Name of the Teacher-Chitra

Guest lecturer, Department of physics and Electronics

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Applied Physics

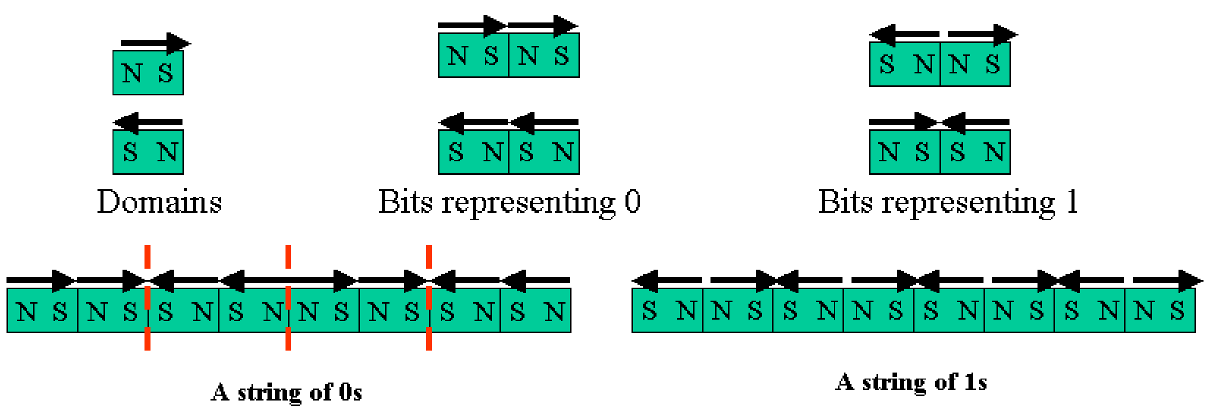
Lecture-1

Topic: Magnetic Recording,Magnetoresistance and Giant magnetoresistance-Part 1

A traditional recording head for magnetic data consists of a coil of wires attached to some current-sensitive device. A ferromagnetic material passes under the coil. Such an arrangement can both write magnetic data to the ferromagnetic material and read magnetic data off of the material.

To write magnetic data, current is sent through the coil in proportion to the desired signal. This current produces a magnetic field proportional to the current. The magnetic field aligns the spins in the ferromagnetic material. As the material moves away from the coil, the magnetic field decreases, and the spins remain aligned until they enter another magnetic field (when they are erased).

Unlike electric storage, magnetic storage can be either analog or digital. The amount of spin alignment depends on the strength of magnetic field, so analog data can be recorded with a continually varying current producing a continually varying magnetic field. Digital data can be recorded by alternating the direction of the current. To minimize data loss or errors, binary data is not determined solely by the direction of magnetization in a domain. Instead, it is represented by the *change* in magnetic orientation between two domains. If one bit of magnetic field has the same direction as the one before it, that represents a 0 (no change). If one bit of magnetic field has the opposite direction as the one before it, that represents a 1 (change). So a 1 is written by changing the direction of current between the two domains comprising a bit, and a 0 is written by keeping the direction the same. Each bit starts with a change of orientation. This convention for recording data identifies errors, since one would never have three domains of the same orientation in a row. In addition, the orientation should change with every other domain. If the computer thinks a bit is complete but the orientation does not change, it knows that some error has occurred. Some examples of domains, bits, and strings are shown below.



To read magnetic data, the ferromagnetic material is moved past the coil of wire. The changing magnetic field caused by the material's motion induces a current in the coil of wire proportional to the change in field. This is also known as inductive reading of magnetic data. If a 0 is represented, the magnetic field does not change between the two domains of a bit, so no current is induced as the magnetic material passes the coil. For a 1, the magnetic field changes from one direction to the other; this change induces a current in the coil.

What are the limitations of inductive reading??

Inductive reading of magnetic data is subject to many limitations mentioned below.

