Introduction to Electronic Circuits.
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Lecture-1.
Introduction to the Course and Basic Electrical quantities.

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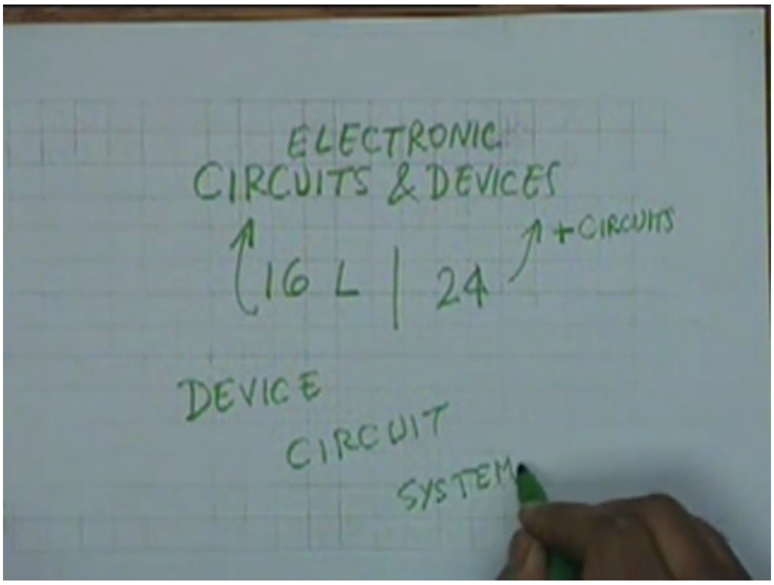

Professor: This course as you, as I have told you is e110m, this is introduction to electronic circuits. In the 1st lecture we shall introduce the course and we shall also introduce some basic electrical quantities, this is my name and we plan on about as I said 40+ -2 lectures for covering the total material. This course shall deal with basically, basically circuits and devices, electronic circuits and devices. And to be able to do justice to electronic circuits and devices, we shall 1st study, about 16 lectures will be devoted to general circuits and then the rest of it, that is 24 shall be to devices + circuits containing electronic devices, this will be the usual.

This will be the general breakup, about 16 to general circuits and 24 to electronic devices + circuits containing electronic devices. To be able to follow the course, we must understand what these arms mean, these terms like device, a term circuit and then often there shall be a term called system. We should also understand, we should also understand what is electrical engineering. At least have a have a broad area of what is electrical engineering. Well, electrical engineering is not your major discipline I understand, right? Is there anybody from electrical, anybody belonging to electrical engineering here, no. Okay.

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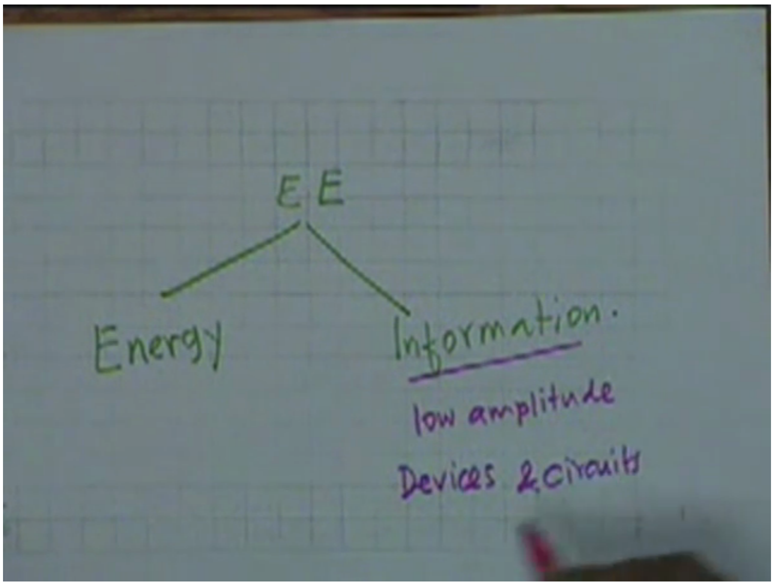

So it is all the more important as to what electrical engineering means EE basically deals with 2 kinds of, 2 kinds of phenomena. One is related to energy and the other related to information. The energy aspect of Electrical engineering is concerned with generation, transmission, distribution and utilisation of Electrical energy, usually high-power energy, that is the electrical voltages and currents that shall be dealt with in consideration of energy are usually high amplitude ones. That is you would not talk of, when you are considering energy aspect, you would not talk of a voltage like a 0.1 microvolts or 1 milliamperes current.

You will talk of currents of the order of amperes or 220 volts and so on. The energy aspect has to do with high amplitude voltages and currents and they are concerned with generation of search high amplitude electrical quantities, generation at a particular point like the Indraprastha power station, then transmission from a power station to another let us say substation like the RK Puram grid and then generation, transmission, then distribution to various houses for example and utilisation of this energy for lighting, for heating and for many other purposes.

