamentals of Aerospace Propulsion
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Lecture – 1

I welcome all of you to this course Fundamentals of Aerospace Propulsion. And if you look at it is quite exiting and fascinating subject so far aerospace propulsion is concerned. And when you look at an open sky, whether during the night time or in the day time, you will be wondering what really it contains, am I right? All of you will be have a wonder, how it is. If you look at a sky in the nighttime particular dark peach night without any cloud, we will see that lot of stars will be twinkling at you. Whenever I see that I remember a song twinkle twinkle little star, how I wonder what do you want and that still is remaining in my mind from the childhood. And I hope and I am sure that lot of you will be having similar feeling to look at what it contains, why it is twinkling, how many stars will be there.

Can anybody tell me how many stars will be there in the sky? There are two hundred billion galaxies right, according to the scientist estimation as of now. One galaxies will be containing something three hundred billion stars, and we are in a galaxy known as milk way and where sun is the one of the star it supports all our you know energy requirement all the life in this solar systems. And this if you look at always man is has desire to look at wonders and how it will understand the thing, and this is a revolution due to the development of science and technology.

Do not think that this modern scientist have found out this. This was their in our scriptures also about very exact next of that like for example, people where thinking the whole universe is expanding one day, it will contract that is nothing, but your big bank theory. So and that you know desire to know and other things, which have made us to think about how to go about it, how to move about it. If you look at it like today we are in moon machine India is having a very prestige's moon machine, how to move about it how to go to a moon and sea. And so also there are planetary machines of USA and USSR's and China and several other countries, now these as motivated in off lead to look at how to have in better propulsive devices such that we can you know meet our requirements. And beside this there are several other application like satellites and others

which will be helpful not only for the winning a war, but also for civilian applications. And besides this you might be knowing you might be wondering how one can really fly because whenever I see in this beautiful campus of IIT Kanpur, birds I always feel how they fly and this kind of questions comes to the mind of the ((Refer Time: 04:00)) from the time memorial that how does a bird fly.

Can we not fly like a bird and there are several stories, I will tell you a story what my grandmother had told me when I was a child. She told me that my great great great grandfather had attempted to fly like a bird, whether it is a stories or reality I do not know, but it was being placed on me as a reality. So, who was trying to stop a wing to is very arm, made out of bamboo, but unfortunately he made an accident which was killed him in the process that is why it became a story. And similar stories you may find in our mythology studying from Hanuman to Jambavan and several others that is a another mythological story, I would like to share with you that is about Greek mythology.

There are two persons one is father Deadalus and his son Icarus who were imprison in the Alexandria the great king Minos. And they try to escape from the jail made a conspiration and by using the principle of the flying, and they made the wing made out of walks and feathers you know like Icarus who is a young and enthusiastic. He did not listen to the advice of his father, and he flied upward to a very high height and because of sun, the waxes got melted and he dipped into them Mediterranean seas. As a result, he was been caught and put into jail.

So, if you look at there are several atoms several things have been twelve stories are being floating around how many failures they have made, but still people have tried. And later on there is a what do call the Sir William Caley who was made a basically a what do call mimic the flight of a kite, and made a what to call a glide in 1804. And after hundred years there was a person known as Wright Brother who made a epoke of flying an aircraft will be discussing more about Wright brothers achievements and their start of the era of the aerospace propulsion you might be knowing the story of Wright brothers and other things.

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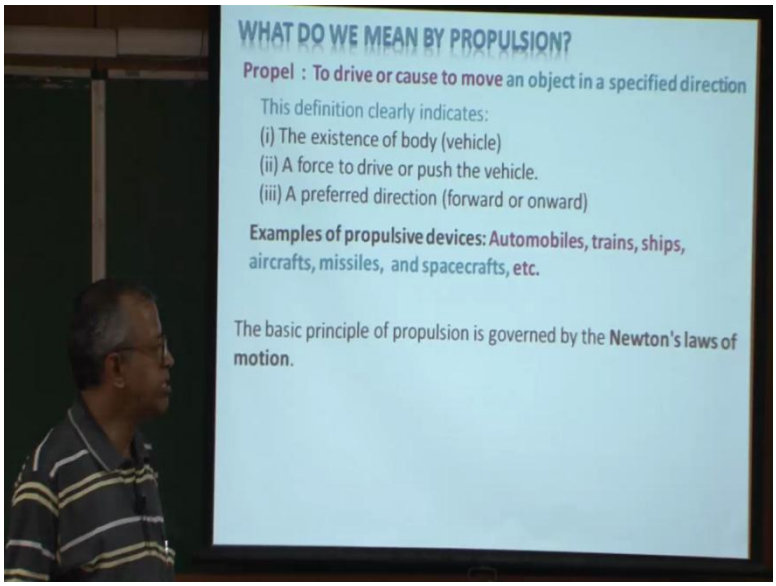

Now, let us ask a question, what do you mean by propulsion? Can anybody tell me like what do you mean by propulsion? Propulsion is basically stands from a word know as propel, it is basically warm, what it means? It means to propel, two propel means to make or a cause emotion to an object or a body. And when we are trying to impart a motion to a body or object, what we need to do. We will have to apply a force, is it possible that we can apply a force in ((Refer Time: 07:49)), certainly no, it will be unbalance force such that it will be overcoming the inertia or a registries. And it must be in a specified direction, specified direction means for a particular direction whether it will be forward or a backward or a sidewise.

