Fundamentals of Electric Vehicles
Technology and Economics
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Lecture 13
Concept of Drive Cycle

Next we are going to talk about energy, why is energy important? Well does the vehicle have enough energy to let the drive take place? It is like fuel, energy is like fuel, does it have enough fuel? Does it store enough fuel? It will give you the range that to which you can travel and that becomes important role and we will talk about energy required. Another thing that we will come across throughout the course okay with all this known torque, power, speed, force and energy you have to now design motor, controller and batteries.

At what voltage should we design all this? You will see that depending on the voltages your currents will become very different, if you have high voltage your current will go down, to give us some power after all battery will give you some power, so if you suppose want a power P, if you want at a voltage V, then the current is that power divided by voltage, if I want a lower voltage my current will go, if I want higher voltage, my current will go smaller.

Normally I prefer lower current. Why? Because current I have carry in conductors and when I carry current in the conductor there is a heat dissipation, there is I square R loss, now one would say well I square R loss should be small, depends on what the current is, we will see the currents in some of these vehicles can become 100 ampere, 200 ampere, 300 ampere I square can become very large, I therefore do not like this 200, 300 ampere.

If I use higher voltage my current maybe more like 30 ampere, 50 amperes, 70 ampere, 80 ampere, much less much easier manageable, ofcourse high voltage has another thing, lower voltage is safer, high voltage is less safe, it will require a complete isolation of all the electrical components with the rest of the vehicles, finally we will have to see where should we pay the cost of isolation and reduce the currents and where I do not want to get into this isolation, let me use low voltage let current go up a little bit. So, this voltage will be become very important.

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A related thing will be, see if I know my peak power requirement, what is the current that I will draw? What is the average current that I will draw? What is the peak power current that I will draw? Currents are plays important role not just in terms of heat loss and conductors, but a battery also is normally designed to give you only so much current, if you try to draw higher currents from the battery, the life of the battery gets impacted we will study that in detail later on in a battery chapter.

So, this is another thing that we have to start discussing and then get into details later on. And the fourth thing that we will discuss start discussing, what are the losses in each sub-system? So, far we assumed everything is perfect, not so, motor never runs at a 100 percent efficiency, you given a certain amount of power, certain amount of energy, certain amount of power, part of that power is going to get lost into heat.

It has a double problem, problem number 1; some power and therefore some energy is wasted, so I will require more energy to drives the vehicle. Number 2; whatever losses are there heat is generated, that heat is going to heat up the battery, heat up the motor, heat up the controller and heat is not good for either the battery or for the motor or for the controller.

You can allow a certain amount of heat after that you will have to do cooling, you have limit the heat, so we have to worry about the losses one is the losses due to I square R, but I square R is not the only losses, in motor there are other losses and heat is generated.

So, wherever heat is generated we have worry, motors consists of a lot of coils, so there is going to be a lot of losses, it is not just in simple conductors, motor basically is a lossy, there are other losses like iron losses, you will see in motors, so it will worried about this, magnetic loss, iron loss are magnetic loss. So, we will start looking at it, as we go on we will look at more and more, all these four things, in next section I am going to start with energy that it travels requires to travels.

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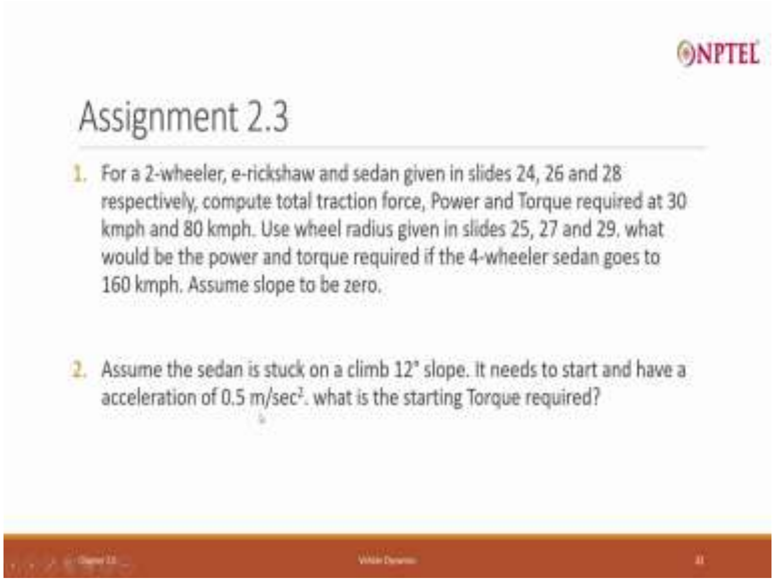