This is the energy aspect, whereas the information aspect of Electrical engineering deals with low amplitude, these are usual and broad definitions, they deal with low amplitude voltages and currents and usually they would be of the order of volts or less. Currents of the order of milliamperes or less, although power also is important , but the power level in generation, transmission, distribution and utilisation of information containing electrical signals or electric voltages and currents, the energy level or the aptitude levels shall never compare with the levels that levels of energy and currents and voltages which are relevant to the energy aspect.

So these are usually low amplitude electrical voltages and currents. Now the information aspect is of course most important in communication of, communication any type of communication from one place to another, from one human being to another or from a group of human beings to another group of human beings. And this is done through electrical signals. So communication is the main main, let us say utiliser of the information aspect of electrical engineering. And this communication is done with the help of what we are going to study, namely devices and circuits.

Broadly a device is a building block for a circuit. For example a transistor is a device, resistance is a device, an inductor is a device, a capacitor is a device, diode is a device and there are many other examples and integrated circuit, a chip is a device and so on and so forth. And a circuit is a meaningful interconnection of devices, meaningful interconnection. Well, you can put a resistor here and a capacitor here without any connection between them but that does not make a circuit. A circuit is a meaningful interconnection of devices to perform a specified function, otherwise it is not a circuit.

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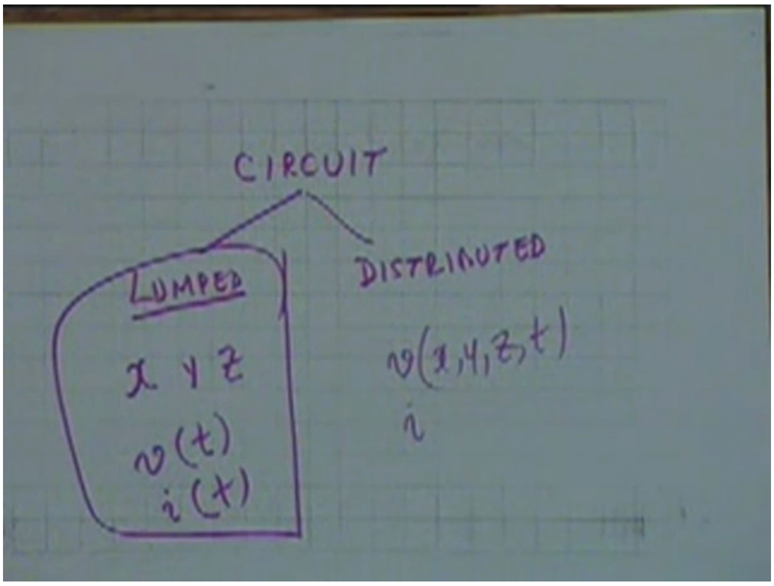

A circuit can be of 2 types. Circuit can be lumped or distributed, these are all new terms and therefore you should pay attention to their meanings and interpretations. When a circuit is so small compared to the wavelength of electromagnetic phenomenon, when a circuit is small compared to the wavelet of the electromagnetic phenomenon, then the total electromagnetic phenomenon and can be thought, can be considered to occur at a point in space. In other words when a circuit is of small dimension compared to the wavelength, the whole phenomena can be thought to be lumped at a specific location in space.

So the space variable X, Y, or Z, they are not important in a lumped circuit, such circuits are said to be lumped. In other words voltages and currents shall only be considered as functions of time t, the space, locations are not important. On the other hand if the circuit is so large that its dimensions are comparable to the wavelength of the electromagnetic phenomenon, for example a transmission line, you generate power at Indraprastha and maybe you transmit it to some point in madhya Pradesh, or from monday Pradesh grid you borrow some power for delhi, the length of the line is comparable to the wavelength and therefore that circuit is a distributed circuit.

In this particular course, where in a distributed circuit you see voltages and currents in general shall depend on the space coordinates and also time. And therefore in general is there should be functions of X, Y, Z and also time, all right. X, Y, Z are the space coordinates and t is the time. In this particular course we shall be concerned only with the lumped circuits, we shall not consider distributed circuits at all. But it is good to know that distributed circuits do exist.

