Fundamentals of Electric Vehicles
Technology and Economics
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Lecture 7
EV Subsystems

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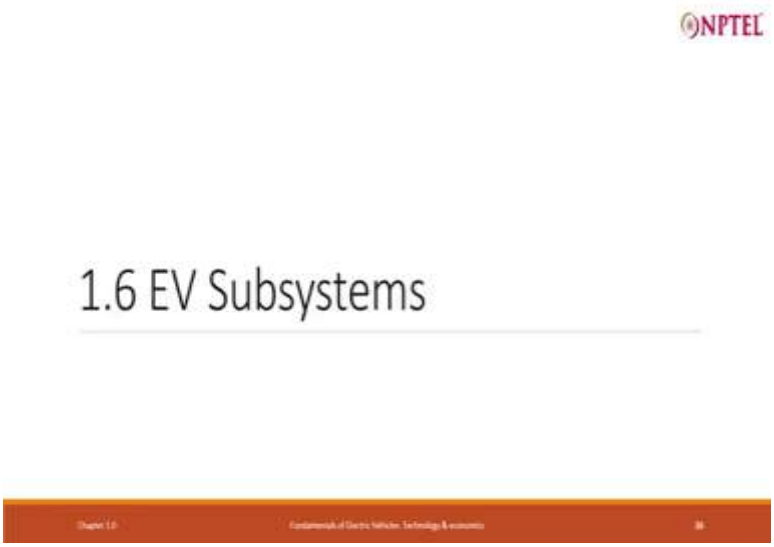

So, we will now go to the next subsection still the introduction going on; on EV Subsystems. But in the meantime a question has come. How could they handle in a cold country? The fact that batteries do not work below 0 degrees centigrade how do they handle? In fact, we at IIT Madras were asked by the Jammu and Kashmir government to go to northern part of J and K in Ladakh and nearby region and put our solar DC system in every home to give them electricity, and that system has a lithium-ion battery.

And the immediate question that came to our mind, but temperatures go below 0 degrees centigrade. What do we do? In the beginning, we are a little perplexed but then one thing to remember, as soon as you start working, battery starts getting heated up. It generates electricity. In fact, we at higher temperature remove that heat, in this case the heat itself will bring up the temperature and once it comes to around 10-12 degrees centigrade, it is not a problem 15 degrees is not a problem.

In the beginning, you have to worry about. Fortunately in our case, we are able to put this system indoors. So the indoor temperature does not go that much and then we created a woolen cover on

this, this heat is getting continuously generated whenever it is used, the woolen cover was so designed to capture the heat. Most of our batteries that we designed for high temperature use, we want the heat to get out; here heat has to be retained.

So the battery packs are designed to retain the heat and therefore (the battery) and insulated such that it does not go out and therefore even though the outside temperature may be lower, it is inside the hood of the battery inside there is insulated and hopefully the temperature will be at least few degrees centigrade. Once a few degrees centigrade will start it will work inefficiently it will behave badly.

In a few minutes it will go 12 to 15 degrees centigrade it will start working alright. So I hope I have answered the question. At times people have tried to put a small heat generator by using some model gasoline to just heat it up. As soon as the current starts flowing, it heats up I square R, which otherwise, you are worried all the time even from a motor, you are trying to remove that here it helps.

Unfortunately, for hot countries like ours, there is no something similar. As you start using, heat only gets added it does not get removed. Let me get into the last part of introductory chapter. And this is what does the electric vehicle contain? What are the subsystems of electric vehicles? And we did this exercise by taking a typical vehicle and start looking at a typical ice vehicle, petrol vehicle, what does it have?

And we started so saying, what part we will retain as it is? What part we will have to throw out? And what will it be replaced with? Or what part will modify it? So, that is what exactly I will do.