1. Since the change in magnetic field will be greater if the ferromagnetic material is moved faster, the induced current is dependent on the speed of the material. Thus the sensitivity of inductive read heads is limited by the precision of the material speed.
2. The other limiting factor on inductive heads is the strength of the magnetic field. As efforts to increase storage density continue, the size of a data element shrinks. Since fewer electrons are now contained in the region of one bit, the associated magnetic field is smaller. This smaller magnetic field produces less change and thus less induced current, requiring more loops to produce a measurable current. As mentioned above, more loops mean more resistance which means more heat (loss!!).

Because of these limitations, new magnetic storage devices use the phenomenon of **magnetoresistance** to read magnetic data.

Magnetoresistance

Discussion Question:

What produces resistance?

What would happen to current flowing through a magnetic field?

Would the magnetic field affect the resistance of the wire? Why or why not?

Magnetic Force Revisited

We know that charges moving through a magnetic field experience a magnetic force given by

$\mathbf{F}_B = q\mathbf{v} \times \mathbf{B}$,

where the bold face on **F**, **v**, and **B** indicates that these quantities are vectors: they have both direction and magnitude. The x is a cross-product, which means that the magnitude (size) of the force is found from

$|\mathbf{F}_B| = q\,|\mathbf{v}|\,|\mathbf{B}|\sin\theta$,

and the direction of the force is found from a right-hand rule: put your thumb in the direction of ($q\mathbf{v}$), your second finger in the direction of **B**, and your middle finger (or palm) will point in the direction of the force. θ represents the angle between **B** and **v**. Be careful when applying this rule to a negatively-charged particle like the electron: $q\mathbf{v}$ points in the opposite direction of **v**, since q is negative.

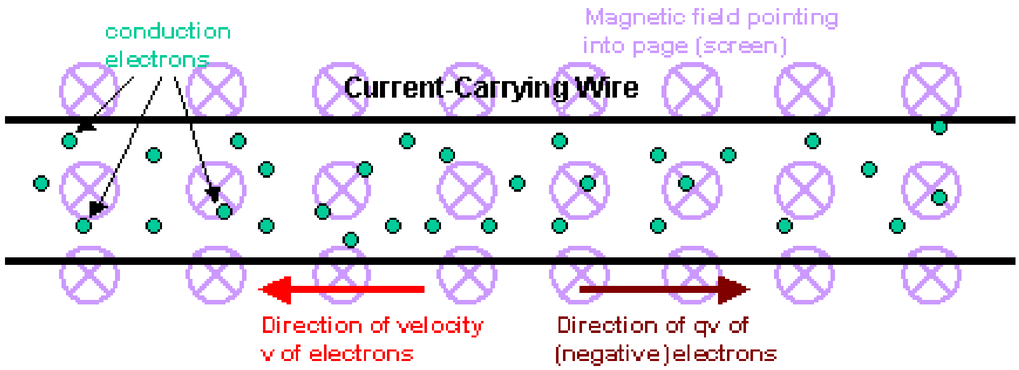
You should understand the following consequences of this force:

1. A charge at rest experiences no magnetic force, since **v** is zero.

2. A charge moving parallel to the magnetic field experiences no magnetic force: since the angle θ between **B** and **v** is zero, $\sin\theta$ is zero.

3. A charge moving un-parallel to the magnetic field experiences a magnetic force perpendicular to both the charge's motion and the magnetic field.
4. A negatively charged particle experiences a magnetic force opposite the direction of the magnetic force on a positive charge.

Let us apply this magnetic force to a charge moving through a wire, as shown below.



The teal conduction electrons are moving to the left (red arrow) through a wire. Since the charge of the moving charges is negative, q**v** points opposite the direction of **v**, or to the right (brown arrow). A uniform magnetic field is present throughout the wire, pointing into the page (lavender x's). Using the right-hand rule, with the thumb to the right representing q**v**, the second finger into the page representing **B**, we find that the palm representing **F** points toward the top of the page. So the conduction electrons feel a force toward the top of the wire. This magnetic force disrupts the normal flow of electrons, causing more collisions with atoms and other electrons, which increases the resistance of the wire. And this is the origin of resistance in the wire in a magnetic field called **Magnetoresistance**.