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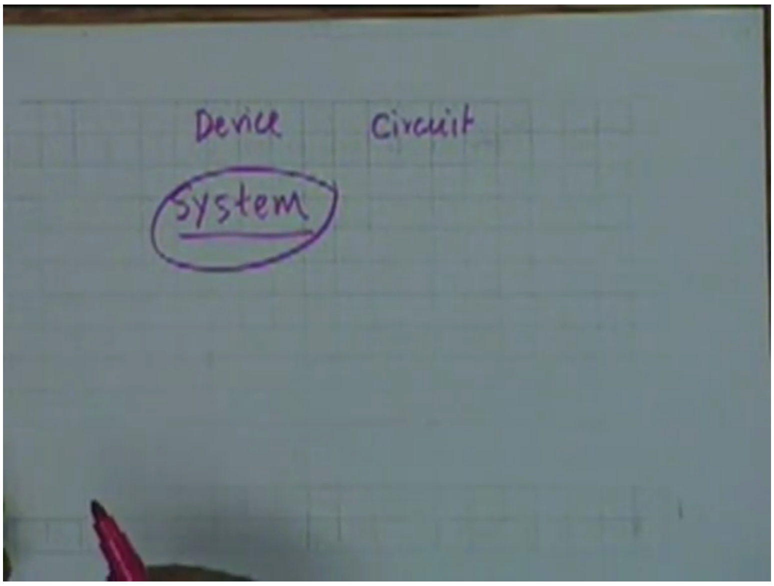

Then you shall often get a term like system, we have already said what is a device, we have already said what is a circuit and then you will also get a term like system. Now a system consider consists of devices, circuits, where circuits are meaningful interconnection of devices, therefore a system contains circuits, it contains devices but now devices can be electrical as well as non-electrical or interface devices. For example a public address system, a public address system, when a political leader speaks to its electorate, well it is not a public address circuit, it is a system because he speaks in front of a transducer which is, which converts sound energy or mechanical energy into electrical energy.

Now a transducer gamma microphone is not purely an electrical device, it is an electro-mechanical device or mechano-electrical device, all right. So a system consists of circuits and devices by devices may include electrical as well as non-electrical and interface devices. A public address system has a microphone which is not purely an electrical system, electrical circuit device, then it contains an amplifier which is in fact an, a circuit, amplifier is a circuit, then the amplifier goes to a loudspeaker which is also a transducer, it is not a purely electrical device, it is an electrical energy conversion to sound energy or mechanical energy.

Now such a conglomeration of circuits and devices, the only difference is the devices may contain non-electrical or interface devices also. Then the total thing, total combination is called the system. For example a public address system is an example of a communication system, there are other types of communication systems and so on. So the word system should be familiar to you.

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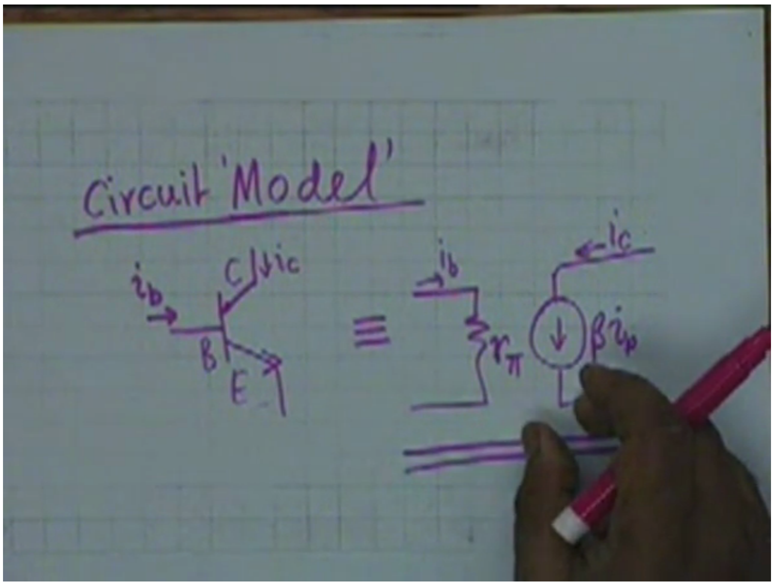

Then we shall also use the word model in many situations. A model in electrical engineering terminology is quite different from the dictionary or the popular use of the word model. A model is invariably associated an adjective circuit, it is a circuit model, okay. A circuit model is an equivalent electrical circuit for a physical device. A circuit model or simply a model, in the context of electrical engineering or electronic circuits, a model shall be used to mean a circuit model and a model is an equivalence circuit of a physical device, physical device could for example be a transistor.

And as we shall see later, if there are, if the current, there are 3 terminals in the transistor base, collector and emitter, we shall see this in details later, I am just illustrating a point. If the current in the collector and the base are given by i sub C and i sub B, then you will see later that a small signal equivalence circuit shall be simply like this. A resistance R pie and beta i sub B, this is a collective current i sub C. Now this is not the physical device, the physical device is this, this is schematic symbol for the physical device. And this one represents the performance characteristics with some approximations of the physical device. So this is called a model, all right.

