Mystery Motor Demystified

Arthur F. Klittnick* and *Malcolm J. Rickard, Physics Department, University of Colorado, Boulder, CO 80309-0390; art@colorado.edu

The intriguing thing about the motor described here is that we would not expect it to work at all. But there is great satisfaction in watching students discover why it does.

We were searching around for good projects for our introductory electricity and magnetism course and came upon plans for this mysterious motor in some science kits for children.[1,2] As shown in Fig. 1, the major component of the motor is a coil (~ 1-in diameter) of about 15 turns of #26 magnetic wire. The ends of the wire wrap around the coil a couple of times to hold it together and then extend outward radially from opposite sides for about 2 in, thereby forming an axle for the coil. Both ends of the wire are completely stripped of their enamel and each is inserted into the back loop of a safety pin. The two pins are then stuck into a piece of cardboard or foam to suspend the coil over a ceramic disk magnet, as shown. A 9-V battery is connected to the two safety pins, which act as both slip ring and bearing.

But why does the motor work? Since it lacks a commutator, we would assume that there would be equal forces trying to propel it in opposite directions and no rotation could be sustained. What is breaking the symmetry and allowing the motor to operate?

Sleuthing

We considered some less-than-satisfying theories, but finally decided to add instrumentation to the motor in hopes of solving the puzzle. Figure 2 shows our test setup. We punched a small (1/16-in) hole near the edge of a black paper disk (5/8-in diameter) and attached the disk to one axle wire with a drop of glue. This disk was to act as an optical shutter for a slot-type optical interrupter. Our optical interrupter (salvaged from an old disk drive) consists of an infrared emitter-detector pair with a gap between them for a shutter. We adjusted the paper shutter so that the emitter's infrared beam would pass through the hole as the heavier side of the coil crossed the bottom of its rotation.

The schematic in Fig. 3 diagrams the simple circuit we constructed on an experimenter board to power the LED infrared emitter and the phototransistor detector. This was connected to an oscilloscope, which displayed a strong negative pulse with each rotation of the coil. We also coiled 12 feet of #17 steel wire to form a small-value resistor of approximately 0.1Ω placed in series with the motor. By reading the voltage across this resistor we found the current. Connecting the resistor to a second channel on the oscilloscope let us determine the relationship between motor current and coil rotation angle.

Figure 4 shows an oscillograph with the top trace depicting the optical shutter pulse and the bottom trace the motor current as the coil

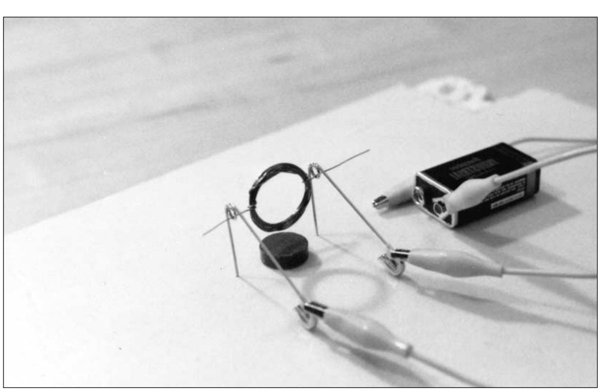

Fig. 1. Mystery motor with ceramic disk magnet below wire coil.

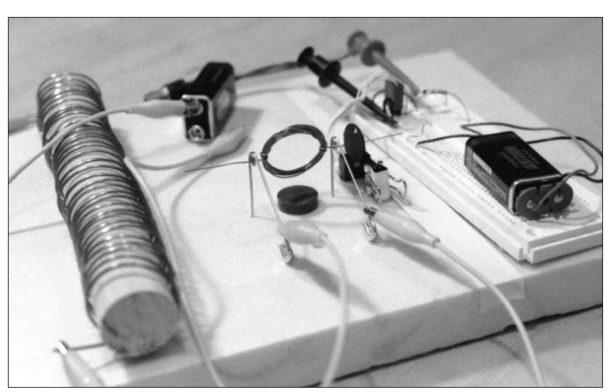

Fig. 2. Mystery motor with instrumentation added. Large coil at left is current-sense resistor. Shutter disk and optical interrupter are at right of motor coil.

