Field Lines of Flying Fur

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Even though students can be taught to trace electric field lines if they're given step-by-step instructions, they really don't seem to understand the concept because charges cannot be seen and the electric field remains obscure. Using an insulated conductor or two and hairs clipped from a rabbit fur, I've developed a demonstration that has my students asking for more—now they can visualize the electric field in three dimensions and want to try their own variations.

It's easy to make tangible the electric field lines around an isolated spherical conductor. I start by placing a charge on the sphere (for simplicity, I will define the sphere's charge as positive). To make the lines visible I sprinkle some rabbit hairs over the top of the conductor; because of an induced polarity in the atoms of the hair, it is initially attracted to the conductor. However, after the hair makes contact with the conductor, there is some conduction of charge. The animal hair, which is not a perfect insulator, allows some electrons to move to the positively charged sphere. This causes the threadlike structures to become positively charged, and thus repelled from the positively charged sphere. I point out that the positively charged hairs are behaving exactly like the mysterious "positive test charge" that students are asked to use to describe the shape and direction of electric field lines. The advantage of the rabbit hair is that it is visible and students can clearly see the movement along the predicted field lines (Fig. 1). My students eagerly gather around closely to marvel at the demonstration. They want to see it over and over again.

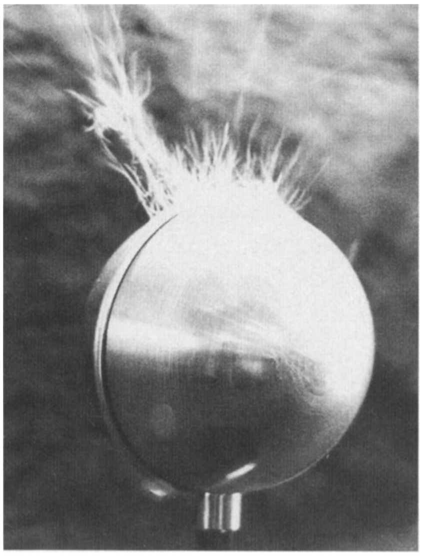

Fig. 1. Rabbit hair being repelled along field lines from a charged conductor.

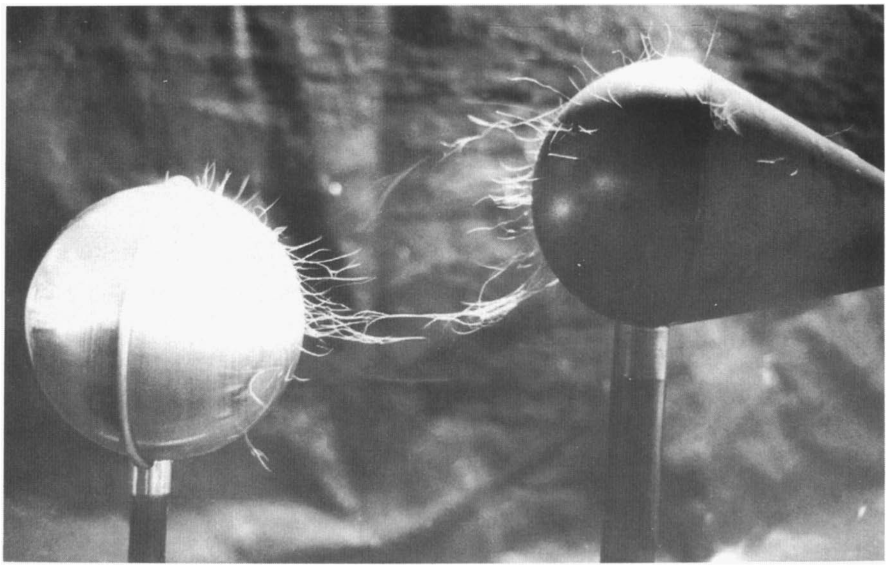

Fig. 2. Rabbit hair moving back and forth along field lines between oppositely charged conductors.

Students get "hooked" quickly; invariably they want to try variations of the demonstration. One variation is to use a conductor that is not spherical, but oblong. Students predict correctly that since charge concentrates at the "pointier" parts of a conductor then the stronger electric field should cause a greater density of field lines. The rabbit hair shows this higher density nicely. The next suggestion is to try the demonstration with more than one conductor. I have tried it with two conductors having the same charge. It works, but it's one of those demonstrations that you see and understand only if you know what you're looking for. However, if the two conductors are charged oppositely, the demonstration is very impressive and a real crowd pleaser. The hairs behave essentially the same way they did with one conductor except that the hair repelling off the first conductor is charged, of course, and so is attracted to the second conductor. Upon contact with the second conductor, the hair loses its excess charge, gains the charge of the second conductor and is repelled back to the first conductor. This back-and-forth movement of the hair very accurately traces out the field line structure in three dimensions (Fig. 2) and continues until all the excess charge on the two conductors has been transferred.

During this part of the demonstration one additional point can be made concerning fields. Since the rabbit's hair has mass, it is also affected by the Earth's gravitational field (a factor that is not addressed in introductory treatments of electric-field-line drawing). The combination of an electric field and a gravitational field acting on the rabbit hair simultaneously makes for an interesting pattern of movement. And, since the charges on the two conductors are steadily being diminished, the pattern of movement is continually changing, eventually to be dominated by the gravitational field, which stays constant. By observing this, students understand the concept of the gravitational field better.

When asked to explain the mechanism of this demonstration, students have to deal with charging by conduction, induced polarity, repulsive and attractive forces, and the reasons for the shape that an electric field takes. I've been pleased to find that even my lowest-ability students are able to speak accurately about the nuances present in this demonstration. Its very visual nature seems to have a remarkable effect on understanding.

Acknowledgment

I would like to thank Matthew Weeder, a 1995 graduate of Tamalpais High School, for assistance in preparing the photographs presented here.

Trick of the Trade

Impulse Demonstration Using a "Half-Bouncy" Ball

To demonstrate that the impulse delivered by a bouncing ball is greater than that of a ball that does not bounce, construct a "half-bouncy" ball. Two balls that look identical but are made of different polymers (so one ball bounces and the other does not) are available through Arbor Scientific and may also be found in local toy stores.[1] You make a ball where one side bounces and the other side does not by cutting a bouncy ball and a non-bouncy ball in half and gluing the two different halves together. This "half-bouncy" ball delivers the different impulses when used in the pendulum setup shown in the figures. In Fig. 1 the ball is released from a height so that the bounce side of the ball just knocks over the wooden block. If the pendulum is released from the same height on the opposite side of the block, the ball does not bounce and the block remains standing. The mass is identical since it is the same ball that is bouncing or not bouncing; the contact speed is the same since the ball is released at the same height from each side.

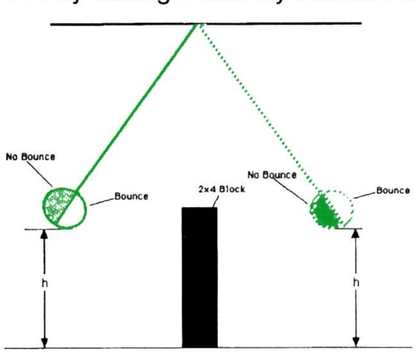

Fig. 1.

The side view in Fig. 2 shows that the ball is suspended by a string in a V shape to keep it from twisting as it falls. The support string can be attached at the same time the two ball halves are glued together.

Fig. 2.

Reference

1. Arbor Scientific, P.O. Box 2750, Ann Arbor, MI 48106-2750; 1-800-367-6695.

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