So, this definition clearly indicates the existence of a body and a force to drive or push a vehicle, and this motion will be in a preferred direction that is a for example, if I look at I walk is it in a preferred direction, how I am walking, is it I am applying a force or not. And even am I applying force, how it is acting on the body. So, these questions all of you will be knowing, but we will be discussing in just to make in more clear and have a feel for it. So, if you look at these are basic principle or what you call we mean propulsion. Now when you talk about propulsions, suppose a insect is moving or a what do call a snake is moving on the grass or a ground or a fish is moving in the water, we look all it has a propulsion or we look all it into something else.

Naturally propulsion, but we never use those term, whenever it is moving very often; however, because it is a related to the motion, it is related to flying a force which will make it the motion, in a particular direction. So, therefore, we call it as a propulsion; however, there as several devices which are like automobiles, trains and ships which are being to be propel and for that we need to have engines. Similarly, we will be looking at in this air aerospace propulsion, the propulsive devices are a craft, missiles and spacecraft and several others one can think of but we will be concentrating on this.

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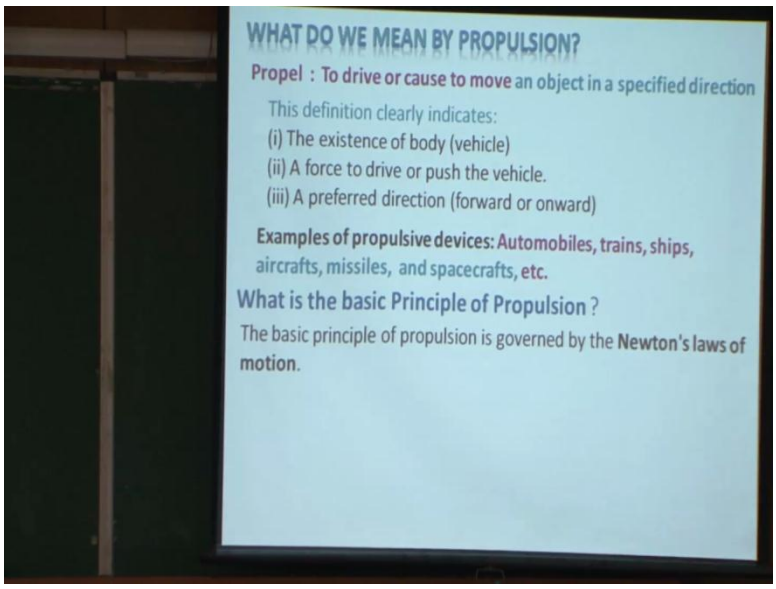

Then question arises what is the basic principle, which will be you know governing the propulsion process. So, we know that one has to apply a force, and it will cause an motion. Now whenever it will cause an motion then naturally laws of motion comes into picture. You must have studied all this thing in high school, but do you have a feel for it? What is this laws, if I say what is first law, what is second law of motion, and third of motion. Some of you may tell me what it is in words. But did you experience those things that is more important to have experience then mugging it of or remembering certain laws are applying it in mathematical sense.

I will take an example, what a child experience this law or not. If you look at a child may be two years or one and half years child will it be experience this laws of motion or not? But you know if they are experiencing, but whereas, when we grow up we are not experience, I will give an example how they are experiencing. And you might have

observe a child as kept a toy in one place you will move around and come and see whether the toy is lying there are not in same exactly same place.

Let us say a baby or a child is playing with a car toy and you will push the car in a particular direction such that it will move and reach and you are catching; a let say ball you know lot of children like to play with the ball. Like you will be throwing to a ball another person another child will catch it or sometimes in of single child is not having way to play or interact now a days it is the go up the wall. So, they will be what you call throwing the ball towards the wall and it bound it back and they catch it. So, what it indicates that is they are experiencing all the three laws of motion. What are those first law of motion can anybody tell me like a what is the first law of motion?

Student: ((Refer Time: 12:50))

Professor: No, please tell me in a words, inertia is ok, that means, a body will remain in the state of rest are of in uniform motion along a straight line, unless it is acted upon by an unbalance force. What is that unbalance force; that means, if it is there, I will apply a force, will it moving? It is not moving, I am applying a force, but if I will apply more force than it is moving; that means, a force, which is acting is unbalance force that will make a body to move. Now how will relate this unbalance force to the change in the motion; something you changing in the motion.

And in this case, there is a friction which is occurring, there is a friction. So, whenever friction is there, this force whatever I am applying must overcome the frictional forces between the surface and the body. Now then only it will move, it will make a move or it will be in motion or motion is important to the body. Now if you look at like what really changing, whenever an unbalance force a being acted upon a body, what is being change, there will be change in moment; that means, rate of change of momentum will be proportional to force.

So, therefore, in that case that we call it as a second law of motion and these momentum will be in the direction of the applied force or the unbalance force. So, unbalance force acting on the body produces and acceleration, because there is a change in the momentum of the body mass can be changing or so also velocity are both of them will be changing, but when will consider the mass to be constant then change in velocity with the respect to time we call it as a acceleration.