Some assignment problems for a 2-wheeler, 3-wheeler and e-rickshaw, we have shown how to compute traction power, torque at different velocity, given a certain wheel radius, what would be the power and torque required? We had basically ask you to learn to compute get some feel of numbers.

Assuming the sedan is stuck on a climb at 12 degrees do not need this stuck, it has to start and during a start it will require a torque plus I will have to give a minimum acceleration for it to get moving, I have taken them a very small acceleration 0.5 meter per second square.

So, now what do I have to do? For that vehicle at 0 speed have to worry about the torque then I have to worry about the acceleration and torque due to acceleration plus there is a drag force, I have to worry about the drag acceleration, ofcourse with the very 0 low velocity so it will be nearly 0, there will be some rolling resistance I have to worry about the force due to that and therefore torque due to do that.

So, I have to combine all this torque and say what is the starting torque required, before I start this new chapter, there were two questions that were asked to me and let me try to answer, the first question was asked is that, when a vehicle is starting is mu going to change? Is there a something called static friction versus dynamitic make friction? mu is related to function. Now, there are two ways of dealing with it, you can either have a different value of mu, mu due to during movement and mu due to starting, that is one way of dealing with it.

Very often that is not what is done, what is in the vehicle computation what you assume, mu is same, but you require certain extract acceleration, minimal acceleration will require, so compute the torque required due to acceleration plus torque required due to the drag mu and that is the dynamic that is during the static. So, in fact in this problem that I talked about in here, I have not done it, I have done starting, but I have to say there is a slope, very large slope 12 degrees, but I also said include a sudden acceleration, it is at 0 speed but include acceleration.

So, take the acceleration of 0.5 meter per second square you can convert that into kilometer, whatever any other units. Now compute the torque due to this plus compute the torque due to slope that is basically a starting torque which could have other way also sort of say mu have changed, but we in electric vehicle or even for IC engine vehicle normally mu is assumed to be constant.

Ofcourse there is a small function of velocity, at high velocity it matters a lot, starting, starting torque is the same as moving torque plus acceleration required, without acceleration fine you cannot move, when you are 0 speed you have to get to some kilometre per hour that is a starting acceleration, starting acceleration is another term used for the change in value of mu.

So, that is a question number one, which I think this problem when you do you will get an idea, we will give you more assignment problem, note down on something like this. There was a second question that was asked and the second question was, a (())(10:42)

Student: (())(10:42)

Professor: Suppose you have a long slope, in many hills the slope is constant and in continue for 2 kilo meters, is the energy requirement is the power requirement all that torque requirement, what will happen? We will actually deal with that to some extent in this chapter of concept of drive cycle, but let me point out, it is related to motor design and battery design, you normally talk about in a motor the power that motor has certain power, but it also has something called peak power.

A motor maybe have 5 kilowatt, but its peak power maybe 8 kilowatt, the same motor it can drive at 8 kilowatt, it can drive at 5 kilowatt so what is the motor kilowatt? What is a peak implies? Actually as far as the mechanical part of the motor is concerned or even the electronic part of the motor is concerned it is the same, a 5 kilowatt motor is 8 kilowatt motor is actually design for torque, it is a heat dissipation for at 5 kilowatt the heat dissipation is small, or whatever is the heat dissipation it is taken care of by the cooling system.

