Introduction to Electromagnetism
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Lecture - 04
What is Electric field?

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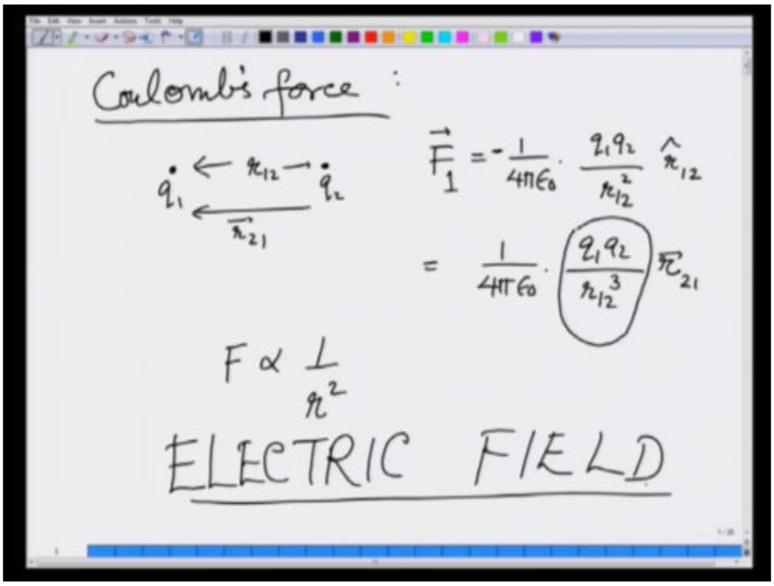

How about Coulomb's force and how different charge is interact with each other? In particular we learnt, if there is a charge q 1, another charge q 2 and the distance between them is r 1 2. Then the force between them, let us say the force on 1 is given by 1 over 4 pi Epsilon 0, q 1, q 2 over r 1 2 square, r 1 2 with the minus sign here unit vector or we load it even better 1 over 4 pi Epsilon 0, q 1, q 2 over r 1 2 q vector r from 2 to 1. This is r from 2 to 1. And this covered all the repulsive and attractive forces.

Now, the other thing we learnt that, how to experimentally checked that this dependence F is 1 over r square. In today's lecture, we want to introduce a new idea called the electric field. Although, when dealing with electrostatic situation, description by electric field and the Coulomb's force were directly between two charges is the same as far as the forces on charges are concerned. But, we will see later that this is a conceptual advance, let me just talk a bit about it.

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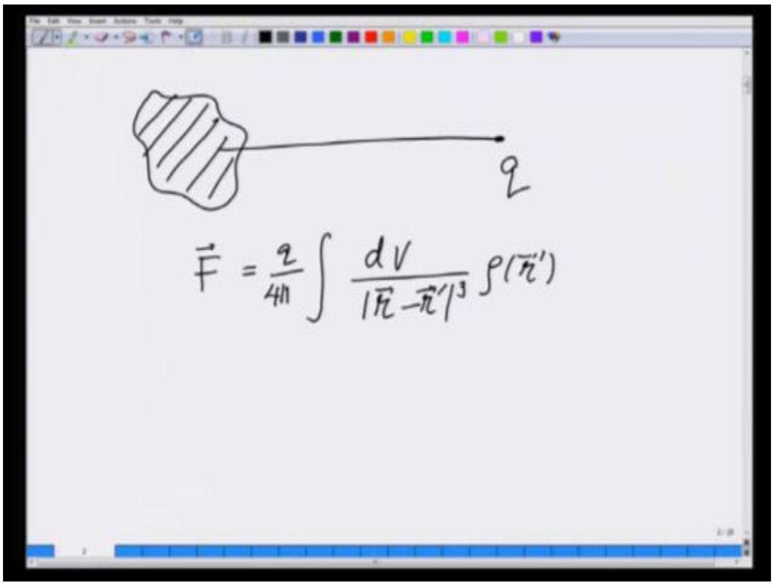

Let us look at a charge distribution and the force is applied on a charge q far away, and last time we saw that this force is given by integration d v over r minus r prime cubed charge distribution rho r prime acting on q.