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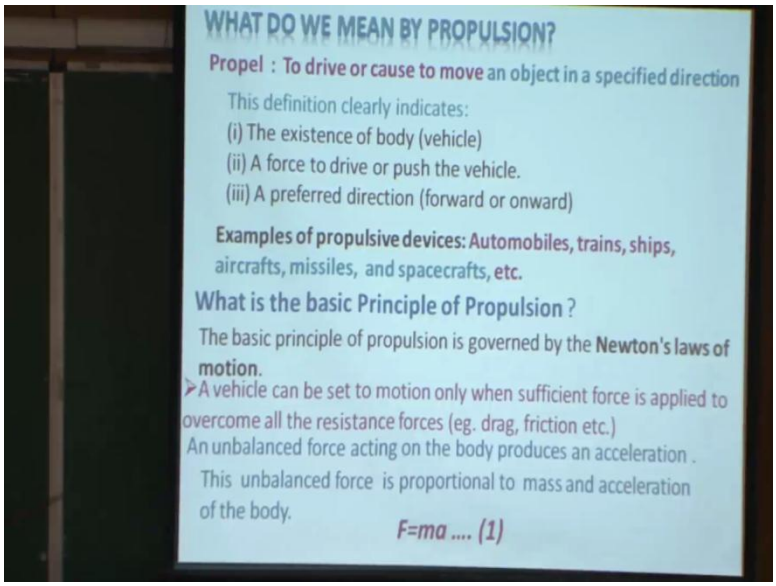

So, therefore, generally, we consider the second law of motion in which unbalance force is propositional to mass and acceleration a body is known as a can be expressed is a mathematical formula which all of you know F is equal to ma. F is the force, m is the mass of the body which is about to move, and a is the acceleration imparted to the body due to the unbalance force and the direction of this motion will be always along the unbalance force and force is a vector quantity that all of you known. So, therefore, this is the law second law of motion then what is the third law of motion every action as an equal, but opposite reaction.

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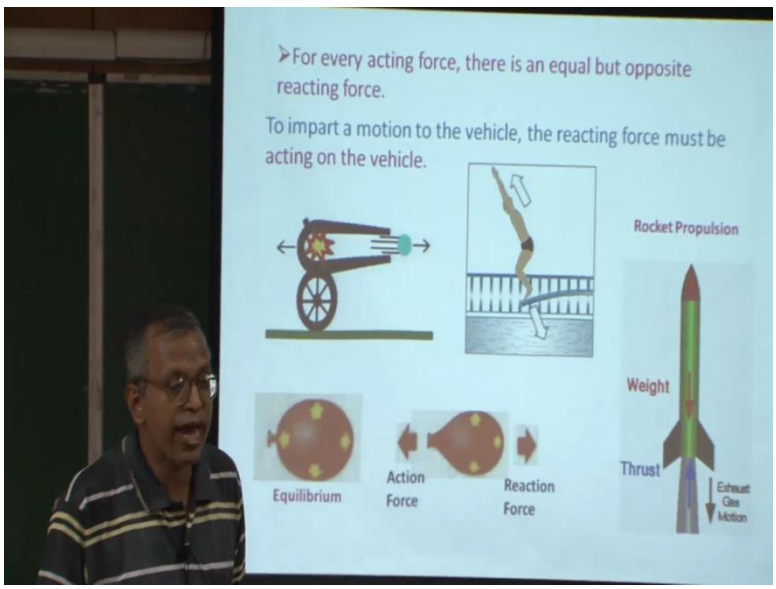

When you talk about this every acting force for an every acting force there is an equal, but opposite reacting force what is the meaning, where this forces will be acting? Will it be acting in the same object or will it be acting in the different object? It will be certainly know if it will be acting in the same object, therefore, there would not to be any motion, it will be in equilibrium. When it is acting on the opposite then there will be having motion. So, this is the third law of motion.

So, as I told you to impart a motion to vehicle reacting force must be acting on the vehicle that is very important; otherwise, there would not be any motion. I will take an example, this is a canon, canon will be you know like imparting a motion to a ball which is their due to the explosion inside the canon. As a result the reacting force will be on the ball and the reacting force on the canon, now if you look at this canon it is made you know the mass will be very very high as compared to the ball mass. So, therefore, the opposite force, which will be acting on a canon will be very very small.

I remember that when I was in high school, I was in NCC, my instructor ask me to keep the bought of the gun that is the 303 gun you know you must might be knowing, along with the body, but unfortunately I do not listen to his advise. And then I got a pen wherever I trigger the bullet, and it came and hit my body, because it is moving so opposite reaction is there. Similarly several other things one can think of right for example, like there is in the swimming pool, there will be a spring boat on which we will try to push and then you will be jumped and put into the what you call swimming pool. So, this is a another example. The way we walk is also by the third law of motion right and in a our scriptures we talk about ever action as a equal, but opposite reaction that is known as law of mass law of what you call Karma. So, that some of you may not be knowing what is that, now this people are not worried about, but it is very important to look at back law of karma which is similar to the law third law of motion.

So, we will take a balloon which is in flatted one and it is in equilibrium, because the pressure which is acting on this balloon which is in equilibrium with the atmosphere. But however, it is having higher pressure you may think how it is happening because it is a elastic medium. So, whenever it is in equilibrium, and if I remove this steam or allow the air to move what will happen, the air will be moving out of these balloon, and there will an acting force action or the action force and there will be a reacting force along with these direction. As a result that balloon will move away from the same place. This a

typical experiment what people do at least it is there in high school book, but nobody does experiment today either in the high school or in the secondary school or even in engineering college that is the fate of the our education system which is very bad.