8 kilowatt this peak dissipation is going to be much higher, that at much higher heat dissipation, what do you do? If it is 15-20 second that extra heat dissipation, motor temperature will go up and 15-20 seconds will pass and now it will cool down so it will be alright. If on the other hand you require a constant 8 kilowatt then you require a very different kind of heat dissipation system, which will take out this P the losses the heat dissipation at 8 kilowatt.

So, I will say a peak power is related to that if it is 15-20 second I can handle it, the motor is actually designed for the nominal power or rated power you can say, because heat dissipation is designed for rated power. So, that is what and we will this look at this later on the heat dissipation.

To some extent same thing about the torque peak torque and rated torque, rated torque is you can keep on running with that torque and heat dissipation will be something that you will have to keep on removing such that the temperature does not go up, if you go to pick torque you will have extra heat generated which is alight for a very short period of time but it is not alright if you will apply it constantly.

Now, look at what does it mean in terms of driving of a vehicle. If I am trying to overtake somebody I need 15-20 second extra power and extra torque, because I will have moving behind I am behind I will actually move like this, this vehicle and then move up 15, 20, 25 second that is a time peak power and peak torque help, nominally I am not driving above the rated power, so that is fine.

What about in slope? And particularly the long slope question that was asked, in a long slope I am actually drive that at that slope for 5 minutes maybe even longer, ofcourse I can reduce my speed and all those kind of things for power, but for my torque speed does not matter. So, that cannot be done using peak torque or peak power, it has to be done at rated torque and rated power.

So, you have to look at the motors rated power and rated torque and you can continuously climb the slope at that rated torque and rated power. But if you are using the peak torque and peak power to drive to go up then it can be only for a short period of time, what about energy required which will be dealing in this chapter. Energy required will go up if it is a short period of time, it will go up, if it is a stays for a long period of time energy requirement will go up considerably because energy is integration of power over time.

So, sure in a long slope energy requirement will go much higher, but remember that we also talked about a concept of regeneration, so if you are climbing for long you require certain amount of energy, after that you are going to climb down to the same extent and if we had a regeneration efficiency, my energy requirement will not make any difference.

But to the extent that I do not have 100 percent regeneration efficiency I have to pay the penalty of extra energy, if I am only recovering let us say 30 percent of the energy during going down, so 70 percent of that has to be spent. All that issue of how much energy will be spent is exactly this concept of a drive cycle. And what is a drive cycle?

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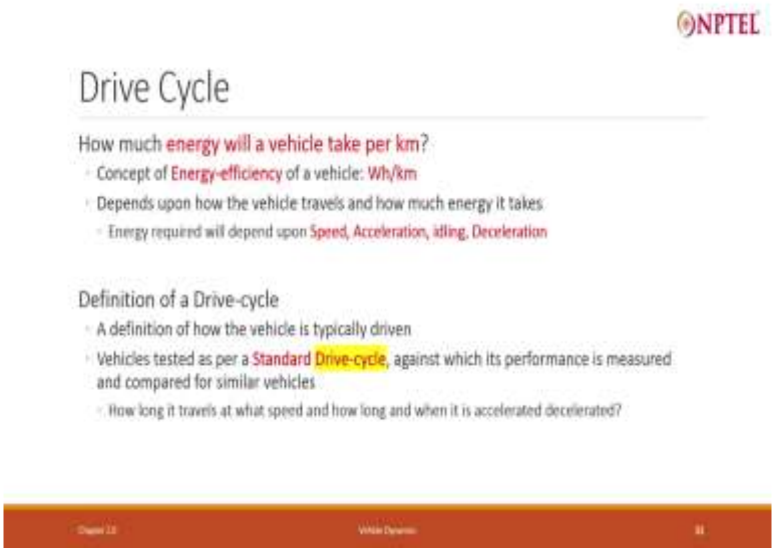

The question that we are asking in this how much energy will vehicle take per kilometre? How much energy will the vehicle take during certain drive? Per kilometre energy per kilometre is very important, it is like your fuel efficiency kitna deti hai, amount of petrol consumed per kilometre or amount of kilometre for one litre of petrol, the kitna deti hai it is a same thing, energy efficiency is defined in terms of watt hour per kilometre that depends on the vehicle design.