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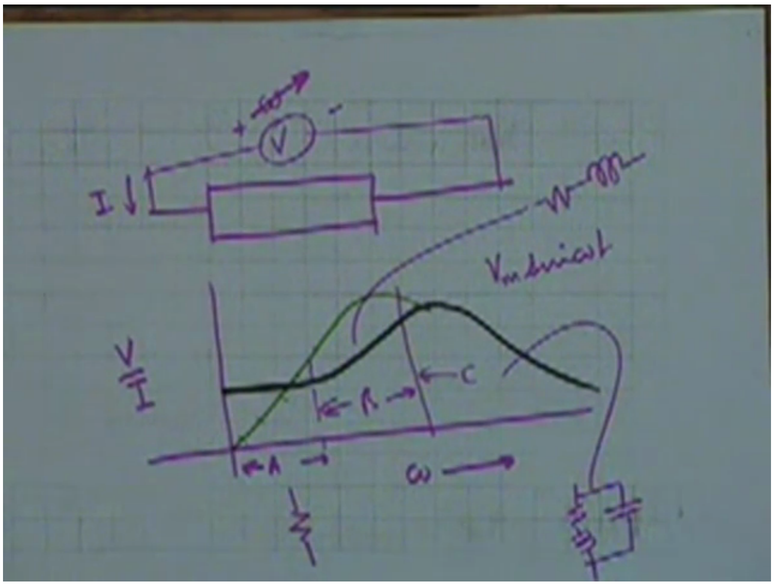

To take a simpler example, to take a simpler example, let us consider resistance, let us consider a resistance. Have you seen a resistance in the laboratory? Resistance, yes, you have with colour codes and all, all right. Take a simple resistance, now if you measure, if you put a voltage generator across it v, all right, and measure the current I, now this v can be of any frequency. In other words a frequency of the voltage, the voltage source is a sinusoidal source for simplicity let us say whose frequency can be varied. So Omega, that is it is of the form vm sin of omega t or cosine omega t, it is a sinusoidal signal, all right, sinusoidal voltage.

If the frequency is varying and you measure the ratio of v by I, all right, then one can show that the variation would be like this, I beg your pardon, I made a mistake, let me use some other colour. One can show that the variation would be like this. If you measure the ratio of v by I and vary the frequency, then it is like this. And then you see, this is the characteristic of the physical device, the resistance as you recall it. And you can see that over this range which we might call A, V by I is a constant, so it behaves as a pure resistance. Over this range A, it behaves as a pure resistance and therefore this is a model for the physical resistance in this range A.

In this range B let us say, V by I increases with frequency and as we shall see later this part can be characterised by a resistance increases with an inductance, the impedance of an inductance, do not be worried about these terms, we shall define and explain later. But over a certain frequency range, the model, no longer a pure resistance model suffices, we have to include an inductance. And over the rest of the range C, it appears that we have to include a capacitance across the resistance and inductance. So these 3 are examples of models of a simple device like a resistance, that you see in the laboratory.

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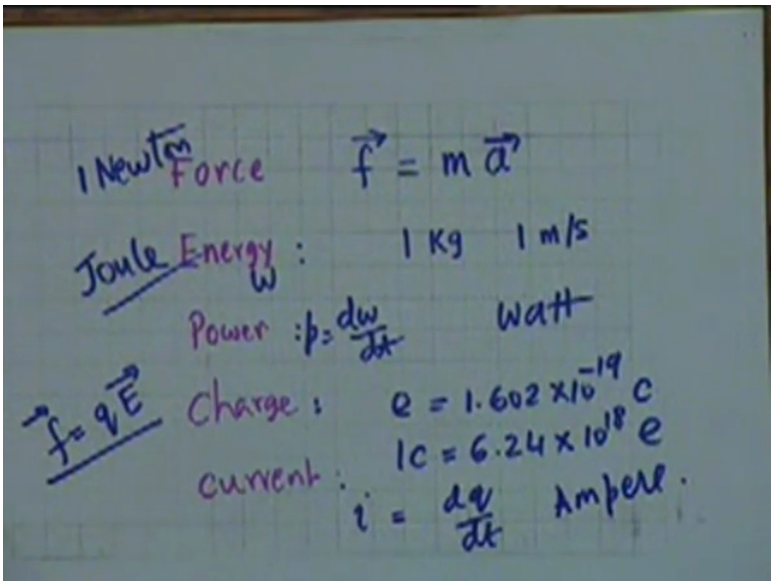

If you make a physical measurement of this at various frequencies, then the model at various ranges of frequencies shall be different. And this is what we mean by the term model. All right, let us go back to some basics, like physical quantities, we will start with force. We will, these are very relevant to electronic circuits, let us review some of the concepts that you might, you must have already learnt in mechanics and also in electricity and magnetism in the

JEE syllabus or the first-year physics course. This is just to refresh our memory about these various quantities.

Force as you know is, is defined with Newton's 2^{nd} law of motion, right. Force is, forces are vectors, you are acquainted with vectors and scalars, yes. Forces is a vector given by m times acceleration, mass times acceleration and the unit of force is 1 Newton in International system of units, SI units. One Newton is the force required to generate an acceleration of 1 metre per second square, to a mass of how much?