Now if you look at this is the basic principle by which the rocket engines you know being what. So, I will show you a figure where the the the hard gases will be jetted outer to the nozzle, as a result it will impart a trust and which will be must be much higher than the weight. So, that and also the frictional forces that drag. So, that it will make a move. So, this is basic principle of the rocket propulsion now we will take this balloon and look at what will be the gas turbine propulsion.

I will take an example, now before getting into that I would like to ask you we are talking about aerospace propulsion. But is there any occasion for as to think about about life propulsion; that means, we propel our life you take a birth; from the birth to the death is a one journey in a particular direction, any of you have wonder, any time how I will propel my life. So, that my life will be smooth and good, I can contribute, I can reach an excellent state, I do not think some of you might be thinking or some of you may not be thinking right and that is the main objective of all education according to me not that what do we do.

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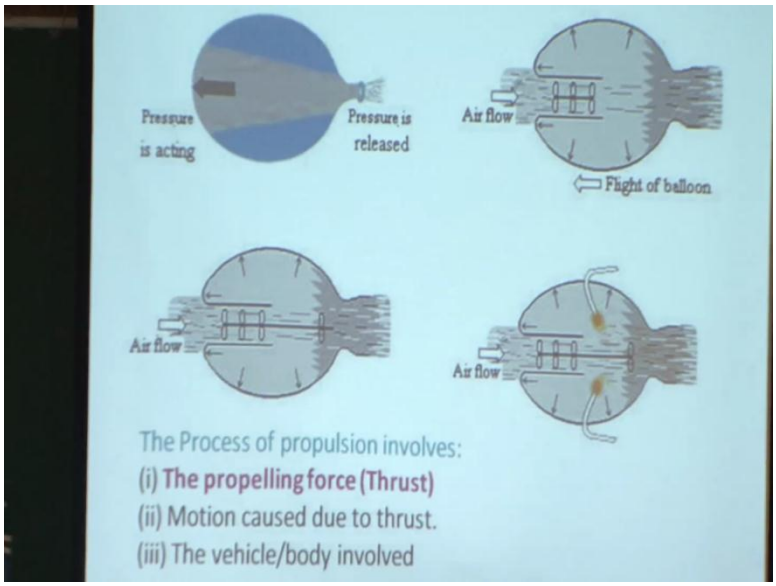

So, I would ask you people to think about this impart and aspect of how to propelling a life which is more important than your aerospace propulsion. Because of that people do

not know how to propel a live all the problems, what we are facing in the society is being cause because of you know not adhering to the principles of humanity. So, I do not want to get into that, but rather I will suggest that let us say that there is a balloon which is acted upon the pressure in acting have seen and their pressure is release here. Whenever the stem is being you know being opened as a result it will be like a nozzle, it will moving, but what will happen, after the air all the pressured air we going out then the balloon will be flat, and it would not move at all.

Suppose I will take this example and then or analysis, I will think of how I will make it a continuous. What is the way can anybody tell me, I want to make it to move. So, what is the way out make my balloon to be moving forever or as long as I wish that means, I need to supply the air continuously. How I can do that, I can think of may be pushing some air, when I will say push some air what I will have to do, I will have to think of using a compression or you can think of using an air inter.

But the compression will be having some mechanical component. So, this component which will have a mechanical rotor, it will move and it will injects the air into that, but whenever I am having these moment of the compression mechanical I need to move it. How I will make it to move, this compression because I love to have to a another device which will give the power for the compressor blades to rotate, such that air can come in. And for that I need a turbine and when I need a turbine, but how this turbine will move it cannot move of its own. So, naturally I will have to give some energy, because if I ask where thus this force comes it comes from the energy; without energy can I have a have a force certainly no, it is not possible. So, what I will have to do, I will have to use a energy. Energy can be any source, it can be chemical energy, it can be nuclear energy, it can be solar energy, it can be any other form as a made of fact; energy having different forms.

So, naturally I will have to using a some energy source, so that I can extract some mechanical work in that turbine and which will run the compression. So for that I need have a combustion chamber, where I will be using some chemical energy for this example and that itself. And if you look at it gas turbine, it is having how many components; one is the air intake through which air will be entering into the chamber and the compressor which will be setting the air and also rising the pressure and there is a combustion chamber which will give some amount of energy to sustain it. It will be

expanded it in a turbine and this hot gas will be expanded in a nozzle further to give a trust and these comprises of you gas turbine engine.

So, this is a balloon analogy what I call of a gas turbine engine and if you look at whole this concepts having three components as I told, that means, the propulsion processes involve propulsion at three. One propelling force at the trust, and other is motion cause due to the thrust, which is a basically a flight dynamics or aero dynamics one can think of. And vehicle body are involve whenever we talk about body, you know body is basically in a structural thing, so that will be come under structural engineering. And then what will be looking at propelling force, and it is the force which will be trying to generate. And whenever we generate this force, we need to use the energy now we will be thinking about how to use this energy for generating a torque or a thrust or a force such that it can make it to move. So, whole ((Refer Time: 27:02)) of this air can propulsion or the aerospace propulsion is related to how to utilize this energy for generating thrust or a force for making it to move move or imparting a motion to a vehicle. So, this is the part which will be concentrating that means, we will be looking at aerothermodynamics of the propulsion.

