Physics in the classroom

Lecture 7

Magnetism story

Once upon a time a knight in armor was riding through the countryside, when he was suddenly snatched from his horse by a strange force. The force held him pinned to a rock. He was horrified to see the remains of another knight. He noticed that the mysterious force held fast to the unfortunate knights armor, but not his bones. So our brave knight managed to reach his dagger and cut himself out of his armor, freeing himself.

Magnetism

We now know this strange force as magnetism, and the strange rock as lodestone, a natural magnet.

Natural magnets were used for many years, particularly for navigational compasses.

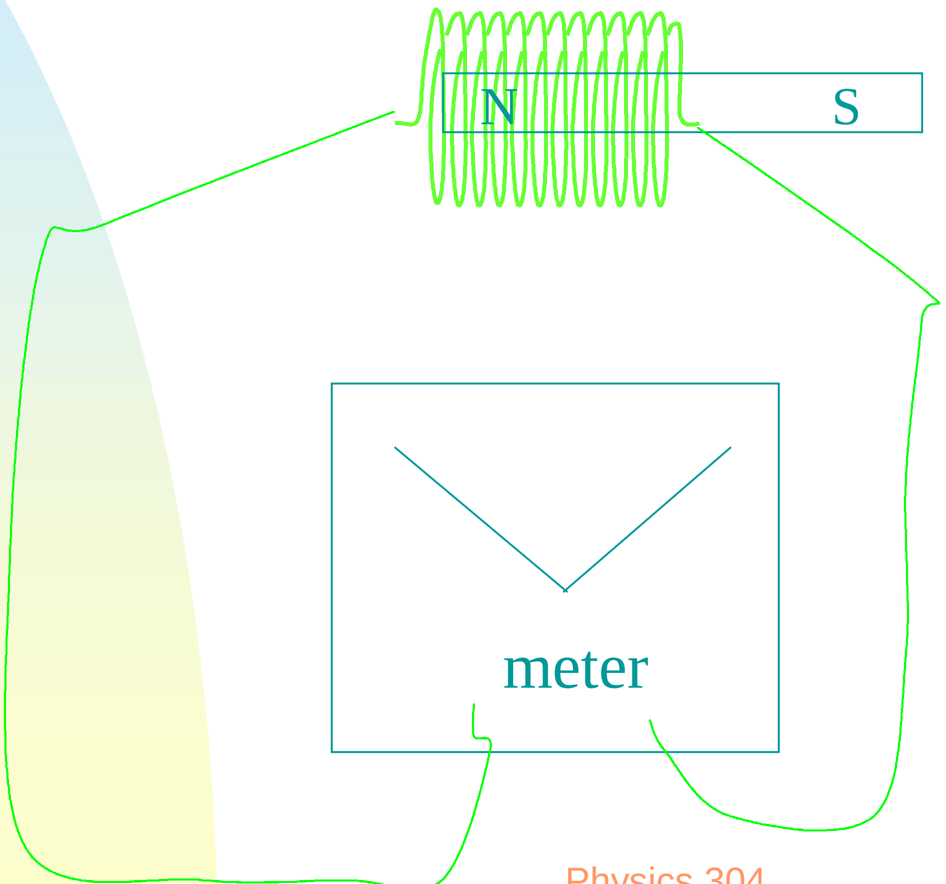
All magnets have north and south poles. When two magnets are brought together, like poles repel and unlike poles attract.

Electricity + Magnetism = Electromagnetism

Electricity was also known for many years, but magnetism and electricity were believed to be totally separate phenomena.

Hans Christian Oersted discovered, while preparing a lecture in fact, that there was a connection between electricity and magnetism. This connection had a tremendous impact on things ranging from electric motors and generators to a clearer understanding of special relativity.