But it does not depend only on the vehicle design, it also depends on how is the vehicle travels, when you do the measurement, what is the speed at which it travels, remember that when it travels at higher speed you require larger power which means large energy is consumed, so you cannot talk about energy, efficiency or watt hour per kilo meter at all speeds it will be different. If vehicle accelerates, it consumes tremendous amount of power.

So, it will depend on how much you accelerate, how much time you are just idling, not moving at all, you are stopped on red light, how well it be decelerates, when it decelerate it gives you back some power, energy, probably fraction of energy. So, at what speed you travel? For how long? Then what is the acceleration, for how long? From what velocity to what how much do you decelerate, for how long? How much are you idling? All these things become important component in the amount of energy consumed.

Therefore, how do you not talk about watt hour per kilometre? You can talk about watt hour per kilometre by defining what is called a drive cycle, this by the way is done in a petrol engine is also going to be done for electrical engineering. It is a standard a drive cycle a standard drive cycle, a drive cycle says a definition of how the vehicle is driven try to standardize the driving pattern.

Vehicles are tested as per standard drive cycle, the standard drive cycle will tell you how long did you travel, at what speed you travelled for how long, at how much did you accelerate, how much did you decelerate, did you wait idol, it will define this and for a class of vehicle it will standardize it and that is called a standard drive cycle.

A standard drive cycle for a 2-wheeler, standard drive cycle for a 3-wheeler, a standard drive cycle for a 4-wheeler. What is the purpose of this? Well, a drive cycle will help you compare if you have made a vehicle, you have made a vehicle similar 2-wheelers and the I can compare what is the energy efficiency of yours vis-a-vis so I will take a example.

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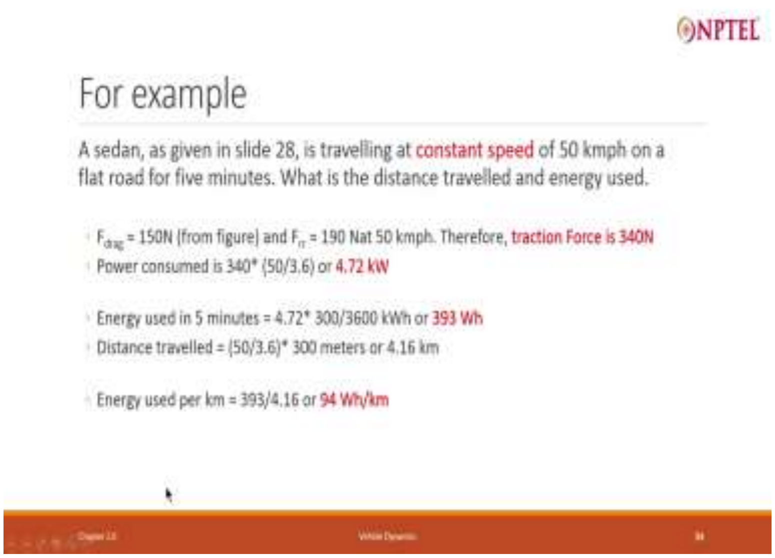

