Basic Electrical Circuits
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Lecture – 03

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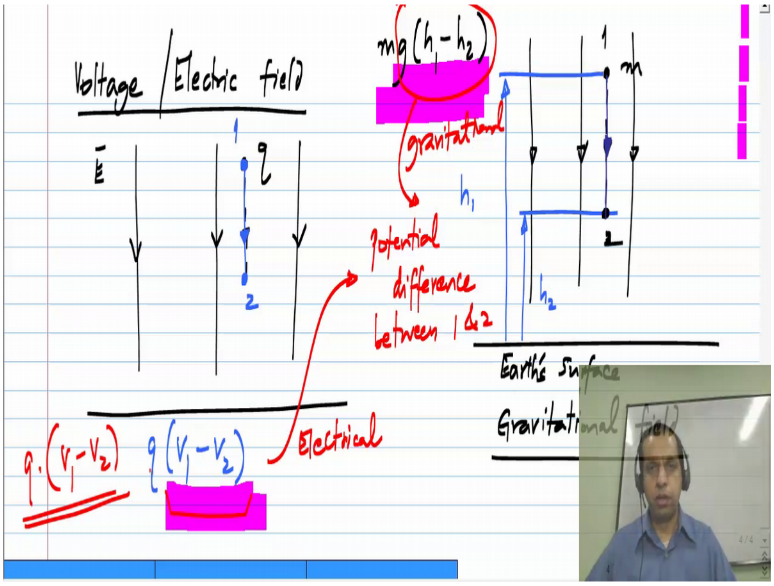

Now the next thing we will look at is basically the relationship between voltage and electric field. So we know that basically charges move under the influence of electric fields, so we need both charges and electric fields. For some interesting thing to happen in electrical circuits the way we provide the fields are by providing voltage differences between different points. Now what is an electric field electric field basically is something which accelerates the charge that is if you place a positive charge in an electrical field that positive charge will be accelerated in the direction of the electric field. Now the obvious analogy for this is the gravitational field; if you place some mass in a gravitational field, it will be accelerated in the direction of the gravitational field.

So let me put down this analogy here. So, you can think of this as earth's surface, but of course, it could be anything else which creates a gravitational field and I will consider a field gravitational field to be pointing downwards. And similarly let us consider some source of electric field we would not worry about what it is. I will just show it in downward direction, because I showed the gravitational field in downward direction. So let us say this is the electric field. Now we know that if we place a mass m in a gravitational field of course, it falls in the direction of the field the field accelerate it. So similarly if you place a charge q in an electric field, it will be accelerated in the direction of the electric field.

Now, again you have already done those such kind of calculations that is if you place a mass in gravitational field, it will get accelerated after certain amount of time what is the velocity taken on by the object and so on. So similarly, you can do so for the charges in electric field. But now we are not interested in such details of the motion of the electric charge. So what will do is instead of dealing with fields and acceleration of charges directly we will look at potential energy or potential of the charge. What does this mean so let say in a object, again I will use the gravitational analogy first.

Let say it set some height h 1 and it falls to another height h 2, so it falls from here to here. You know that the object will gain energy, so perhaps initially it was being held stationary and then at this point when it goes from here to there in gravitational field. It will gain some energy, and you also know that the amount of energy gain is m g h 1 minus h 2 then we also know that the voltage is related to the integral of the electric field such that when the charge moves from point 1 to point 1. It gains an energy which is equal to q times V 1 minus V 2, where V 1 is the potential at point 1 and V 2 is the potential at point 2.

So, you can see the analogy between energy gained by an object falling in a gravitational field and the energy gain by a charge which is falling in an electric field. When I say falling I mean being accelerated by the electric field. So, now, instead of dealing with the gravitational field directly, what can be done is to deal with gravitational potentials. Now you know that the energy gained is proportional to the mass itself and mass is the property of the object that is placed in the field. Whereas, this part of it g times h 1 minus h 2 that is the property of the field itself, so that is term to be the g times h 1 minus h 2 this is basically the potential difference between 1 and 2. So in this case, it is the gravitational potential difference, similarly this V 1 minus V 2 is also the potential difference between 1 and 2, this is the gravitational potential difference and this is the electrical potential difference.