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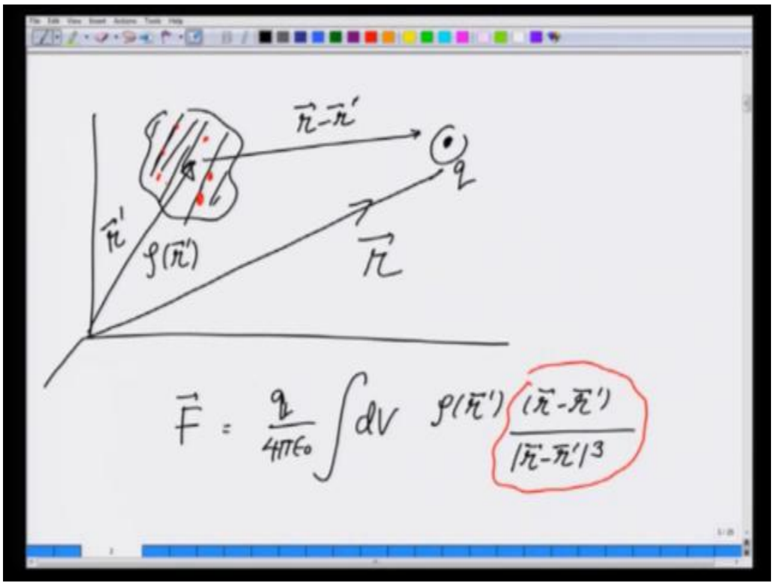

What we learnt in last lecture is interior charge distribution is given, let us say this is rho r prime and I am calculating force on a charge cube at a distance. So, let us make the co ordinate system, this is at vector r and this vector is given by r prime, the distance from here to here is this vector is r minus r prime. Then, the force on q is given as F is equal to 1 over 4 pi Epsilon 0.

Since, this charge q, I will put a q here, integration volume integral rho r prime r minus r prime over modulus r minus r prime cubed. Notice that, this quantity here is actually 1 over r square or 1 over the distance between the charges square. When I integrate this, when I am calculating force due to each small distribution, small charge here and adding it up, which was a principle of superposition we learnt earlier. The question we ask now is, is it that I always need the other charge to find the force or this is original charger solution itself does something in the space. So, that in other charge q is a force, let us understand that.

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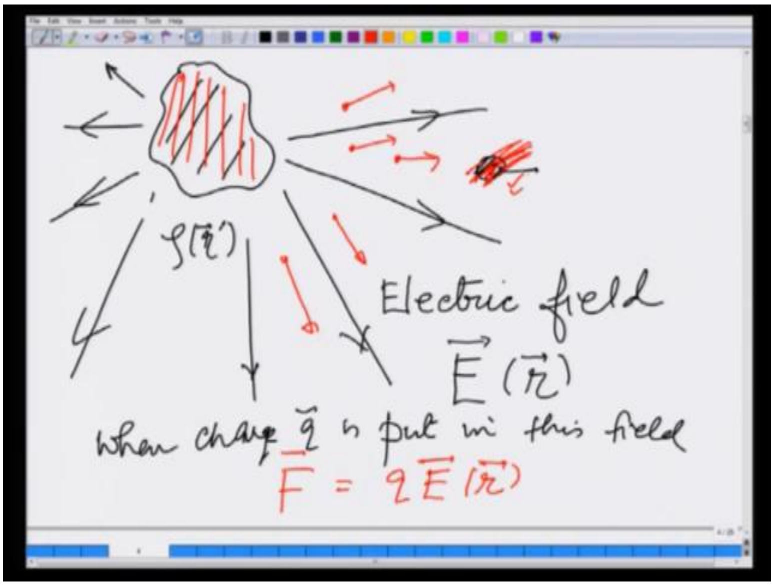

What we are going to now say is that is the charge distribution, given here rho r prime itself creates a field around it that means, it distorts something around it. It creates something lot of lines around it, so that if I put a charge somewhere, because of this photograph I have created which I am going to call the electric field, a force is applied on this.

So, charge distributions creating an electric field around itself and I am going to denote it by E vector at r. So, that when charge q is put in this field, the force on this charge is given as q times E. So, notice, what we are saying is, even if this charge is not there, due to the presence of this original charge distribution of field is created inside. By field, we mean at every point, at every point, there is a vector, at every point, there is a vector point in a certain direction and when I put an extra charge on this, it creates a force.

