Electromagnetism
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Lecture – 23
Introduction to Electrostatics

After getting introduced to the mathematical background that is required for this course Electromagnetism let us move on to Electrostatics. So, we will start the electrostatics with the principle of superposition.

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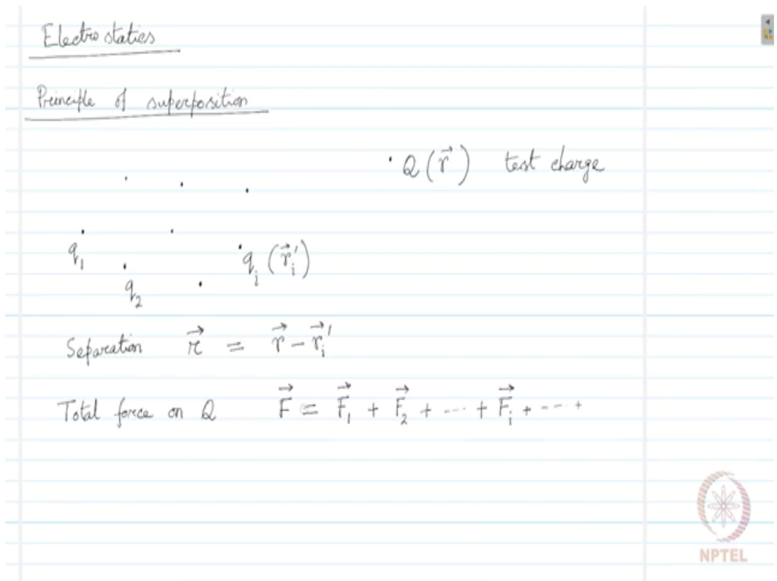

Let us consider a situation where we have few charges distributed over a region, we consider few point charges distributed like this, where this one is say q 1, this is q 2 and so on, say this is q i ith charge at r i prime position, r i prime is the position vector for this ith charge. And let us consider a test charge here marked as capital Q at location position vector r this is the test charge.

Now, the distance between the test charge and the point charge at ith position, the separation can be given as curly r vector equals r minus r prime r i prime. So, if we now consider the total force on the test charge capital Q due to this charge distribution that we have we can write the total force on capital Q as the force due to the first charge plus the force due to the second charge plus the force due to any ith charge plus so on.

So, the force the amount of total force on Q would be the vector sum due to the force from all charges, this is the principle of superposition. And this is very important in the context of electrostatics, we will find its use later on. One must remember that it is the force that we are summing and no other quantity.

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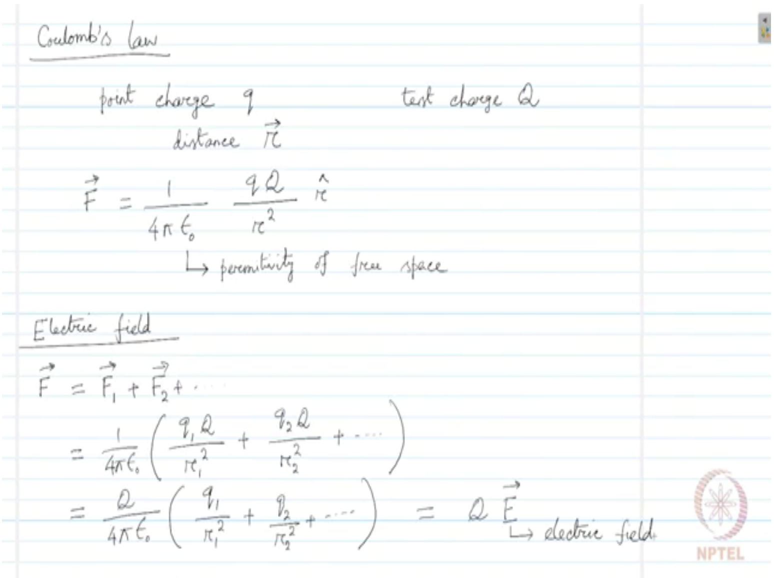

Now, let us move on to finding an expression for the electric field, the force in due to two charges the electrostatic force due to two charges and the expression was given by coulombs. So, it is known as coulombs law. If we have a point charge small q and a test charge that is also a point charge capital Q at a distance curly r vector, then the force acting on the test charge capital Q due to the point charge small q will be 1 over 4 pi epsilon naught small q times capital Q over r squared along the r cap direction.