Now from this, it should also be clear that what matters is the difference in potential between two points, so that is why it is many times called the potential difference voltage is called the potential difference because what matters is the difference in potentials, because we choose let say the earth surface to measure this height h 1 and h 2, but we do not have to do that we could measure it from the bottom of a bed or from the top of building, where then h 1 and h 2 will be different from before, but h 1 minus h 2 will be exactly the same as before. Similarly, here what matters is the difference in potential between 1 and 2, the potential at 1 or 2 can be arbitrarily assigned to any value that is they can both be arbitrarily shifted by a certain values by shifting the reference, but the difference between them will remain constant.

So, basically instead of using electric field, which accelerates charges; we will use potential difference between two points which also accelerates charges then we will not characterize it as acceleration of the charges, but as the rise in potential energy, but also it is not the energy itself, what we normalize it to unit charge so that figure of the charge itself, which is property of the object and keep only the potential difference which is the property of the field that the charges in. So the potential energy gained by falling in an electric field is nothing but the charge times the potential difference between the two points. So what is the bottom line here instead of dealing with charges and electric fields we deal with currents and voltages. You can see that these are some sort of aggregated quantities current is basically the total amount of charges that is flowing through the wire or across the surface in general, but we will consider them through wires and elements. And similarly this voltage also you know that the mathematical definition of voltage is the integral of the electric field so basically voltage difference between two points represents the energy gained by a unit charge by going from first point to the second point, so we will deal with these things instant.

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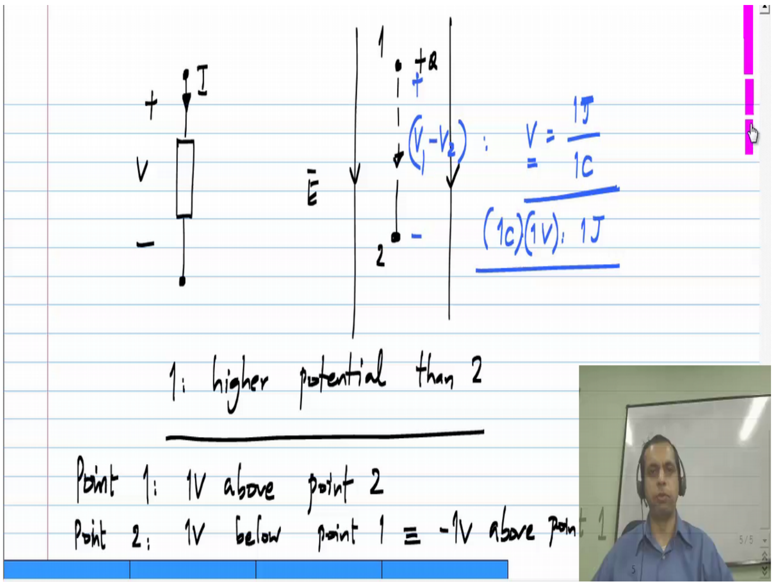

Now, why are these things useful again like I said a point is that we will have electrical elements which have at least two terminals. And this definition of voltage and current lets us deal with only the terminal characteristics, we would not have to worry about the spatial extend of the device or how it is arranged in space and so on. If you deal with charges and fields you will have to do that. So it turns out that for our purposes, we can simply look at the voltage difference between the terminals and the current through the terminals and make some relationship between voltages and currents and that completely characterizes the element and using these terminal characteristics is much, much simpler than trying to find the distribution of charges and fields.

So, just like in gravity a mass falls from higher potential to lower potential a positive charge falls from higher potential to lower potential in an electric field that is the definition. So if you have an electric field like this, you know that the positive charge will tend to move in that direction. So first of all this means that 1 is at a higher potential than 2; and how much higher is basically characterized by the potential difference V 1 minus V 2. The unit of potential difference, it is volts. So basically if 1 coulomb of charge moves over a potential difference of 1 volt, it gains 1 joule of energy, so the volt is nothing, but 1 joule per coulomb.

So, now, we could say that let say the point 1 is 1 volt above point 2, we could equally well say that point 2 is 1 volt below point 1, which is exactly the same as saying point 2 is minus 1 volt above point 1. Now this is kind of obvious or this is like saying the upper floor of building is 10 meters above the ground floor that is of course legitimate, we could also say that the ground floor is 10 meters below the upper floor, and we could also say that the ground floor is minus 10 meters above the upper floor. It is ((Refer Time: 12:11)) way of saying it, in normal conversation we would not do it, but with voltages frequently you encounter both positive and negative potential differences, and you should be comfortable working with them. So saying that point A is 1 volt above point B is the same as saying point B is 1 volt below point A or point B is minus one volt above point A. So the same thing can be said in many different ways and you should become comfortable with this.