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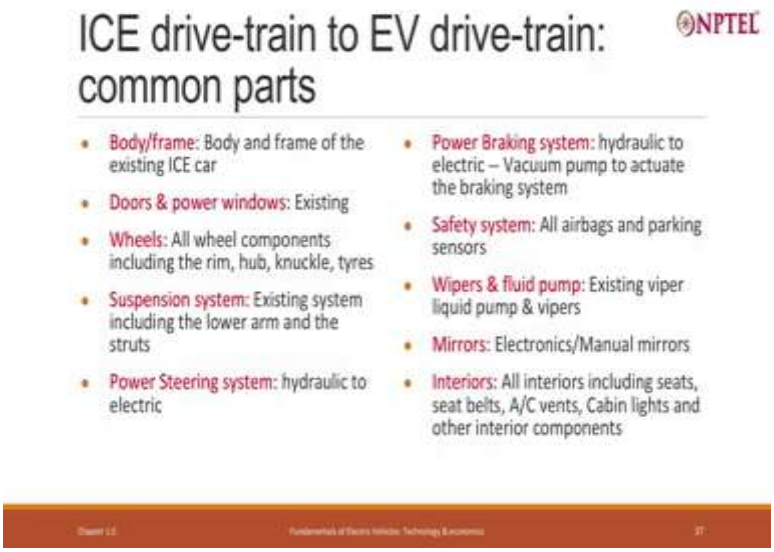

So, start with some of the parts which are common. For example, body and frame. Well, body and frame is required for petrol vehicle, it is required for a electric vehicle. Now, there are changes that you can make.

Because body and frame are also the weight, significant weight can you use a light weight material? It helps a lot for electric vehicles. In fact, it helps more for electric vehicles because it means battery consumption goes down and battery is expensive. Petrol is less expensive. So, there is no less incentive to work on that.

Student: (())(05:03) they have to handle lot of vibrations from the engine which would be generally (())(05:11)

Professor: So, very interesting thing has been pointed out to me that a petrol vehicle has a lot of vibrations. Because it has a lot of vibrations the body and frame has to design for certain strength. The electric vehicle there is going to practically no vibration except the one coming from the road. So, therefore, you may not need the same strength so that what can be done to improve the body and frame we will not deal with it now. Doors and power windows very similar except they are any ever operates on the battery.

Wheels; the only thing that I will do in the wheels is improve what I call rolling resistance we will talk about it. Why? Because that will help in reducing the energy that I consume per kilometer. Now, in a petrol vehicle I may not do it because it increases the cost. In this vehicle

we will point out these vehicles, electric vehicles, whatever extra cost that we had to put in the wheel will be more than recovered by a reduced cost of the battery.

Suspension system any vibration will require. Again being less vibration, you may require less suspension, but by large we can begin with what we have. Power steering systems; now power steering system in older vehicles used to be hydraulic and this are driven by hydraulics, so when you move the power wheels, yes, you could do that because of hydraulic but we do not have hydraulics here, we will have to replace by electric motor.

Already it is being done in the newer vehicles will have to adopt that more. Power braking system; breaks which has power brakes. So you do not ever really push very hard. Again, traditional vehicles first of all did not have the power brake, then when power brake was introduced. It used to be hydraulic system. Now increasingly, it is starting to use electric brake. We will come to regeneration later, not now, there is a regeneration also we will come to it later on.

Safety systems, all airbags and parking sensors will have to have. The other safety system that we have to worry about battery and we will talk about it when we discuss battery. Wipers, fluid pump; pretty much the same. Mirrors; pretty much the same, interiors; pretty much the same. So what I am pointing out a lot of things I can take from existing vehicle, I can improve it, but I improve it over longer term.

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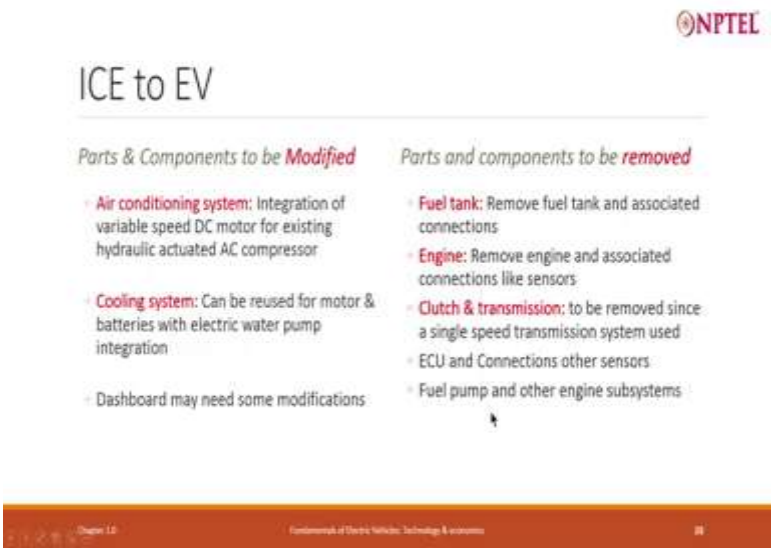