Student: 1 kilogram.

Professor: 1 kilogram, all right. So the unit of force is one Newton. Energy is expressed in joules, and energy is the capacity for doing work. If 1 kilogram mass moves with a velocity of 1 metre per second, then it has a kinetic energy of half a joule, 0.5 joules, okay, so the unit is joules. You can have many other ways of defining a joule but this is good enough. Power is the rate of doing work, so if energy is denoted by W, then power P is equal to dw by dt, rate of doing work. I therefore the unit should be joules per second which we call a watt. Now charge, charge is usually defined in terms of Newtons, that is you place 2 charges and express the force of attraction or repulsion between them in Newtons, all right.

But charge for electrical engineers, for electrical engineering and electronic circuits we shall define, we shall conveniently defined, it is an absolute definition, we shall currently defined in terms of an electron. As you know and electronic charge is 1.602 times 10 to the -19 coulombs and so 1 coulomb can now be defined in terms of the charge of a certain number of electrons. And this number is 6.24 times 10 to the 18 electronic charge. You can also describe 1 coulomb in terms of the force experienced by a charge, okay.

You know the force experienced by a charge is given by the charge multiplied by the electric field qe and therefore a coulomb is that amount of charge which experiences efforts of one Newton in an electric field of one volt per metre, all right. You can define that way or you can also define a charge in terms of the current, it is the , 1 coulomb is the amount of charge transferred by a current of 1 ampere in 1 second. And this, this brings, we are not making absolute definitions, these are convenient ways of looking at these various quantities. Absolute discretion you look in the physics course, how to measure absolute measurement of charge and current and all that.

This brings us to the definition of current, current i obviously is the rate of flow of charge, that is dq by dt and the unit should be coulomb per second which has been named after ampere, the great electro, electrical engineer and the unit coulombs per second is given the name of ampere. Now in considering current, since current is related to flow of charge, we must distinguish between the polarities of charge.

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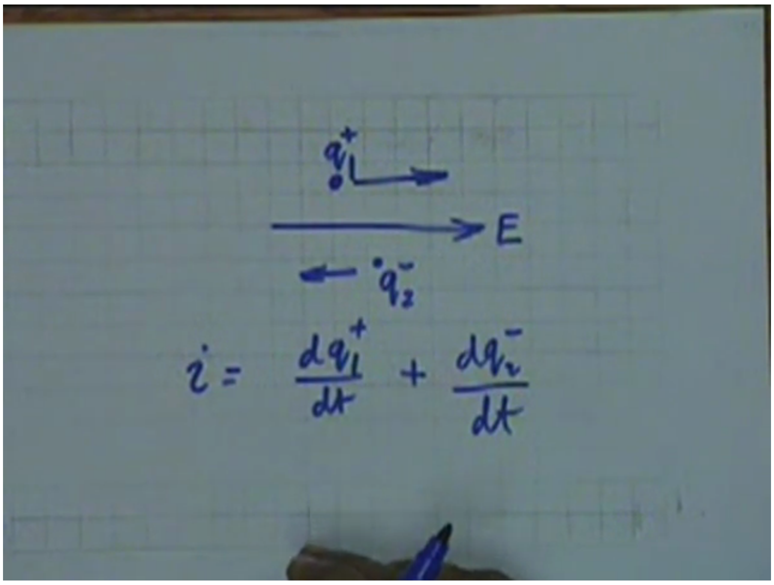

Suppose we have an elected field in this direction E and you have a positive charge, let us say q1 + and a negative charge, let us say q2 which is negative, all right. Then the positive charge shall move in which direction?

Student: In the direction (())(24:07).

Professor: In the direction of the field, it shall move in this direction and this shall move in this direction. The current then shall consist of 2 components, one due to the motion of positive charge, the other to do the motion of negative charge. Now a negative charge moving from right to left is equivalent to a positive charge moving from left to right and therefore the current here shall be dq 1+ by dt, that is from left to right due to the motion of positive charges + dq 2 - dt, it contains 2 components, one due to positive charge, the other due to negative charge.

This shall be useful when I consider the electronic devices like a diode or a semiconductor transistor, where there are carriers, charge carriers of both polarities, positive as well as negative. And therefore you shall have to consider both the components of charge, of current.

One should also recall the definition of potential because voltages basically defined from a potential.