We will explain why what is epsilon naught later epsilon naught is known as the permittivity of free space. We will explain it later let us now introduce the concept of electric field we have seen that the total force can be expressed as the superposition of F 1 plus F 2 plus so on which is nothing but 1 over 4 pi epsilon naught q 1 capital Q times r 1 squared plus q 2 capital Q times sorry divided by r 2 squared plus so on. Taking the capital Q out, we can write it as capital Q over 4 pi epsilon naught q 1 over r 1 square plus q 2 over r 2 squared plus so on, or we can write this as capital Q times the electric field E. That means, if we bring a test charge q in this region it will experience an electric field, and due to that electric field the force on it would be the amount of charge times the electric field.

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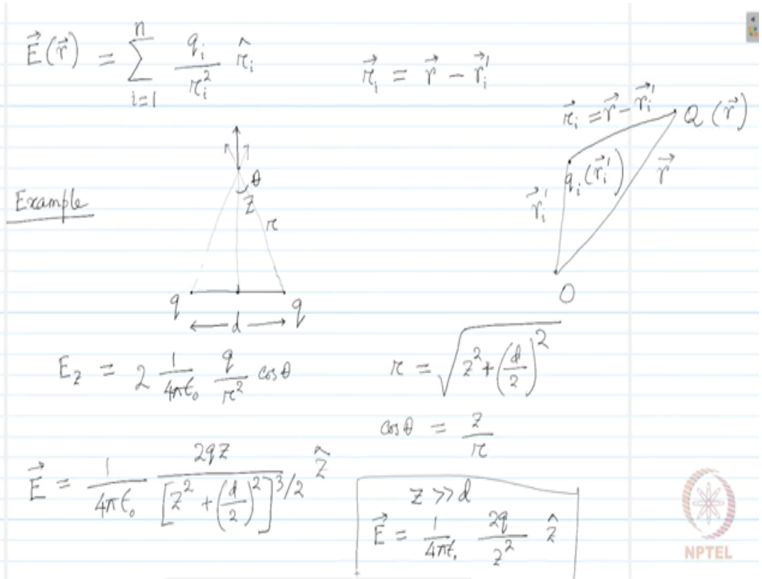

That means we can define the electric field E that is a function of a position vector as if there are n charges, then q i over r i squared r i cap. Now, here we must remember that the coordinate of a charge is represented by the position vector r prime r i prime, and the at a point that is represented by the position vector small r, we bring in the test charge. So, the distance between these two points are given as curly r r vector that is the distance from the position vector r to that position vector of the test charge r to the point charge r i prime.

So, this is known as curly r i. It is like here is our test charge q i, it is position vector is given as ri prime this is a point charge here we have our test charge q capital Q and its position vector is r. So, the vector connecting these two would be given as r minus r i prime vector, and this is denoted as curly r i with respect to any arbitrary origin let us say located here. So, this much is r i prime and this much is r.

So, we have found the expression for electric field. Now, let us consider an example. Let us consider a charge distribution with two point charges. We have one point charge at the left of value magnitude q, at the right we have another with the same magnitude, and the distance between them is d let us say. We want to find out the electric field at this point which is z distance above the by the line bisecting sorry it is above the bisecting point of the line connecting these two charges Q.

So, if we have this kind of an arrangement, we can see that the electric field due to the left hand side charge would point in this direction, the electric field due to right hand side charge will point in this direction, and the resultant direction of the electric field would be along z-direction. If we consider this angle to be theta, then we can write down that the z component of the electric field from one charge q is 1 over 4 pi epsilon naught q over r squared cosine of theta, where this is r this length. And for if we consider both the charges, we will have to multiply it with 2, and r will be given as z square plus d over 2 squared square root of this, cosine of theta is given as z over r.

With this we can write the resultant electric field as 1 over 4 pi epsilon naught 2 q z over z square plus d over 2 whole squared power 3 by 2 z cap. Now, if we consider the limit where z is much greater than d, then in this limit we will have the electric field expressed as 1 over 4 pi epsilon naught 2 q over z squared along z cap direction that is valid only within this limit.