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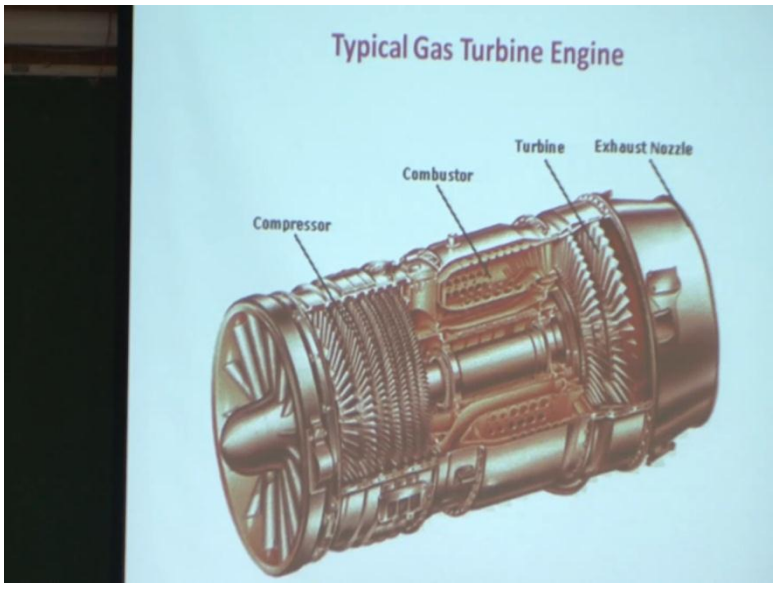

So, with this we will be covering the subjects in a following manner as I told you, let us look at typical gas turbine engine which looks like a air intake, and this is a compression this a combustion chamber, which is quite looks to be complex. And the turbine which is

having two stages, there are several blades involve and this having a nozzle. Keep in mind that have not shown here in air intake through which air will be entering into this engine. Now this is basically a gas turbine engines. So, as I told you that we will be looking at the whole kind of a aerospace propulsion and which is aerothermodynamics of the propulsion or aerospace propulsion which will be covering in this course.

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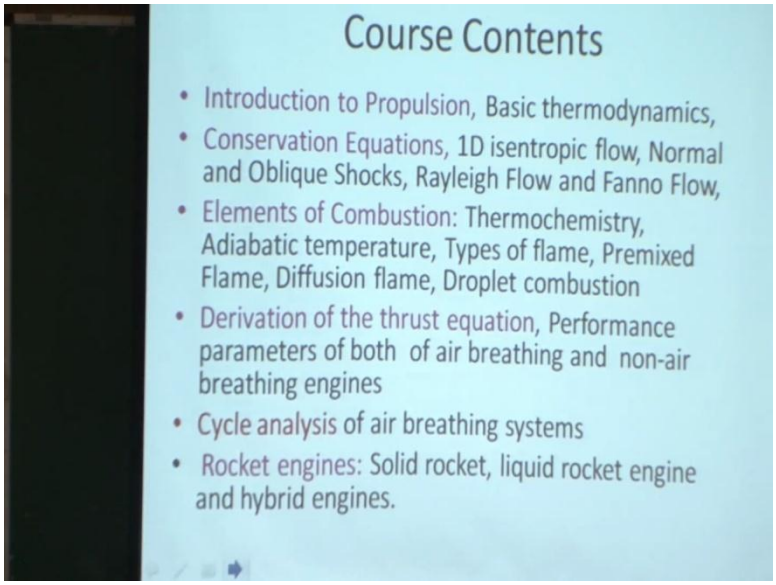

And in this course, we will be doing in this way, in following way because as I told that I will be starting with the introduction to propulsion, and basically I have already introduce you something. But I will be giving you overall view of the whole gamete of propulsion in a very nozzle and then will be concentrating only on the gas turbine engine and the rocket engines for that we need to review. The basics of thermodynamics that is the review of the basic thermodynamics then will be looking at what are the equations that governs that is a conservation equations which will using. That is one dimensional a isentropic flow and whenever we talk about this flow it will be at high velocity and then there might be a chances of you formation of shock.

So, we will be discussing about normal shock, oblique shock and then will be moving into a Rayleigh flow and Fanno flow. And some of you might be knowing, but will have to recap which you let relook at it from the different angle, and as I told that will be mainly dealing with the chemical energy for our you know propulsion devices. So, therefore, we will be looking at elements of combustion. Till this portion of the course

which will be basically being covered to make you a depth in the fundamentals which are equal to delving into the aerospace propulsion.

After this we will be looking at derivation of the thrust equation, in which performance parameters both air breathing and non air breathing engine will be covering. And then will be looking at cycle analysis of air breathing engines, I will be talking about real cycle analysis, ideal cycle analysis, how we can use for the design of an aircraft or aero engines particularly. And then will be looking at briefly about solid rocket engine, liquid rocket engines and hybrid engines etcetera. And for this that is who will be referring several books and which I have just jotted down few of them.