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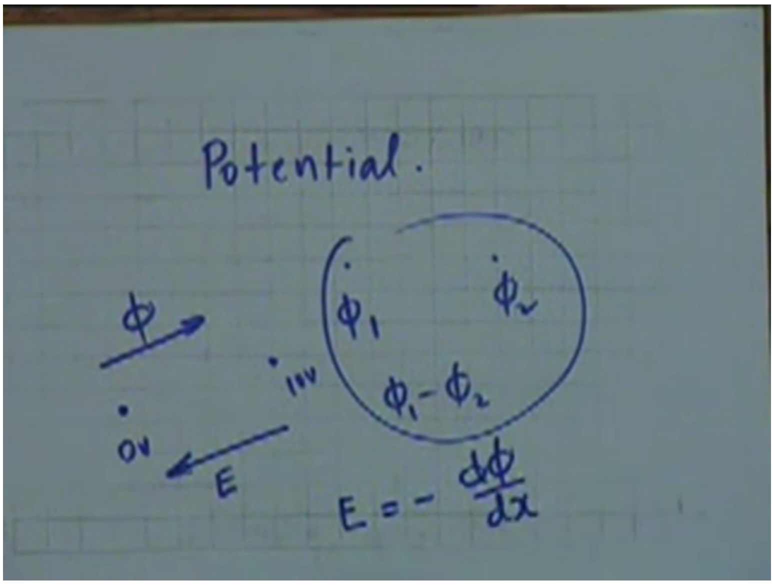

Potential, electric potential at a point in space is defined as the amount of work required to be done to bring a unit positive charge from infinity up to that point, all right. And potential difference between 2 points, let us say what should I use for, let us say phi 1 and Phi 2, if these are able to absolute potential of the 2 points, then Phi 1 - phi 2 is called the potential difference between these 2 points of the voltage between these 2 points. And as you know for measurement of voltage, voltage is basically difference of potential between 2 points and it becomes absolutely convenient if we can fix a reference potential.

And the reference potential is that of the Earth, not this Earth, the Earth down below, it has to be conducting Earth, all right. That is considered as 0 potential and therefore all potentials are considered as voltages. But you must remember that voltage is indeed a potential difference and therefore if you have a reference, when you say the line, the overhead line is 11 KV, that means taking the ground as 0 potential. Right, this must be understood. It should also be understood that if potential increases, let us take 2 points, if potential increases in this direction Phi, that does that say this is 10 volts and this is 0 volts, all right, potential is also expressed in volts, okay.

This is the reference and this is… If potential increases in this direction, then electric field direction is in the opposite direction, that is this is the direction of electric field. Electric field by definition had the directions of electric lines of force which emanate from positive charges and terminate on the negative charges. All right. And therefore Phi, the direction in which Phi increases and the direction in which E sets up are poor into each other and the things that relationship is E equal to - d Phi by dx, the negative gradient of potential, this must be understood.

That brings us to the concept of an electric field. Electric field, you see we are, we are all, we are mixing things up while defining one in terms of the other, then defining the other and so on. This is a convenient way of refreshing memory because all the absolute definitions are known to you. What is an electric field? And electric field is, well 1st existence, an electric field exists around a charge or a set of charges, all right.

A charge or a set of charges, there exists an electric fields, you could let say a sphere charged with let us say + Q or you could have able to spheres, one is + Q and the other is let say - q. And so whenever there is a charge around, there exists an electric field. The property of electric field, the manifestation of an electric field is that if you put another charge, another charge nearby, it will either be attracted or repelled. In a specific direction, it shall move in a specific direction which shall indicate the direction of the electric field.

And the amount of force experienced, if this extra charge is a unit positive charge, that is one coulomb, then the force experienced will give you the value of the electric field and the direction in which this force is exerted will give you the direction of the electric field. And therefore electric field is specified by 2 quantities, one is the magnitude and the other is the direction. So it is a vector quantity. Alright. Now this, this charge need not be the set of charges or the charge which sets up an electric field need not be stationary, it could be moving. Now if the charges are moving, then in addition to electric field, there also appears a magnetic field. All right.

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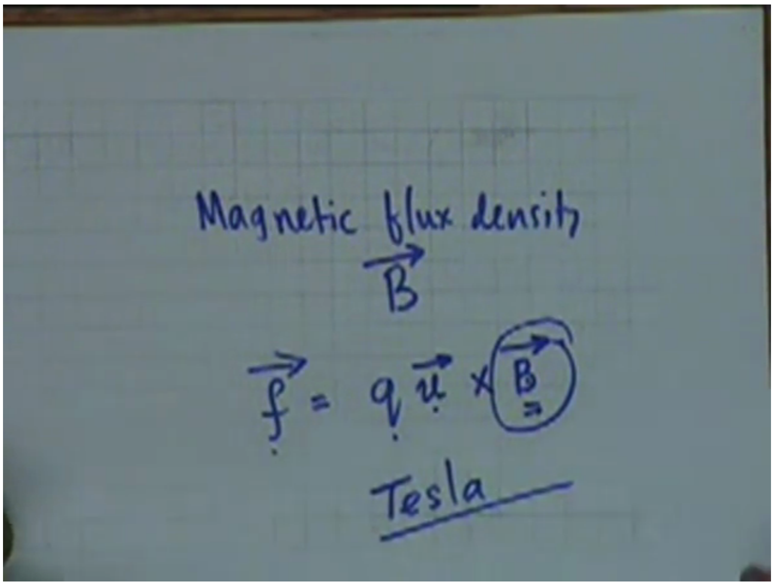

