Physics 152

Lecture 30

- Magnets
- Earth/Dipole Field
- Charges & Magnetic Fields

Wednesday, April 11, 2007

Announcements

- Help sessions
  - W 9 - 10 pm in NSC 119
- MasteringPhysics
  - Hwk #4 due Wed., Apr. 11
  - WU #19 due Fri., April 13
  - Exam - Thurs., April 12

Announcements

- Thursday, Apr. 12, 2007
  - 9 am - 3 pm; 4 - 6 pm
  - Exam #2

  - Hint: Be able to do the homework (MasteringPhysics and workbook) and you’ll do fine on the exam!
  - You may bring one 3"X5" index card (handwritten on both sides), a pencil or pen, and a scientific calculator with you.
  - I will put any constants and mathematical formulas that you might need on a single page attached to the back of the exam.

Ch. 32: The Magnetic Field

The other mysterious attractive/repulsive force!

We know now that electrical charges are responsible for producing electric fields. And that a charge in an electric field will experience an attractive force toward a charge of opposite sign and a repulsive force away from a charge of the same sign.

But how does magnetism work?

Magnetism

Bar Magnet

Unlike electrical charges, which can occur individually, we always find the magnetic poles in pairs.
Magnetism can be induced in some materials by rubbing the material with a magnetized object or by placing the object in a constant magnetic field for an extended period of time.

Soft magnetic materials are those which acquire and lose magnetism easily (e.g. iron).

Hard magnetic materials are difficult to magnetize, but difficult to unmagnetize as well (e.g. cobalt).

The Earth produces its own magnetic field. Humans, birds, and microorganisms all take advantage of the existence of the Earth’s field to help guide themselves.

The compass needle is a piece of magnetized metal. The North Magnetic Pole of the needle points in the general direction of the Earth’s North geographic pole.

So if the North Pole of a magnet points toward the Earth’s North geographic pole, what does that imply about the Earth’s magnetic field?

I.e., is the magnetic pole near the Earth’s north geographic pole a North magnetic pole?

No!

In fact, the North pole of a magnet always wants to point in the general direction of the Earth’s North geographic pole (which is a South magnetic pole).

We’ve already used this term without defining it. But you probably already have a good sense for what it implies...

Magnetic Fields

As with the gravitational and electric fields, the magnetic field helps us determine the direction of the magnetic force at any point in the vicinity of a magnetized object.

Thus, the direction of the magnetic field at any point in space is the direction in which a compass needle points!
Also as was the case with the other fields, the density of the magnetic field lines tells us the magnitude of the field: the more tightly packed the lines, the stronger the field.

The Earth’s Magnetic field appears very similar to that of a bar magnet.

There’s not really a bar magnet at the Earth’s core, however. It’s much too hot! The iron in the Earth’s core is molten, not solid.

Let’s try to figure out the nature of the magnetic force.

We already know that like magnetic poles repel one another while opposite magnetic poles attract.

And we know that electrical charges respond to magnetic fields. Let’s look at how they respond.

What happens when we put a stationary charge into a uniform magnetic field?

What happens to a positive charge moving parallel to the magnetic field lines?
What happens to a positive charge moving anti-parallel to the magnetic field lines?

What happens to a positive charge moving perpendicular to the magnetic field lines?

Magnetic force requires 3D:

So we need to invent a **new notation** to depict the forces in the TWO dimensional world of my presentation slides and web pages, and your homework and exams.

Back to our problem...

What is the direction of the magnetic force in this case?

Right-Hand Rule:

Fingers point in the direction of the magnetic field.

Thumb points in the direction of the motion of a positive charge.

Palm faces the direction of the magnetic force.
The magnetic force is out of the page.

What is the direction of the magnetic force in this case?

And which way would the force point if the charge was negative rather than positive?

You still use the right hand rule, but since the charge is negative, you reverse the direction of the resulting force.

The Earth’s field exerts a force on charges moving perpendicular to the field lines. This force protects us on the Earth’s surface from the high energy, charged particles emitted by the Sun.

The field shields us from most of these particles. However, in the region of the magnetic poles, the charged particles move along the field lines, through the atmosphere, towards the Earth’s surface.
On what does the magnitude of the magnetic force depend?

- The strength of the magnetic field ($B$).
- The magnitude of the charge ($q$).
- The speed with which the charge is moving ($v$).
- The direction the charge is moving with respect to the field ($\sin \theta$).

The force is given by the equation:

$$
\vec{F} = q\vec{v} \times \vec{B} = q|\vec{v}| |\vec{B}| \sin \theta
$$

**Units:**

- Tesla
- Weber / m$^2$

1 Tesla is a very strong magnetic field. So, magnetic fields are often measured in the cgs (i.e., centimeter, gram, second) unit of Gauss.

$1 \text{ Tesla} = 10^4 \text{ Gauss}$

The Earth’s magnetic field is about 0.5 Gauss near the surface.

A proton moves at right angles to a magnetic field of 0.1 T with a speed of $2.0 \times 10^5$ m/s. Find the magnitude of the acceleration.

Worksheet Problem #5

**Concept Quiz!**

**CAUTION**

Watch your step

**Mass Spec**