Electromagnetism
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Lecture – 73
Magnetism, force and torque on magnetic dipole

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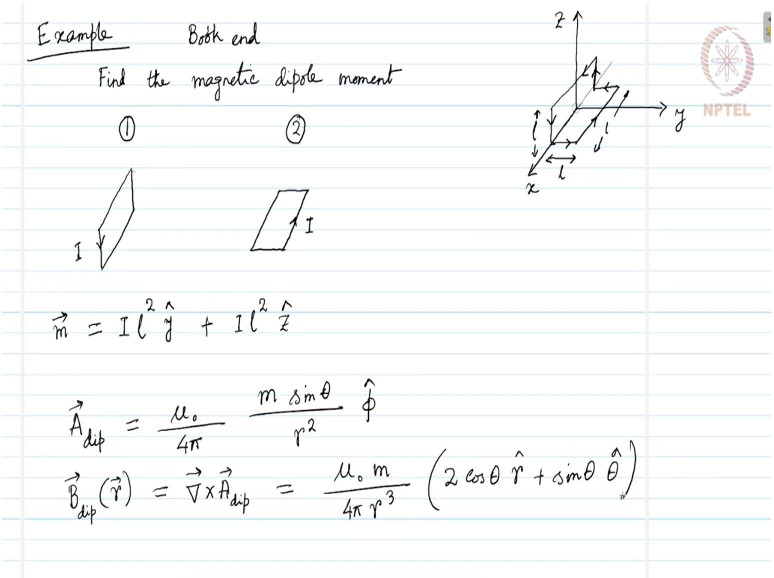

Now, in matter, if we consider magnetic field, what happens? In matter so, materials can behave like diamagnetic, paramagnetic, ferromagnetic, anti ferromagnetic or ferrimagnetic. So, diamagnetism is the universal feature when we apply some magnetic moment, the electrons orbital motion changes subject to that magnetic moment and that response will is called diamagnetism. Paramagnetism, ferro magnetism, ferrimagnetism and anti ferromagnetism these things come from the spin of the electron.

So, that part we would not discuss. We will just discuss about the torques and forces on magnetic dipole, what happens? If we have a magnetic dipole subjected to a magnetic field, what happens on this? We will try to discuss that now.

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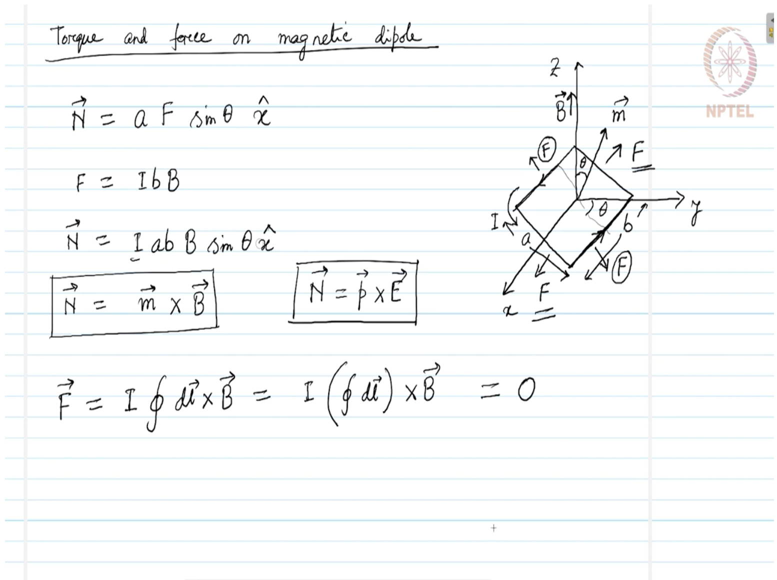

So, let us consider the torques and forces on magnetic dipole. Let us consider a magnetic dipole in the form of a rectangular current carrying loop. Here is our x axis this is y axis and this is z axis and this current carrying loop carries the current I in this direction, but it is not in x y plane rather it is tilted a bit. It is, this part is lower and this part is higher in z. It is arranged like this.

Now it is subjected to a magnetic field along the z direction. So, due to that magnetic field, what will be the force on this current carrying loop? Let us find that out. The current on this arm here is along this direction. So, v cross B will give us a force that is along this direction.

If we go to this arm we will find a force along this direction, if we come to this arm, here the force is along this direction, here the force is along this direction. And if we have a uniform magnetic field B, we will always have the forces being equal and opposite to each other.

Now, this force here and this force here, they will balance each other, this force here and this force here they will balance each other, but there is something interesting in the fact that we have different z values for this line here and this line here therefore, it will develop a torque. If this angle with z y axis b theta.

Then we will have a magnetic dipole moment vector m that is perpendicular to our rectangle and that will make a theta angle with the z axis. Now with this we can write the expression for the torque as a, a is the length of this arm, b is the length of this arm. So, this will be a times F times sin theta and the torque would act on x cap direction.

So, what is the force on each segment? So, the force the magnitude of the force we can calculate as I small b times capital B, where B is this length and a is this much length. Given this, we can write the expression for the torque as N equals I a b times the magnetic field magnitude sin theta x cap.

Now, that means; we can write the torque in vector form as N equals m, the magnetic dipole moment vector cross B, the external magnetic field that we have applied along z direction in this problem that vector.

So, this is the torque in the context of a magnetic dipole under the influence of a magnetic field. It is actually very similar to the torque for an electric dipole moment p under the influence of an electric field. These two are very similar and in a uniform magnetic field the net force on a current loop is always 0.

So, we can calculate the force that equals current times closed integral over d l cross B and that is given as the current we have taken it out because, it is steady current throughout the loop and it does not change as a function of the space times closed integral over d l cross B. Because B also does not change over this loop B is uniform. And that is going to give us 0.