What are the parts which have modified? Air conditioning system. Now, air conditioning system is required from a new vehicle also. The point is the air conditioning system has the compressor and this compressor in a traditional vehicle are again hydraulically driven. So, essentially petrol is driving that. What we here need is electrically driven. Well, electrically driven air conditioning system is well understood we have to bring that too.

Same thing other cooling system which cooling of battery, cooling of motors will require it and once again they have to be electrically driven. Dashboard may need some modifications. So, these are some modifications, all you need a new parameters how much battery is there etc-etc. Parts which can go away there is no need for fuel tank of course, instead that a battery will come ofcourse the engine will go away.

Clutches and transmission; we will see that the motor that we are going to use will not use need any more transmission we can actually the motors are such that we can get rid of many of these things. The engine control unit connections, fuel pumps, other subsystems, many of them can just go away. This is a huge advantage cost of that will go down.

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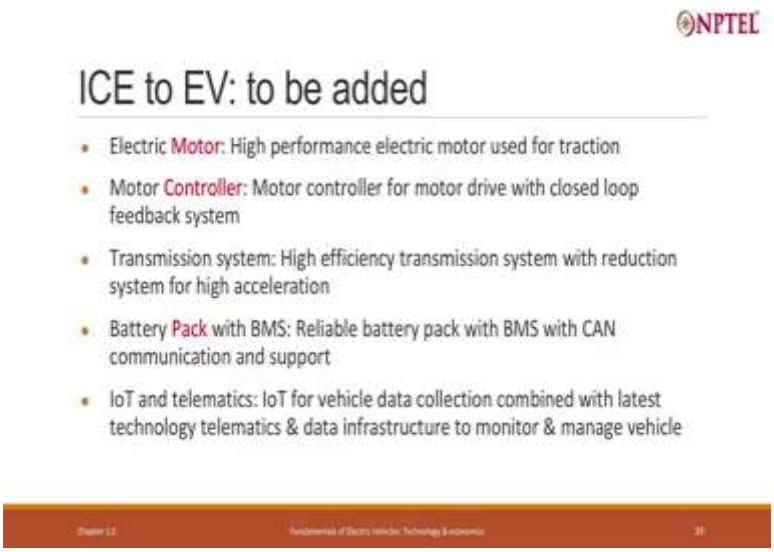

What do I have to add? The first most important is electric motor and motor controller. Now, this has to be high performance electric motors and motor control also has to be also high power because this is the heart of the system. This is what has been done extremely well. And these two important part are very important components. Equally important system is a battery pack. Battery pack is the, what stores the energy and the most expensive component. So has to extremely carefully decide.

What about transmission system? Transmission systems, gears, all those things were required in a electric engine because those engines had a limited range of motor RPM and torque. Fortunately, electric motors, you can design for large variation in torque, it can go to low torque to high torque and it can go to low speed to high speed and generally therefore, only a single gear is used and you do not require complex transmission system, but you will require some minimal transmission system for that.

As a told you battery pack BMS will be important. Today all vehicles are starting to use Internet of Things and telematics remotely getting the data and you will see electric vehicles if they will become even more important. So this is what the systems will consist of.

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You also have to add multiple DC-DC converters. You have a battery that is giving you some voltage. There are other subsystems lights will require another voltage. You do not have to alternate battery, you can just do a DC to DC converters. A vehicle control unit or sometimes called master control unit, VCU MCU, essentially manages these things not a major role.

In fact, a motor controller manages motor, a battery BMS manages the battery and yet there is overall vehicle managing. It will probably collect data from all of this. It will set parameters transmitted to even remotely if required, this is a unit which will have the software not much, but it is important unit.