And if there is a magnetic field, then we define what is a quantity called magnetic flux density. And is we shall denote by B, B is also a vector. And the definition of magnetic flux density or the unit of magnetic flux density, well we shall not have much to do with magnetic flux density in the course on electronics. Maybe sometimes we shall be required to but it is good to know that magnetic flux density is defined again in terms of the basic unit, basic quantity which is the force, comes from Newton's 2nd law of motion. It can be shown that a force expressed by a charge q moving with a velocity u, velocity vector is a vector quantity, moving with velocity u in a magnetic field of flux density B is given by this.

Force is equal to charge multiplied by scalar multiplication, q is a scalar, multiplied by the cross product of u and B. The cross product of u and B, the magnitude is product of the 2 magnitudes multiplied by the sin of the angle between the 2 and the direction is perpendicular to the plane containing u and B following which rule, right-hand rule. We will not go into more details of this, perhaps it shall be done little later. And you will have much more to do with this in the course on introduction to electro-mechanical energy conversion, if you do take that course.

But let me point out the clever way of defining the magnetic flux density. Obviously it shall be equal to the force exerted on a unit positive charge, 1 coulomb, moving at a rate of 1 metre per second. So that is how we define the magnetic flux density. You see we have defined force in newtons, so we say absolute mechanical quantity, there in absolute standard for this, there is a standard for metre, this is standard for time. So metre per second is the velocity, this is a new trends and we have already defined coulomb and therefore it becomes very convenient to give a unit to B, that is the magnetic flux density.

And this is named after the Czechoslovakian, was he Czechoslovakian, I am not too sure, the gentleman tesla, Nikolai tesla. So a unit, unit of magnetic flux density in the SI unit, System Internationale is a tesla.

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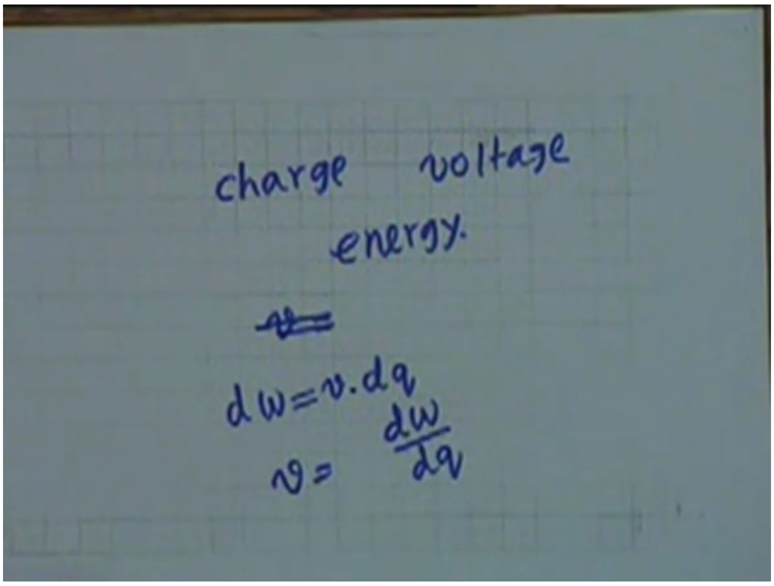

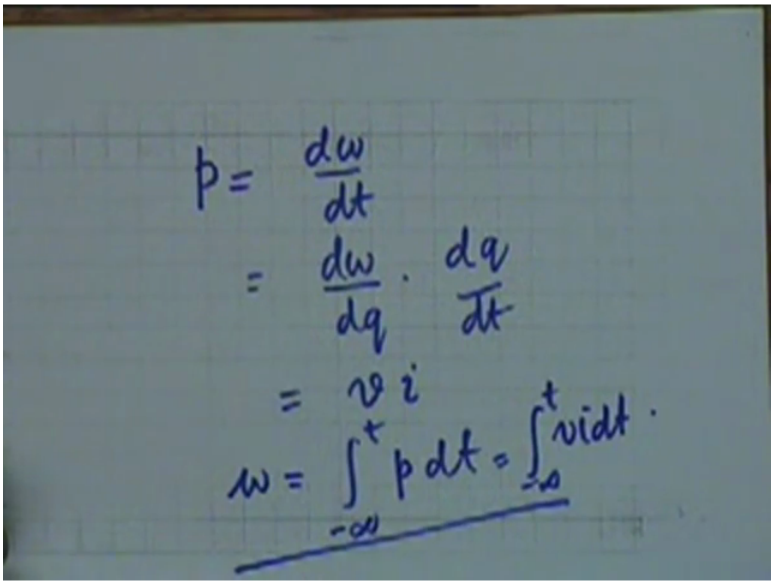

Now let us go back to charge and voltage and energy. Well, the voltage at point considering the ground as reference is obviously, let us put it this way. If you wish to move incharge dq, an elementary charge dq through a potential difference v, then the amount of work that is required to be done is v times dq. This is the amount of work required to be done, dw, all right. So dw is equal to v dq, in other words v can be written as dw by dq. This is the relation between voltage, energy and charge, v is dw by dq, all right.