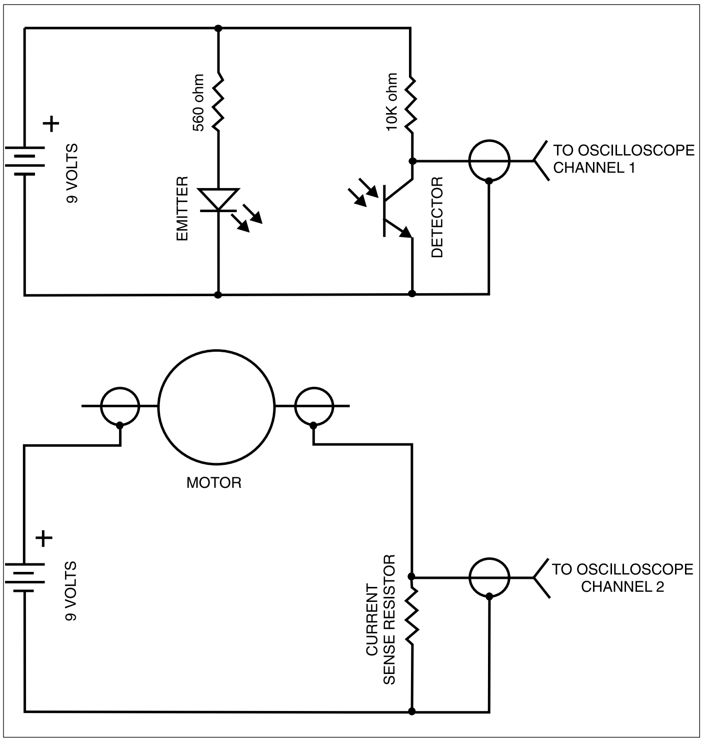

Fig. 3. Schematic of motor instrumentation. Emitter and detector are part of optical interrupter.

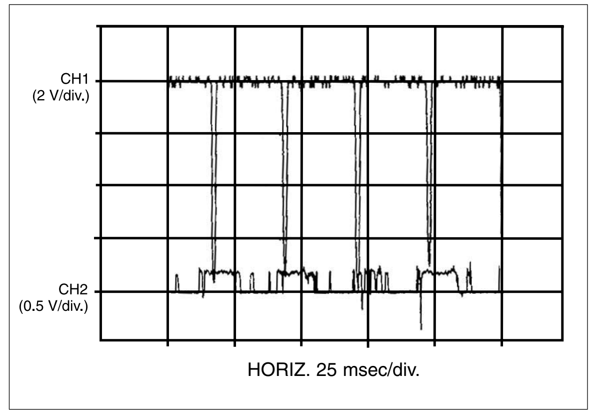

Fig. 4. Oscillograph of motor operation. Upper trace (CH 1) shows negativegoing pulses as heavy side of coil passes bottom. Lower trace (CH 2) displays motor current.

rotates. We could see that current flows through the coil only during that portion of rotation corresponding to the time that the heavy side of the coil is at the bottom of its swing. And therein lies the clue we had been looking for.

Solving

As the coil flails around on its loose safety-pin bearings, it makes contact only when its heavy side swings through the bottom. As the heavy side swings upward, it forces an axle wire away from its safety pin, and electrical contact is lost. Thus, since it flows for only half of the coil rotation, the motor current will produce a tangential driving force in only one direction and the motor can turn. Gravity and the imbalance of the coil break the symmetry and make it self commutating. The axle wires can be easily bent up or down to adjust the motor balance for best performance.

Similar motors are available with the insulation scraped away from only one side of the axle wires.[3] This forms an elegant commutator, but of course without any enigma attached. Though the "mystery motor" is marketed as a toy for children, investigating its operation makes an intriguing project for university physics students (and their teachers!).

References

1. Junior Scientist Electricity Lab (Radio Shack #28-275) .
2. Electro-magnetix® Minilab Science Kit (Educational Design Inc., 345 Hudson St., New York, NY 10014-4598).
3. World's Simplest Motor™ (Yeany Educational Products, Palmyra, PA). Available from Edmund Scientific, #V52-874, for $4.95.

etcetera...

Apples and Oranges

On a windy March morning I walked down to the front gate to pick up the morning paper. When I got back to the house, I was asked, "Is it as cold outside as it is windy?"

I thought for a moment and then, knowing that I could never be proved wrong, I said, "Yes."

A^2B