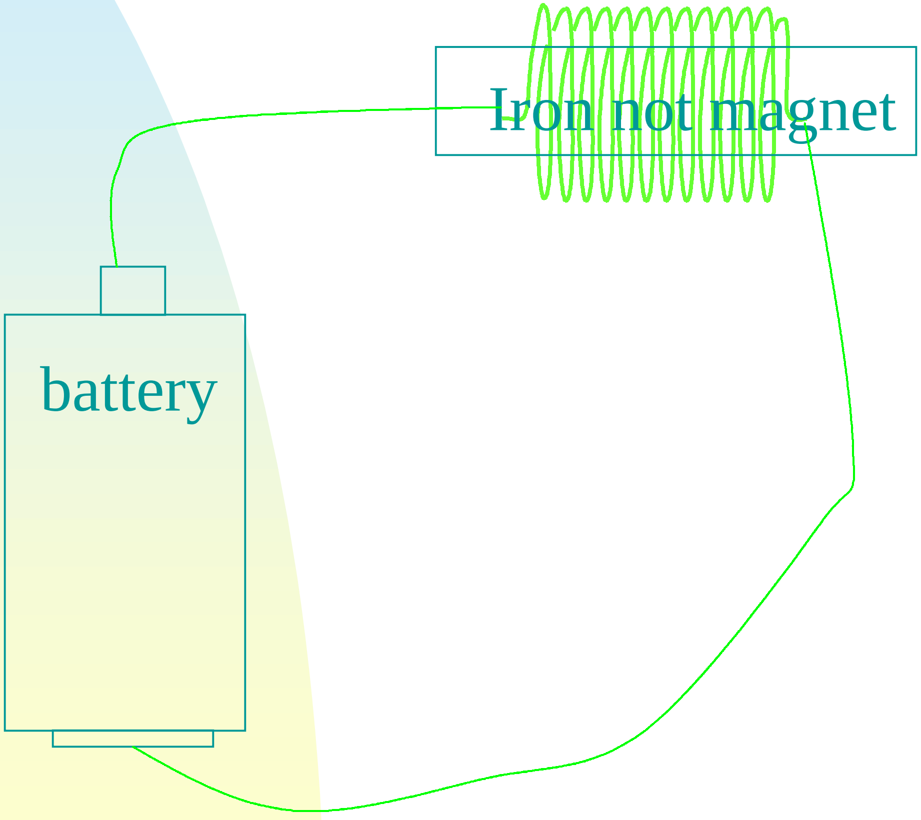
Changing magnets produce electricity



Electricity produces magnetism

All electrical currents produce magnetic fields. These fields are usually very small. They can be magnified by wrapping current-carrying wires into a coil. They can be further intensified by inserting a piece of iron into them. This arrangement is commonly called an electromagnet.

Electromagnet



Electricity ↔ Magnetism

So, moving magnets produce electricity and moving charges (electricity) produce magnets.

Electric generators

Electric generators produce electricity by moving magnets relative to coils of magnets, in much the same way we produced electricity by moving a magnet in and out of a coil of wire.

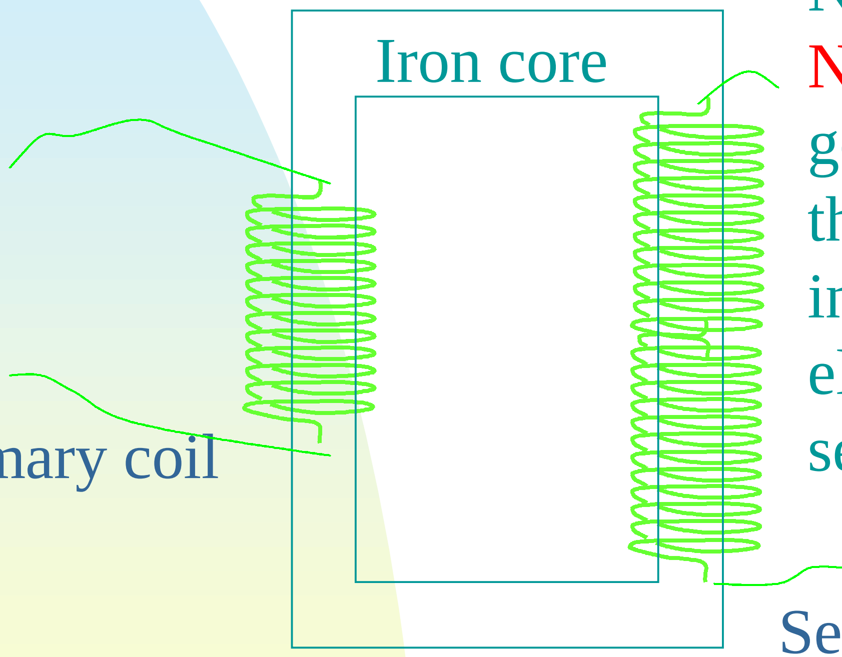
Electric motors

In some sense electric motors are electric generators in reverse. A typical electric motor operates by creating an electromagnet with the incoming electric current. That electromagnet is repelled by a permanent magnet inside the motor. This repulsion produces the desired motion.

Transformer

No, not the toy that transforms from a robot into a flying machine. A transformer converts electrical power at one voltage and current to electrical power at another voltage and current. Transformers are often found in residential neighborhoods. These transformers convert the high voltage, low current electricity in electrical power lines into low voltage, high current electricity suitable for household use. Other examples of transformers include the little square boxes that plug into the wall and convert household electricity to electricity suitable for small electrical appliances such as tape players or CD players.

More Transformers



Primary coil

Secondary coil

Notice the two coils of wire are NOT connected. The power goes from electrical power in the primary to magnetic power in the core and then into electrical power in the secondary.

Power in = Power out

The idea that you can not get something for nothing seems to be a recurring theme in physics.

In an ideal transformer, the electrical power that flows in through the primary is the same as the electrical power that flows out through the secondary.

This leads to a relationship between the number of coils in the primary N_1 , the voltage across the primary V_1, the number of coils in the secondary N_2 and the voltage across the secondary V_2.

$$\frac{V_2}{V_1} = \frac{N_2}{N_1}$$

Example

A transformer with 100 coils on the primary and 10 coils on the secondary is plugged into a wall outlet which has a voltage of 120 Volts. What is the voltage across the secondary?

$N_1 = 100$
$N_2 = 10$
$V_1 = 120V$
$V_2 = ?$

$$\frac{V_2}{V_1} = \frac{N_2}{N_1}$$ rearranging $$V_2 = \frac{N_2 V_1}{N_1}$$

$$V_2 = \frac{10 \text{ x } 120V}{100} = 12V$$

Demonstrations

- Jumping ring
- Magnet in a tube
- Magnet, coil, galvanometer, bar magnet.