Various ways of demonstrating the magnetic force on moving charged particles have been described in the physics teaching literature.\textsuperscript{1-4} Here we describe a simple experiment to demonstrate the magnetic force in an electrolyte. All you need for this experiment is a glass dish (d ≈ 8 cm), two copper ring electrodes (d\textsubscript{1} ≈ 2 cm, d\textsubscript{2} ≈ 7.5 cm), a solenoid with an iron core (ours has N = 600 turns, R ≈ 9 Ω, rated for 2 A), a dc power supply, copper sulfate solution (approximately 20 g of copper sulfate/100 ml of water), connecting wires, and an overhead projector. A similar experimental setup was developed\textsuperscript{5} by E. Morgan using a salt solution and a bar magnet with zinc or copper electrodes. The setup we describe is both very simple and easily viewed using an overhead projector.

The smaller electrode is placed at the center of the dish and the larger one is coaxial with it (Fig. 1). The dish is placed on top of the solenoid. The dish is partly filled with the copper sulfate solution and the coil is connected to a dc power source. The copper electrodes are connected in parallel with the coil. The entire setup is placed on the overhead projector.

**Demonstration and Physical Interpretation**

The circuit is shown schematically in Fig. 2. With 15 V applied across the ring electrodes, a current of about 0.8 A flows through the copper sulfate solution. The magnetic field is perpendicular to the plane of the dish and has a magnitude of approximately 30 mT.

The electric field between the electrodes causes the positive (Cu\textsuperscript{2+}) ions to move radially toward the negative electrode and the negative (SO\textsubscript{4}\textsuperscript{2-}) ions to migrate toward the positive electrode, as shown in the figure. The ions move perpendicular to the magnetic field lines of the coil. Since the positive and the negative ions travel in opposite directions, the magnetic force ($F = qv \times B$) acting on both has the same axial direction (counterclockwise in the situation shown in the figure). As a result the
solution is observed to rotate after a short time (about 10 s). Some cork particles floating on the surface of the liquid make the circular motion more visible.

If the direction of electric current between the electrodes or the direction of the magnetic field of the coil is reversed, the direction of the rotational motion changes correspondingly.

More Details

The magnitude of the electric field between the electrodes decreases from the center to the edge of the glass dish. The magnetic field of the coil decreases in magnitude from the center to the edge of the glass dish. Because the magnetic field has a radial component that increases with distance from the center, the angle between the velocity of the particles and the field lines also changes. In addition, the copper sulfate solution is a viscous fluid whose velocity must go to zero at the boundaries. The influence of these factors can be observed in the experiment as a noticeable change in the rotational speed of the liquid from the center to the edge of the dish, with zero speed at the inner and the outer ring electrodes and a maximum flow speed somewhere in between (closer to the smaller electrode) that can reach about 10 cm/s.

Conclusion

The experiment we describe provides an effective way to demonstrate the magnetic force on moving charged particles. We believe that this classroom demonstration, accompanied by appropriate explanation and discussion, helps our students to better understand the magnetic interaction.

References


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From Our Files

**Lord Kelvin Demonstrated**

J.T. Lloyd, “Lord Kelvin Demonstrated,” *Phys. Teach.* 18, 16-24 (Jan 1980). The author, the demonstrator at the Glasgow University physics department where Kelvin taught and did research, shows a number of Kelvin’s demonstrations, including his own version of the Kelvin water dropper electrostatic machine.