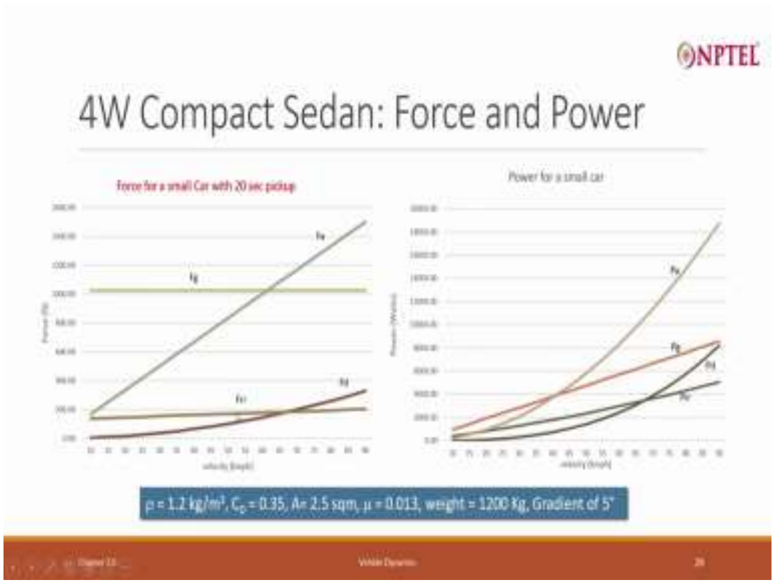

A sedan, which is driven at a constant speed of 50 kilometre per hour and let us assume this is the vehicle, this is the vehicle, the vehicle sedan it is in page number slide number 29 here not 28 because I probably added a slide here, area is 2.5 square meter, drag is 0.35, weight is 1200 kg and suppose it is driven at a constant speed of 50 kilo meter per hour for 5 minutes compute the distance travelled and energy used.

So, if I compute the distance travelled and energy used which I will do out here, the drag is what? 150 Newton meter that is what comes at 50 kilo meter per hour, 50 kilo meter per hour drag comes to 50, 150 Newton's, rolling resistance is higher 190 Newton's at 50 kilo meter. And if I am driving at a constant speed and let us assume no slope only the drag and the rolling resistance has to be taken into account.

So, the total force that I have is 340 Newton's, power consumed is known, therefore 340 Newton's multiplied by the velocity, velocity is 50 kilo meter per hour I have to convert it into meters per second by dividing by 3.6 and actually I am consuming 4.72 kilowatt to overcome this 4.72 kilowatt, I am consuming throughout for 5 minutes I am consuming 4.72 kilowatt, what is the energy that I am consuming?

4.72 kilowatt for 300 second, this was the velocity 300 second, but I want to 300 second divided by sorry 5 minutes 500 minutes is 300 second, but actually why do I divide by 3600? Converting into hour, because I want to actually right down not in terms of watt second but watt hour and if I do this calculation I get 393 watt hour.

So, every I am consuming 393 watt hour, if I continue drive this from 1 hour, it will be 393 watts, watt hour, if I continue to, well for 5 minutes I am consuming 393 watt hour, if I continue to drive for 60 minutes I will consumed 12 times this, what is the distance travelled? Well, 50 kilometre divided by 3.6 for meter per second into 300 seconds that gives me so many meters or 4.16 kilo meters.

So, what is the energy used per kilo meter? So, I consuming 393 watt hour, (())(24:29) 4.6 kilo meter, so per kilo meter and consuming 94 watt hour per kilo meter. So, if I am taking a ideal vehicle and just overcome drag and rolling resistance at 50 kilo meter per hour, I will consume 94 watt hour per kilo meter.

Now, is this the energy efficiency of the vehicle? No, this is assuming I am traveling constant speed at 50 kilo meter per hour, but what if I accelerate or decelerate? What if my velocity goes to 30 kilo meter and then 70 kilo meter? I will consume different watt hour per kilo meter. So, this is a watt per kilo meter for that drive, for a standard drive it will be something else and therefore I have to define standard drive.

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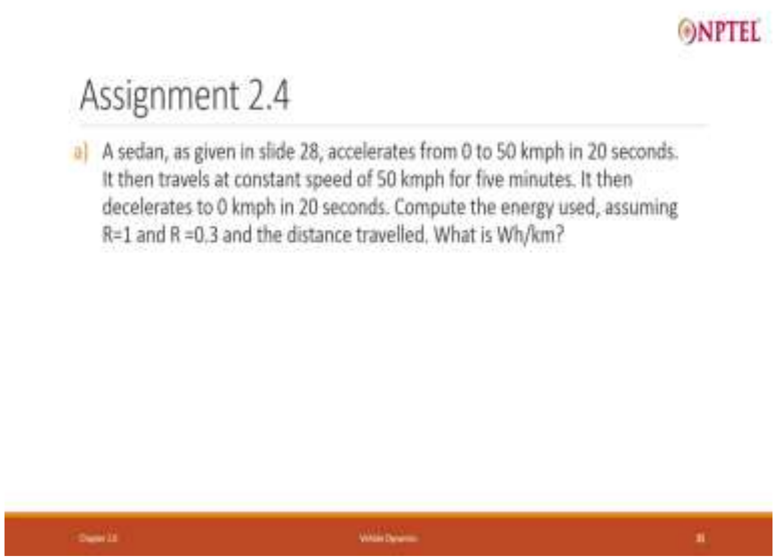