Now, as far as calculating force on q is concerned, weather I think in terms of fields or I think in terms of when this charges are brought to whether there is a force, it does not make a difference. Then, why I am introducing such an idea of a field? Is it real? Can I really check, if there is a charge distribution it creates this field around itself? We will see later in the course that it is a real quantity that is capable of propagating from one place to the other. So, it is a real, real entity.

So, from now onwards, we are going to focus on the electric field produced by charge distribution, because that is what really is a physical quantity, and later we will see that is what really you now take information from one place to the other or it apply forces on for a given charge. So, what we are going to now talk about is the electric field.

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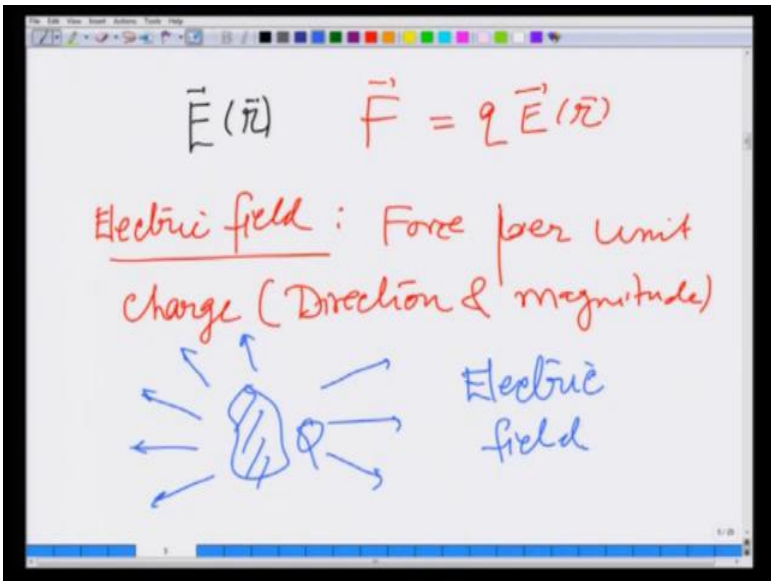

As I said is now that given any field E at r, the force on a charge q, put there is going to be q times this E r. That means, by definition electric field is nothing but force per unit charge direction and I need the both are equivalent to force per unit charge. So, that is the way I am define it mathematically, but conceptually is a advance, as I said, what we are actually suggesting is, given a charge distribution, q it is creating a field around itself.

So, this exist something around it that I am calling the electric field and it is direction and magnitude is given by force is applied on a unit charge.

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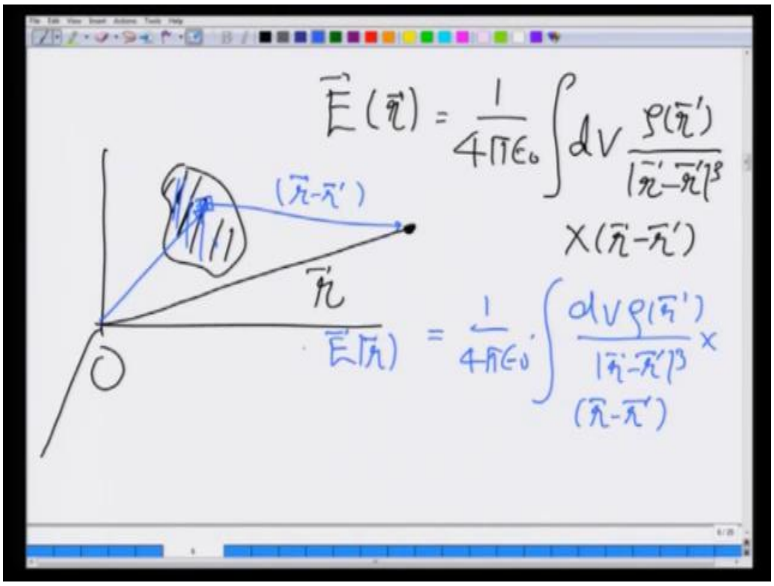

So, let us see, therefore given this distribution of charge the electric field by definition at point r is going to be 1 over 4 pi Epsilon 0, integration over this volume rho r prime over r minus r prime cubed times vector r minus r prime. Let us see, what we are doing, we are taking this as the origin, I am calculating field at a point r.