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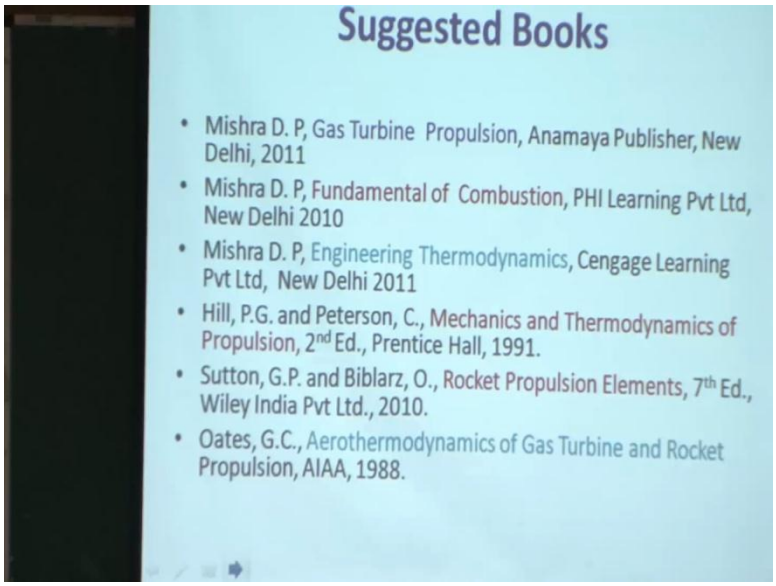

And for the aero engines will be looking at this gas turbine propulsion publish by Anamaya. And Fundamental of Combustion will looking at what you call by myself D. P Mishra, and Engineering Thermodynamics will be looking at some portion by the Cengage 2000. Beside this will be referring this book Mechanics and Thermodynamics of the Propulsion by Hill and Peterson, and there is a very classic book the Sutton G, P. and Biblarz, Rocket Propulsion Element will be using it. And beside this, the Aerodynamics of Gas Turbine rocket propulsion - Oates. And all these books except the first one available in the library, and I hope that it will be you can use, you can refer any other book as a matter fact. So, my suggestion would be, you should you know try to have your own notes that will be useful for to cater to your needs

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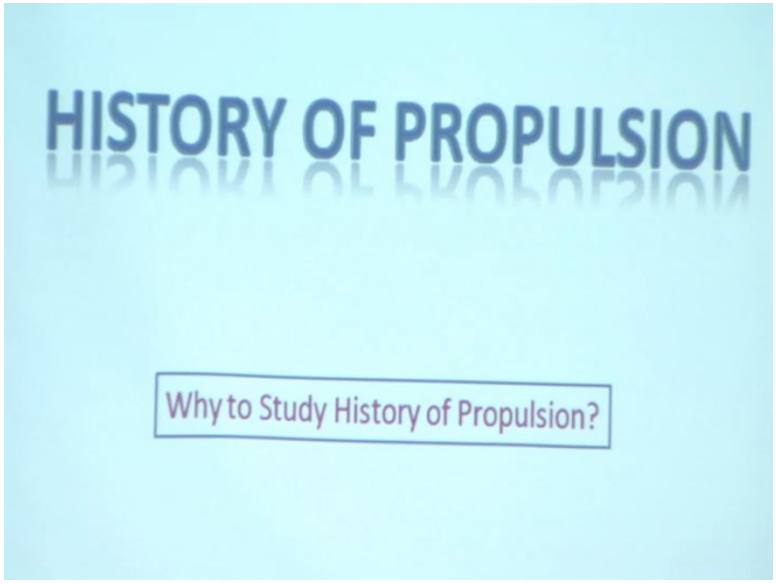

Now, we will be moving into the, what you call history of propulsion; question arises why will look at history, because it is a very very boring subject. At least to me, it was a quit boring subject to look at history, am I right? Some of you may not like into look at history, although our mind always move to the past or it will be moving to the future, but really remain in the present state that is the nature of the mind. Am I right or wrong? So, always reading about the past or imagining about the further whether bad or good or ugly. So, there but however, we need to look at the history of the propulsion or history of any other things just to look at what we can do such that we can act today for the better future. So, therefore, we need to look at the history of propulsion.

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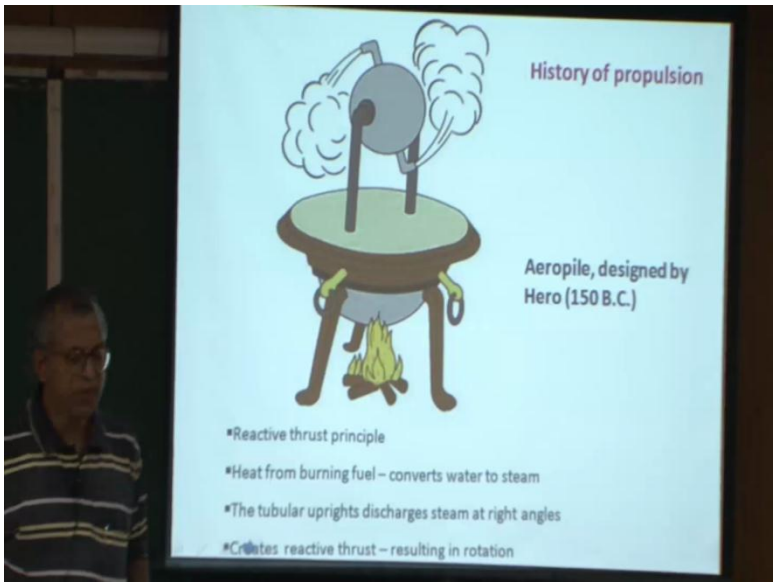

I will just give a bar side view of the history of propulsion, if some you where interested you can make a ((Refer Time: 33:13)) on that, it is a very worst. But I will start with a a very what you call a Alexanderia scientist who was living in Alexanderia in 150s name is Hero, who design a aeropile in 150 B.C. - Before Christ. And he has come up with a device which is shown to be here. I think it looks little awkward to look at today is not that compact, and then you know jazzy to look at, but still then it gives a very great principle.