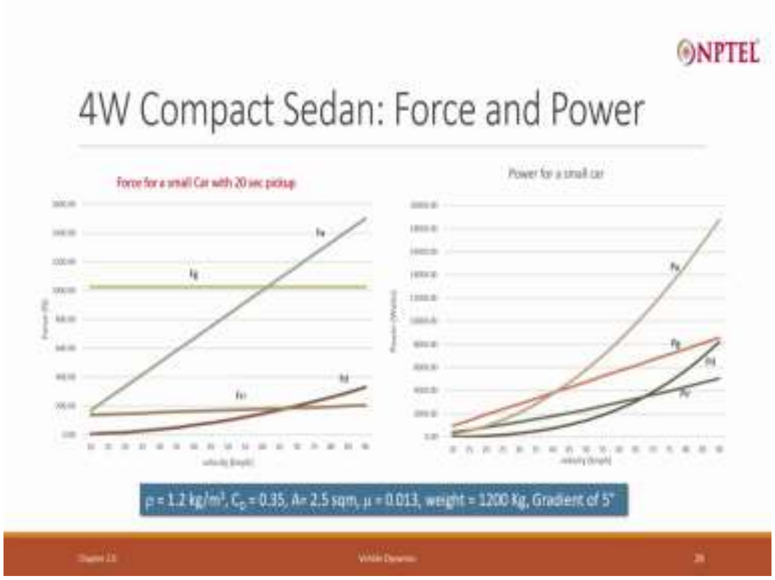

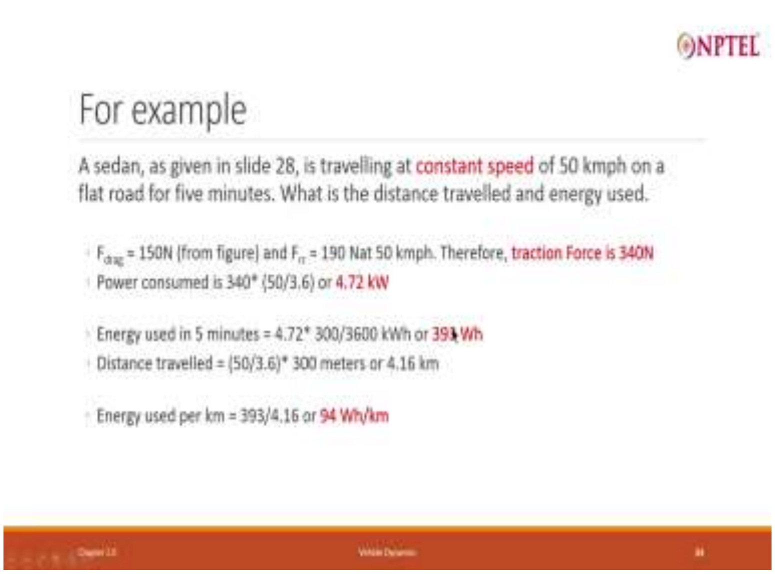

I am giving you a assignment problem, where I change the drive, I have taken the same sedan, this time first I am accelerating from 0 to 50 kilo meter per hour in 20 second, now when I am accelerating at 0 to 50 kilo meter per hour in 20 second, I can actually compute the power requirement due to acceleration and that is coming close to 6000 watts for 20 seconds.