And therefore if you understand this, it is very easy to see that the power which is the rate of change of energy dw by dt can be written as dw by dq, how does vi, that is what I am showing, times dq by dt. And dw by dq is v and dq by dt is i. So the power in electrical engineering is simply the product of voltage and current. So volts amperes is the same as watts, all right? And if you want the energy W, energy by definition, power by definition is the rate of doing work, P is dw by dt, so energy must be the P dt, let us say from - infinity to t, if you start at - infinity to t, this is the total energy consumed by an electrical circuit where and this can written as - infinity to t vi dt. Let us consider, yes…

Student: (())(35:28).

Professor: Why do you start at - infinity, okay. Let us take a capacitor and we charge it to a certain voltage let us say capital V, all right. If we take that, if we take the lower limit as 0, then you shall have to consider the initial voltage on the capacitor. That is you have to do 0 to t + the effect of the initial voltage because initially also there is some energy in this. If we take - infinity to t, then all initial conditions have been taken care of. And therefore we say from time immemorial, whatever the history, the device of the electrical circuit may have gone through, we do not, we supplement reply vi and multiply by dt and integrate from - infinity to t.

There has to be a reference of time when you are considering an electrical circuit. If that reference is taken and 0, then you must see what was the condition of the circuit in 0 - because electrical circuits can store energy, they are dynamic, dynamic devices, this is dynamic phenomena. They can store energy, they can dissipate energy, they can deliver energy and therefore you must consider, it is safe to consider from - infinity to the present time. We shall breakup this integral to 0 to t + the condition at 0 - later on, all right, to take care of all that happened from - infinity to 0 -, all right.

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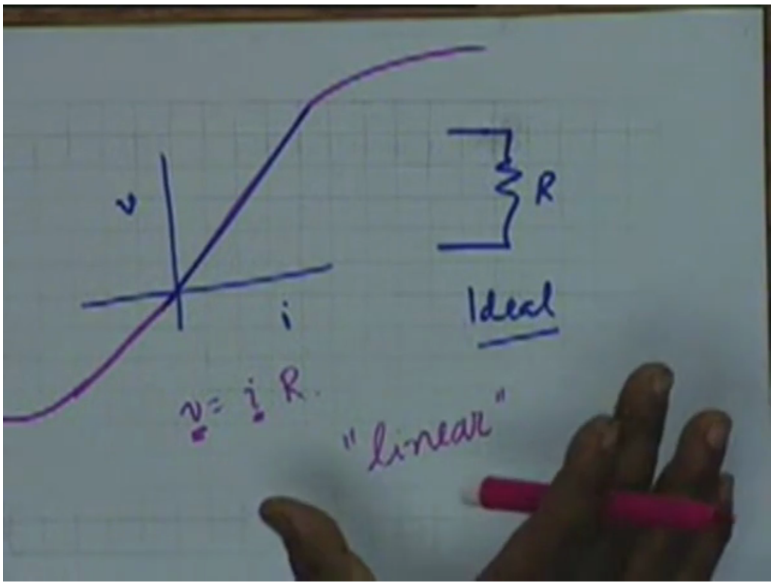

Let us consider a simple resistance whose model, that is we are considering a resistance in a range of environmental conditions such that the model is a pure resistance like this. We call this an ideal resistance, okay. Ideal, that is it contains only resistance, nothing else. An ideal resistance you know by ohms law that if you plot v versus i, it shall be a straight line with the slope of, with slope of R. V equal to ir, therefore dv by di shall be equal to R. Now this is an appropriate point to introduce the term, introduce another term, that is a term called linear.

We shall consider all electrical devices in this course as linear. There are resistances which may not behave, which may not obey ohms law, there are resistances which may not obey ohms law. For example a thermistor or an electrolyte, it may be such that it behaves, it obey ohms law for a certain region and then it saturates like this. Such a resistor is called a non-linear resistance. A resistor in which v is linearly proportional to i is called the linear resistance. And we shall always consider in this course linear resistor, unless specified otherwise, we shall also considered non-linear resistor a little later but most of the resistors that we consider shall be linear.

This is a good point. Next time, in the next lecture we will go to the other kinds of circuit elements and consider the implication of linearity in them. Thank you.