For example, it contains a bowl, which is shown here; and this bowl contains water, and it is having a close with a lead and from this lead, there are operate tube which goes to this kind of a chamber, which is spherical in nature - hollow spherical. And similarly, this is having a another operate which connected. Keep in mind that this hollow sphere is having a two nozzles which is opposite direction, whenever this water is boiled steam is being formed, and this is being boiled using a wood by burning of wood. Earlier days wood was a major fuel, and in feature I guess that will be the only fuel after may be fifty or hundred year, because it is renewable in nature. So, therefore, this steam whenever it will go through this and it will be jetted to this nozzle it will give a couple and that is nothing but your reactive forces or reactive thrust, so that demonstrate the reactive thrust principles.

If you look at 150 B.C people were not knowing what are the laws of motion, but they have devise this thing, they have come up with this idea, it is a marvelous idea when I think of. It may looks to be trivial today, but if you look at 150 B.C., it was a great thing. What it says to us, so for history is concerned; that means, you should not be bog down by the principles, which is not there, but however, you can do the design, you can think of that is the mind. In modern days the peoples mind is restricted and constricted by these laws, which are being formalized. Newton's came in 17th century, but Hero who was really hero who found out that what is to be done and this principle is being utilize later on for the development now.

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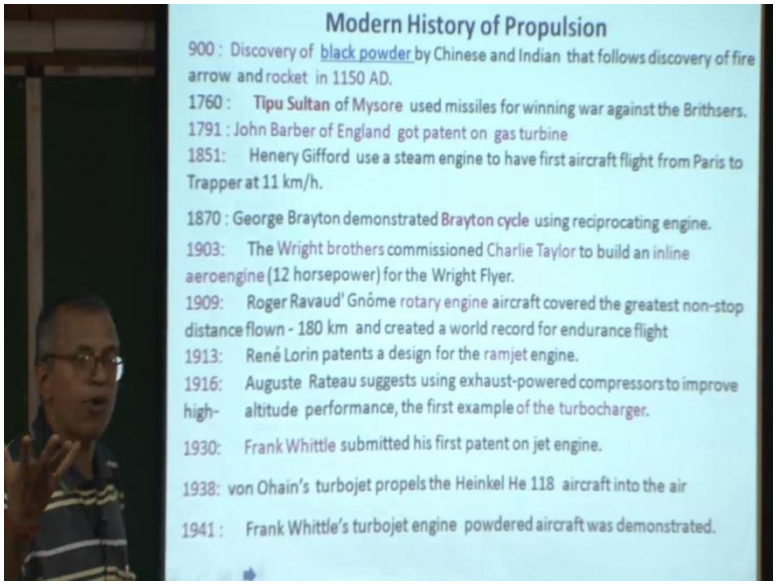

And I will just tell you a brief history very much like this 900 around 900, the Chinese and of course, there is a controversy Indians found out the black powder. What is the constituent of this black power, which is also known as gunpowder. Do you know which is used for your rockets, rockets and then you know for your bomb in Diwali festivals. And then they found out the way of attacking enemies or defending the enemies discovery of fire arrow. Later on around 1500, 1150 AD, the Chinese people made a rocket, which is similar to our fire rocket, if you look at history. But it was a making an epoke have a impact later on this Mongols and other warrior groups in Arab countries and other things Japanese, you know like samurai is another thing, they learn these techniques so also Indians. And it spread to the all the thing, because it was driven by the winning a war. So, if you look at today also the arsenals and the all aerospace related

things are being misused abused by the the armies and politicians is very important to note. So, therefore, one has to worry about.

Later on, there are several other things which I am not talking about it. In 1760 the Tipu Sultan of Mysore who fought four wars right, and he won all three wars created a havoc, but unfortunately he lost the fourth Mysore war to the Britisher and he was killed. And they were using a what you call missiles or the rockets, basically he is the missile man. Although we know in modern days, the Abdul Kalam is the missile man. But Tipu Sultan and was the missile man of this country, who are having created lot of things. And the Britishers took their rocketry systems to the England, there is a person known as Congreve, who really made several investigation and tried to mimic this design and was successful, they use against Napoleon in 1812 and won the war, against Napoleon one of it. So, what I am saying this is a that means, the rocketry is started basically from India and which we do not know.

Then of course, the 1719 John Barber England got a patent in gas turbine engine, this is long time back, but it was not being used, why it was not being? You got a patent got patent means, basically an idea which was you know put in his name, so that other people cannot copy it, but why it was not coming up… But, later on in 1851 Hennery Gifford use a steam engine to have the first aircraft flight from the Paris to the trapper at a kilometer of you know at a speed of 11 kilometer per hour. It was a very very small, if I look at person can run, you know in this 11-kilometer, wow more than that even. A normal man can walk may be 7 to 8 kilometer per hour. But what was the thing I guess when I investigated I found that there was a balloon in that which was making it to drift and this engine which was a very bulky was not producing any thrust. That is my interpretation some of you may look at it. So, therefore, it is the wind which made the move, and it was floating only you know, so that was the my interpretation. So, it is very important to look at that.

Now having said this thing and if you look at the steam engine at that time was very very popular. I will tell you another thing the subject thermodynamics, you know was really developed because of steam engine that means, the engineering need not to be come after the science. That means, if you are good enough in science, it does not guarantee you that engineering would engineering should come up. So, engineering come first or science of course, is required for to have a good engineering, but it is not that way. So, in

other words, what I would like to suggest one should not be bog down by the constant of the development in science so far engineering is concerned.