Then it travels for 50 kilo meter per hour for 5 minutes, then it decelerates 20 second and as I compute the energy required assuming R equal to 1, R equal to 1; 100 percent regeneration, what will be the energy required? Can someone tell me?

Student: (())(26:32)

Professor: It is exactly the same 393 watt hour, why? Whatever energy I spent during climbing up during accelerating I am recovering that during deceleration, because R is 1, but in reality R is not 1, let us take R equal to 0.3, now I have to actually compute the energy required during reacceleration.

I have to add the acceleration force plus the drag force plus the rolling resistance force, compute the power required for all these three, I have to add the power, that is a power that I will be requiring for accelerating, figure out how much time will I require to get to 20 second (interval) in 20 seconds I am going to get it.

And I compute the energy and then I also compute the kilometre travel, well the previous kilometre travel what I had was assumed earlier the 4.16 kilometre was in the when I was traveling at 50 kilometre, but during acceleration also, I will be traveling some distance. So, I compute that and then divide it I will get watt hour per kilo meter.

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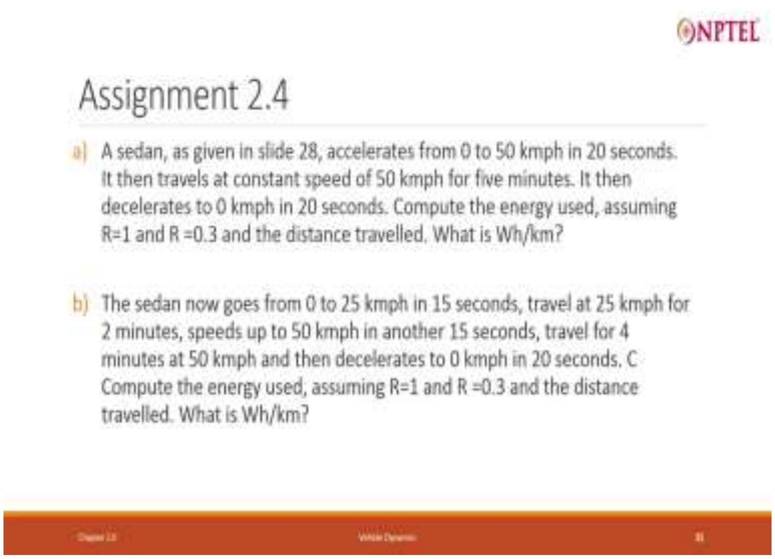

I take a second problem again assignment problem this time I am traveling starting from 0 to 25 kilometre for 15 seconds, travel at 25 kilometre or 2 minutes and then I speed from 25 kilometre per hour to 50 kilo meter per hour in another 15 seconds travel for 4 minutes at 50 kilometre per hour and then decelerate to 0 kilometre per hour in 20 seconds, compute the energy required.

So, method is same, compute also the distance travelled, compute what is watt hour per kilometre, these problems are somewhat not very difficult problem that will get you used to the concept of a drive cycle, what is pointed out is very little correct, we have assumed what is assumed that only the acceleration force is reversed the drag and rolling resistance is not reversed.

So, ideally only for the acceleration force or the gradient force you should apply R, but you know acceleration force and gradient force are so much more than the rolling resistance and drag that all that is taken into account in R itself the regeneration efficiency and you do not separate them you just compute that and just resumed the regeneration efficiency if it was only for acceleration deceleration may have been 0.35 due to combine it is only 0.3.

So, you just assume that and in reality in computation R is assumed for all; all the energy we are assuming that during climbing up and climbing down net energy consumed is 0. So, not exactly correct with R equal to 1, but if you want you can do this detailed calculation, but that gets into a little bit of trouble we just assume that is same.

For hour first course will assume it is same, it is a combined and we will not separate out, otherwise things will get complicated. (())(30:35) just like that, is the road always same? Is the rolling resistance always same? It is not, it will vary, we do not take that into account, so we have somewhat simplified, in reality you will get slightly worse result and you will say regeneration efficiency is lower, that is fine, okay.