You will require various isolation circuit, one of the biggest risk about electric vehicle is the shock from the battery to the passenger. So, you need to isolate certain parts from other parts. Remember metal conductor is there, it will otherwise conduct. So, isolation circuits will be important and use. Then you need charging infrastructure. Ofcourse, there is onboard charger which will sit inside the vehicle.

We will talk about it in detail later. And there is what is called external chargers, which is not really a vehicle, but it is a charging infrastructure just like petrol pump infrastructure that is important component of electric vehicle and various software and remote monitoring. This is the subsystem of electric battery.

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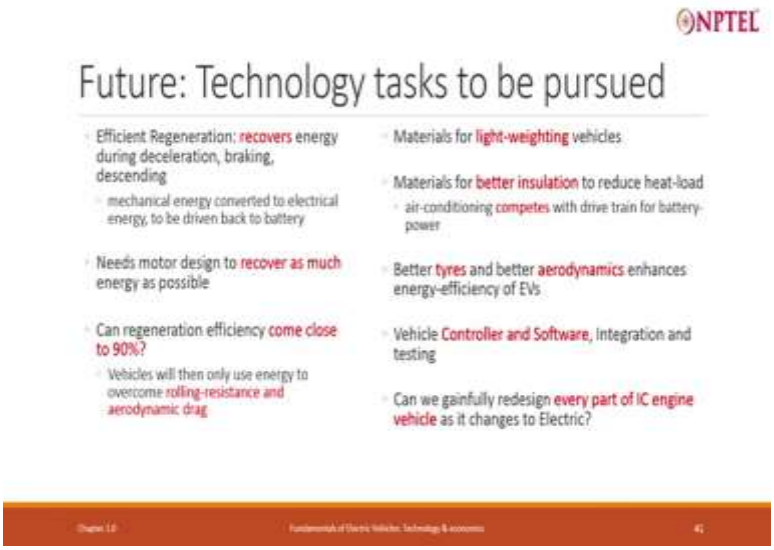

There are multiple technology tasks they have to be continuously pursued for a significant amount of time already some work is going on, but you need to do more. For example, I briefly mentioned regeneration. One of the advantage of electric vehicle is that when you decelerate when you are climbing down when you are decelerating applying brake.

Now what do you do in a vehicle, we essentially try to stop the vehicle reduce speed, you are wasting energy. In electric vehicle, it is easy, when you apply a brake, you can actually run the motor in reverse direction and when the motor runs in reverse direction, it actually generates electricity.

So very good braking system is what is called regenerative braking where essentially you start to convert the energy in the vehicle, the kinetic energy in the vehicle when you want to slow down, or potential energy when you are coming down it convert that back into electricity and recharge the battery. This is called regenerative.

You know one of the interesting thing is when you will see in the next chapter, we will start talking about how much energy does it take for vehicle to move from one place to another place at a constant velocity. One will be able to do that, and we can figure out the energy. Then one say, how much energy does it take to accelerate? And that was coming high. But we found, find that that same amount of energy is available when you decelerate.

Suppose the vehicle is going at 50 kilometers per hour, you go to 80 kilometers per hour, you will spend so much energy when you go back to 50 kilometers per hour that much energy can come back. Similarly, when you are climbing you will use electricity when you climb down you should get back that. That is where regeneration comes, how efficient is regeneration?

If we will make the regeneration 100 percent, the interesting thing will be no energy is required for acceleration because there will be corresponding deceleration. No energy required for climbing up because there will be corresponding climbing down. Unfortunately, regeneration is not as that good it starts at 10 to 15 percent going towards 30 percent, but over time this will improve.

Our friends will design better and better motors to capture back the energy as much as possible. That is going to be a huge advantage for the time being, well, whatever we can pick back, is good. But this is a important technology task, very important fundamental task that during deceleration, during braking, during descending, can I recover all the energy and you need motor design for that.

Can regeneration come to 90 percent? Wow! Waiting for that, will it happened during my lifetime? I do not know. This is what the key thing is. Next important task, lightweight vehicles, can I get material? Remember that you do not need as much vibration, can I create that? So, continuous work that will go on. Lower cost, good strength but lighter weight. You will learn that heat load is a major problem in countries like India.