How you can develop, engineering is concern, then there will be some ingredients with the minds of the people that make useful thing, I will be discussing little later on. So, if you look at 1870 the George Brayton demonstrated Brayton cycle which we will be discussing in this course very often. And using a reciprocating engine, generally it is today it is Brayton cycle is whenever Brayton cycle being discussed, it is for the gas turbine engine, but it was started with a reciprocating engine. And as I told there is a epoke making event by the Wright brothers, who really you know for the first time make an aircraft to fly in 1903 and that is the history being created, which uses the 12 horse power engines.

And 1909, Roger Ravaud Gnome use a rotary engine aircraft, and covered a great non-stop distance of 180 kilometer created a world record for endurance flight, because it was flying for a longer period of time. And if you look at this is a turbo you know like a kind it is a quite a good event and but I am always you know fascinated about the Rene Lorin who invented two things so far aerospace propulsion is concerned. But he invented several other things he was a very innovative person. So, 1913 he patents the design of the ramjet engines and I will tell you also how he talked air breathing engine little later on that is 1908.

So, 1916 Auguste Rateau suggested using exhaust power compression to improve the performance engine that means, he was the first person to introduce a turbocharger to the aircraft engines. And 1930, the Frank Whittle submitted his first patent on the jet engine generally the what you call frank whittle is known as the father of the gas turbine or the jet engines am I right? But however, there is a person von Ohain's who is really the father of the turbo jet engines who made it in 1938. And whereas, of course, the Frank Whittle, 1941, he found a turbojet engine to power an aircraft. But if you look at most of you may not be knowing who is this von Ohain.

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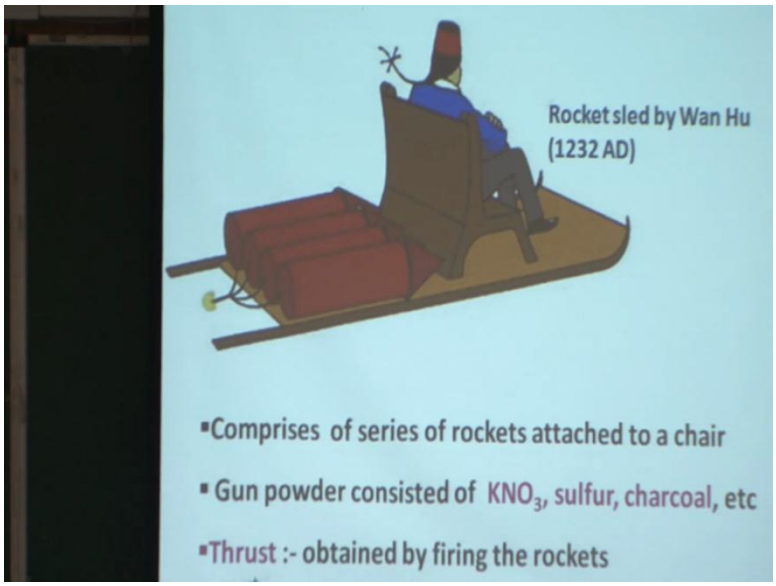

We will be discussing about it. I will just look at what is the adversity of a person scientist one who designed this rocket sled, and it looks to be a very very awkward and you know to our mind. But to if you look at he used a series of rockets attached to the sled, and he sit down the chair and fire the rocket and it flew for sometimes in the passes he lost his life, what a great sacrifice he has made for us to think about. Today we are very much frightened and we are having we are suffering from the fear and which is being circulated by these market forces.

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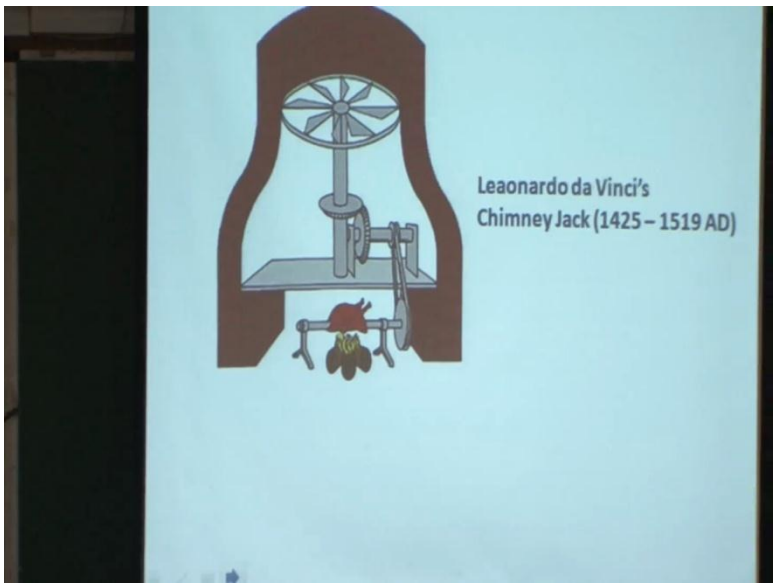

So, therefore, and I am always fascinated about another person who is a visionary who is basically an artist, he is not a he was not a scientist. But the kind of imagination he was having it is much higher than the modern engineer can think of. So, what I will say, I will stop over here. We will discuss in the next class that is tomorrow which we will have an media lab.

Thank you.