Due to this charge distribution here and due to this small volume here, the electric field is given by at a distance r minus r prime. It is given by 1 over 4 pi Epsilon 0, d v rho r prime over r minus r prime cubed times r minus r prime. And due to this entire charge distribution, I just integrated all, this becomes the electric field by principle of super position.

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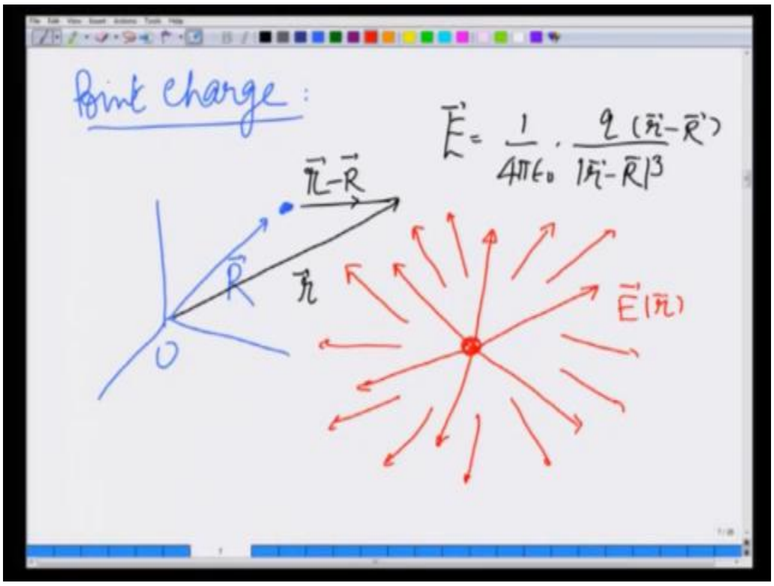

For example, if I take a point charge, let us say at some position vector R, then the electric field at some other position r is going to be E equals 1 over 4 pi Epsilon 0. This is effective from here to here, this will be r minus R is going to be q over r minus R cubed r minus R. And the way it is going to look, I will draw it in different color is all these lines, three lines going away from this point charges, this is how I am going to denote it.

So, notice that field exist everywhere, because given a unit charge or given any charge, anywhere around the point charge is going to experience a force. So, by definition field exists everywhere, but that fields exist independent of whether the charges there or not, even that we do not feel any force this charge by itself is creating a field.

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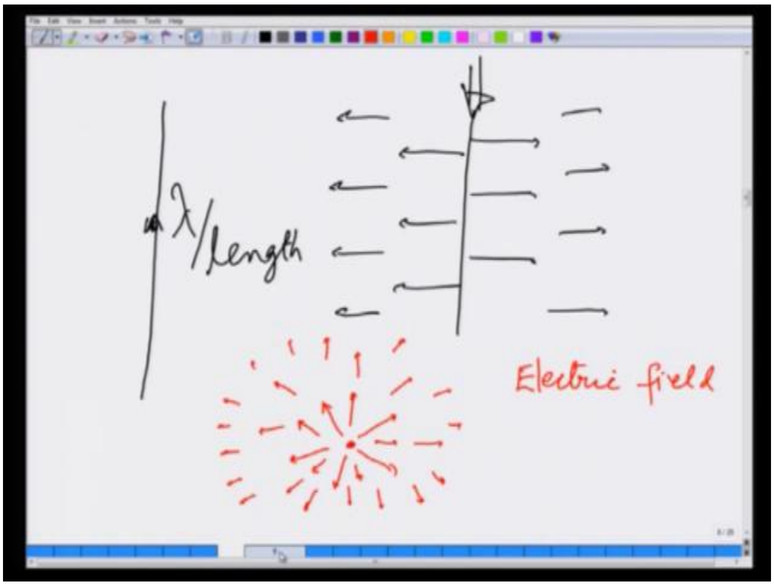

Let us look at a line charge, you know the previous lectures, we did a line charge of carrying a lambda per unit length and what we saw is that, it creates field like this around it. So, anywhere around it, I put a charger experiences is a force, if I look at it from the top, let us look at it top, this is the line charge. The lines are all going out as you go further away; a field magnitude becomes a smaller sometimes indicated by making smaller arrows, we go further away arrows becoming a smaller.