Our temperature outside is 45 degrees, Sun is shining, you keep a car park, how hot it becomes. When suppose you parked in locked the temperature goes up to 70 degrees centigrade. Now, what do you need to do; you need to do cooling. Even while you are driving, the heat is coming in and you need to do cooling. Well, air conditioning systems are there, but they consume electricity. Earlier you will take petrol convert that to use that to run the air conditioner or cooling systems.

Well, so, suppose the vehicle typically ran 15 kilometer per liter because the cooling system required it may run at 11 kilometer per liter. Not such a big deal. Yes, it will cost you something extra. Does not impact too much because petrol tank is big, you have enough petrol, yes, you are

paying more. Not so, with electric vehicle, your electric vehicle for a limited range. Now, you start using that electricity for cooling the say that electricity will have to used.

Suppose you used 20 percent of that electricity for cooling, what will happen? You have that much less range. So, in electric vehicle, the heating, sun, external temperature matters more and while you have to design better air conditioning and all that, the same time can you do better insulation? Can you ensure that sun does not heat you as hard. You may use glass which reflects most of the heat energy and does not take it in.

You will say it cost extra; well, it will pay for itself because you will require lesser size of battery. Better tyres. I talked about how better tyres will give you less energy consumption, higher energy efficiency. Continuous development has to be keep on going on better a vehicle control and software. You have something minimal to start with but it will keep improving the question will the challenge will be, instead of taking the current vehicle, remove certain parts and retrofit certain part, can we think of designing electric vehicle from scratch?

And redesign every part keeping in mind not IC engine, but electric engine and how much electricity will it consume during operation first, and then during production. This is the kind of technology task that needs to be pursued and is going to be pursued.

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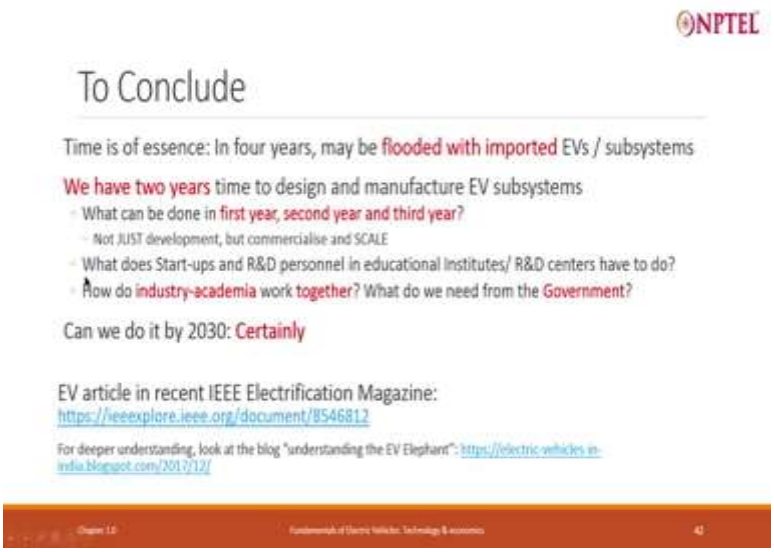

Well finally I am coming to the end of my introduction. Electric vehicles are going to happen and it is going to happen in India too. For India, time is of essence, maybe 4 years. We will see 24, 25 we will see lot of electric vehicles.

Either we understand India design things for India's requirement or somebody else outside will do and start exporting to us. And then we will keep on playing a defensive game. What India requires and the course is for that purpose towards that, that you learn every aspect and start designing work and development work.

India we have good youngsters who can design and develop. Wait for 4 years will be flooded. I will say we have 2 years serious time to quickly start designing and manufacturing and we need to start thinking of what can we do in 1 year? What can we do in 2 years? What can we do in 3 years? Can we take this, this, this and clear it? Can be to take that? We need this kind of detailed program.

Ideally, funding agencies should do that, but funding agencies does not have that capability. People like us who are R and D personal have to define the program. Very often the governments do not listen to us. The question will be, what is the role that startup can play? Startups can play a major role because a lot of work will require very, very hard work 6, 14 hours a day, 5 and a half days, 6 days a week, failing multiple times and succeeding.

It is not a systematic R and D; it is trying out impossible. Failing, failing, failing and successing success. That is what R and D supposed to be. But established R and D does not do that. Startup does that. So, startup will play a major role R and D personnel who want to really contribute exactly does that anyway, they take up challenges they take up impossible. So, you require R and D personnel in Educational Institute, R and D centers in companies to work.

