The Demonstration with a Solenoid, Battery, Iron Core and Aluminum Ring

When we energized an electromagnet and caused an aluminum ring to move, several basic electromagnetic effects were at play. They happened simultaneously, but in the listing below they are arranged as a chain of events with the related physical principles in parentheses:

Initial condition: The ring hangs straight down suspended by a thread with an iron core passing through a nearby solenoid and through the ring without touching the ring. One of the ends of the wire from the solenoid is connected to a car battery and the other is about to be connected to the other terminal of the battery.

When the second wire is connected to complete the battery-solenoid circuit, the 12 V from the battery causes an electric field to exist within the wire of the solenoid. (A voltage causes an electric field.)

That electric field causes an electric current to flow through the solenoid. (Electric fields within metals cause a current to flow.)

That current produces a magnetic field in the solenoid. (Current through a wire produces a magnetic field which is enhanced by the solenoid geometry.)

That solenoid magnetic field tends to align magnetic domains within the iron which enhances its strength. (Magnetic domains in iron align in an external magnetic field.)

The increasing magnetic field passes through the aluminum ring causing an electric field around the ring. (A changing magnetic field causes an electric field around it.)

This electric field within the aluminum ring causes current to flow in the ring. (Electric fields within metals cause a current to flow.)

The current flow in the ring causes a magnetic field within the ring. (A second case of currents causing a magnetic field.)

The magnetic field from the ring is directed oppositely to the magnetic field of the solenoid causing the ring to be pushed away from the solenoid. (Like magnetic poles push away from each other.)

In less than a second, the current in the solenoid has increased to the maximum value allowed by its resistance and the magnetic field in the solenoid reaches its maximum value. There is now magnetic energy stored in the magnetic field of the solenoid.

Since the solenoid magnetic field is no longer changing, the electric field in the aluminum ring falls to zero. The current in the aluminum ring, the magnetic field of that current, and its pushing force against the steady magnetic field of the solenoid also fall to zero.

Gravity then pulls the hanging ring back to its original vertical position.

When the battery wire connection is then opened, the magnetic field in the solenoid begins to collapse generating a voltage across the solenoid. (Changing magnetic fields cause electric fields around them and a voltages across solenoid wire ends.)

That voltage pulls electrons off the air molecules in the widening gap as the wire connection is pulled apart. The faster it is pulled apart, the greater will be the rate of fall of the solenoid magnetic field and therefore the greater the voltage. The magnetic field energy must escape across that widening gap, and as it does so, a plasma arc is produced. (Strong electric fields can ionize (strip electrons off from) air molecules.)

As the solenoid field collapses, it once again induces an electric field in the aluminum ring. This time, however, the electric field is in the opposite direction from earlier, and the current and magnetic field caused by this electric field is also opposite. The ring is therefore now pulled toward the solenoid. (Opposite magnetic poles attract.)

As the magnetic field and current in the solenoid diminish toward zero, the induced electric field, current, and magnetic field in the aluminum ring diminish toward zero.

Gravity then brings the ring once again to its original vertical position.

When a 60 Hz alternating voltage from a power outlet is used instead of a battery, there are time delay effects with cause the ring to always be pushed away. Those phase shift effects leading to magnetic levitation are, unfortunately, beyond the scope of this course.