So, by making these pictures, what I am make you feel is that, something exists around a given charge and that is the term called electric field. And you also seen, how to obtain it from a given charge distribution, other the example of fields, let me just talk about them, so that you get a field for this.

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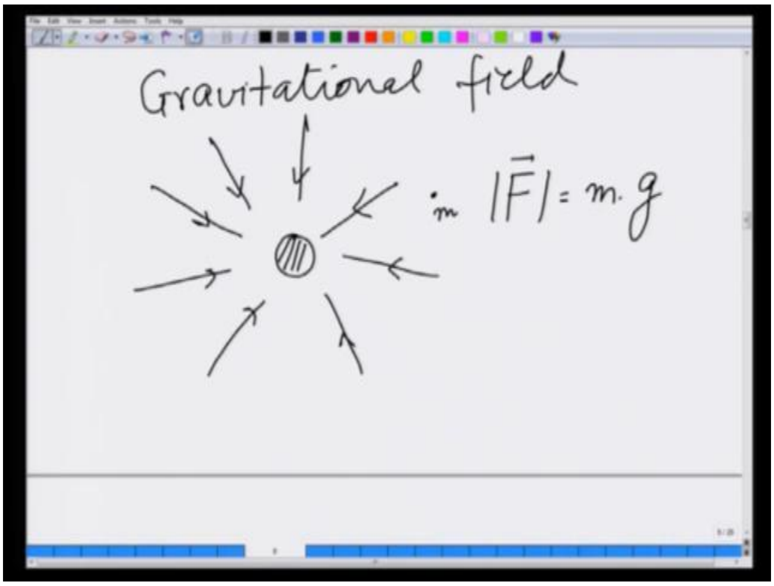

Other examples of fields, a very obvious example that you are familiar with is gravitational field, in which I can say that, if there is a mass, it creates a gravitational fields around it. So, something exist that gravitational field exist, because if there is mass is being somewhere and given any other mask put here. It experiences is a force F vector whose magnitude is given by m times is gravitational field, which we call g, gravitational acceleration.

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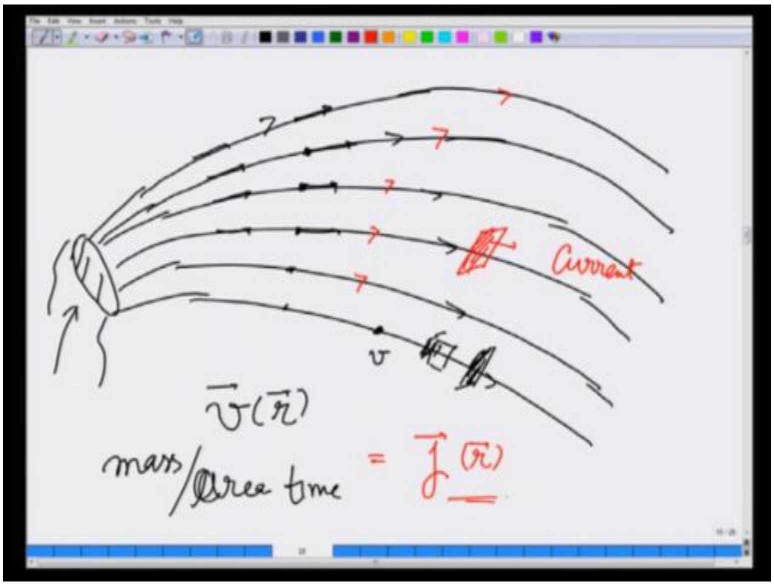

Another example of field is going to be, suppose there is fluid point and I try to see, how the velocity of this fluid is changing, this may be coming out of what a tap here and fluid may flow like this. So, you see at each point, there is a different velocity associated with this water flowing out of the pipe. It obviously, each one follow the trajectory like this, but there at each point, there is a velocity, I can say, there is a velocity field.

I can also ask, what is mass percent unit area, per unit time, flowing through any cross section here or it cross current here and that is what called current, which give me the direction of flow as well as the amount that fluid flow. So, this current j r is also field, which exist everywhere is a vector quantity. So, these are some example of the field, I given in two examples of what electric field around two different charges looks like.