It will also require a lot of industry and academy at work together because lot of innovation is required. A lot of our industries used to importing (())(23:29) we have knowledge, there is no reason to do that. We can work together and we can design. We have to answer the question, what do we need from the government?

First; no interference. Second; support for R and D, particularly R and D to innovation to commercialization, unless commercialization is taking place, it is of no use. Fundamental R and D, fine, somebody can do this. But the idea here is R and D to all the way to commercialization, and this is what we need to do and we can do it. Can we do it? Can we do it by 2030? Can almost all the vehicles in India by 2030 will become electric vehicles?

Yes, I will say at least 85, 90 percent, probably more. And India's got started. And this course is only a step in the direction, this time to train 5000 people, 10000 people, every year, such that large number of people start working. Of course, the government has to invest, the industry has to invest and Academy has to really focus on not just academic papers, but R and D all the way to commercialization; innovation, all the way to commercialization.

We need plenty of startups in this area, but startups which are not trying to just retrofit things and like they do it in auto clubs and win a competition forget about all this competition. Make serious products which can win in the market. Something that can win against the best in the world. I will see what we need in India is something which is as good or better than German design. Or (fake) things has to be extremely affordable.

So, today Chinese make low cost product. So our products has to be better than China in terms of price. And in terms of quality of production, and giving making sure there are no faults, Japanese are well known. Can we have a quality of Japan? So, I always believe India's R and D requires all the way from idea, R and D, innovation to commercialization with designing capability of Germans, the cost reduction capability of Chinese and the quality of production of Japan.

This is what we need. And I think young people coming out of our colleges are well, preparing them. So they, if they are determined they can do it. Really lots of startups can do it. And we will certainly do it by 2030. Either you will do it or you will do it or someone else will do it. There are some references that I want to give and these slides will be available. First; there is an article that we wrote, me and Dr. Prajyotkar wrote in December 2018, in IEEE electrification magazine. It is a very interesting article, short article, 6-7 pages article, gives you a very good overview, a lot of it what we talked about.

But if you want to understand a little bit deeper want to understand at the sum of the cost numbers, and figure out more, you can look at a blog that I wrote almost 2 years back; probably a little more than 2 years or 2 years back, called understanding the EV elephant. All of you heard of the story called 7 blind men and the elephant. Electric vehicle today in India is like that elephant.

Everybody says that they know, everybody has gone in touch that elephant a bit. Very few have over full understanding what we try to do in that blog, understanding the EV elephant is try to get a comprehensive understanding. And what we will do in more detail in this course is get a comprehensive understanding. Still, that blog will give you a very good idea because it gets into a little more details, then what we will do in the course.

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There are various other reference materials. Ofcourse, the first one as I pointed out was IEEE Electrification Magazine article there is a understanding the EV elephant blog. There is a report which is also downloadable. It is a WRI, World Resource Institute or Worldwide Resource Institute and the Center for Battery Engineering Electric Vehicles of IIT Madras brought it together a guidance document of on accelerating electric mobility in India.

There is another very interesting report, NITI Aayog Report; we are involved in writing that zero emission vehicles towards a public framework. So we are giving you all these references. You can actually use that. Thank you. And what we will do next is start getting into the vehicle dynamics. What does it really take? We will get into a little bit of mathematics very little. Figure out how much power a vehicle will take?

How much force it will require? How much energy will it consume? And then we will talk about can motor give us that power? That can motor give us that speed? That we require how much battery energy will consume? Can motor give me the power to get the peak power requirement that the vehicle has? Vehicle has to speed up something, will require look at all these things from next class onwards.

In the meantime, I have given you an assignment and from today you will have 7 days to actually answer those assignments. They are several assignments, there are several questions. You do not actually had to solve them. There will be blocks given and you have to and put the answer in that

block. Remember that we are going to do auto-correction. You can solve it, but you have to put the answer in the block so that we can autocorrect.

After that, when the last date of assignment is over, and we will put that in the website, we will actually also give you the answer and maybe solve a few problems if required. But till we get into a little more detail, this was introduction of what is the vehicle dynamics. Till that time. Thank you.