Making a Simple Self-Starting Electric Motor

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A simple electric motor[1] has a problem in that the current applied to the motor per se can rarely trigger its rotation. Usually such motors begin to rotate after the rotor is slightly turned by hand (i.e., manual starting). In a *self-starting* motor, the rotor starts to rotate spontaneously as soon as the current is applied. This paper describes the initial condition of the rotor required for self-starting.

Suppose the rotor is placed in the *horizontal* uniform magnetic field established by two permanent magnets (stator). The maximum torque[2] is applied when the plane of the rotor loop is horizontal [Figs. 1 and 2(a)]. Hence, it is advantageous for self-starting if the loop is laid horizontally. In one such configuration, both arms (the axis of rotation) of the rotor (AWG 25, enameled wire) sticking out from the *top* of the coil are put on paper-clip cradles and the loop (diameter ≈ 20 mm) is easy to level with minimal adjustment because its center of gravity is initially below the axis of rotation[3] (Fig. 1). We used two identical disc-shaped permanent ferrite magnets (diameter = 30 mm, thickness = 5 mm) as a stator. To achieve nearly uniform magnetic field through the rotor, the magnets were chosen to be larger than the loop.

Figure 2 is a sketch of the rotor as it rotates between the two stator magnets. The rotor coil appears as an ellipse. A current in the coil causes it to behave similar to a bar magnet. The polarity of the magnet depends on the direction of the current (indicated by arrowheads). To help visualize the interaction between the coil and the stator field, we show in the figure the fictitious bar magnets with induced N and S poles.

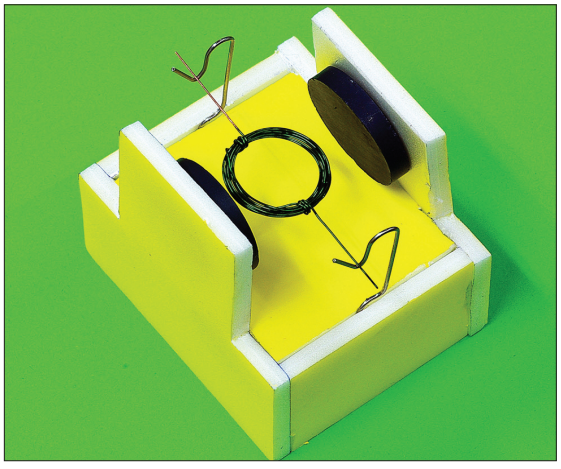

Fig. 1. Setup of a simple electric motor for self-starting. The half-stripped (right) arm of the rotor is put in the cradle with its stripped side facing downward and the loop being horizontal.

The enamel coating on one arm of the rotor was peeled off completely (all the way around). On the other arm it was peeled off only halfway around—the other half was left intact. In Fig. 2 we represent the cross-section of the half-stripped arm with a half-filled circle (◐) drawn inside the rotor loop. The stripped half corresponds to the white half of the circle, the unstripped half corresponds to the black half-circle. Current flows through the coil only when the stripped region of the arm is in contact with the cradle (not shown) beneath it. As we will now show, the half-stripped arm serves as an elegant commutator.[4]

The initial orientation of the rotor is shown in Fig. 2(a). Suppose it to be initially at rest. The direc-

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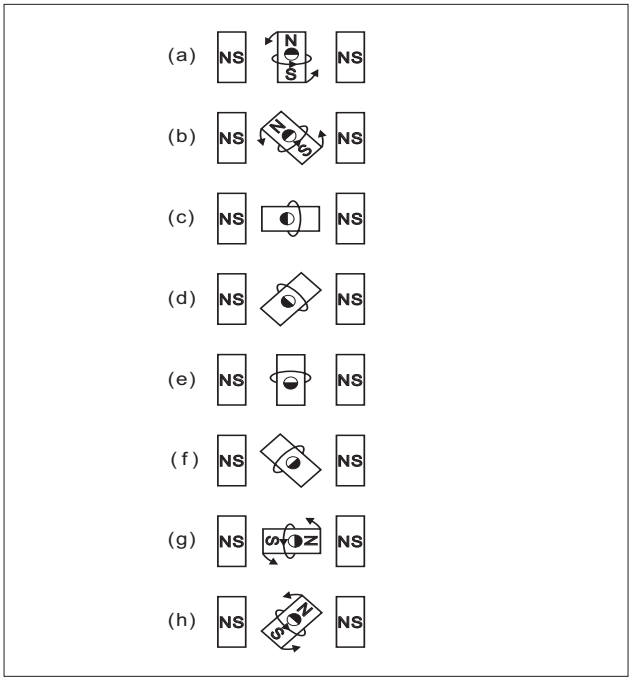

Fig. 2. A complete cycle of operation of a simple self-starting electric motor.

tion of the current through the rotor coil was chosen arbitrarily, as it only affects the rotational direction of the motor. The stator magnets exert forces on the rotor electromagnet as shown by arrows drawn at the corners of the bar. If the torque on the rotor is large enough for self-starting, it will begin to rotate counterclockwise. As the coil rotates [Fig. 2(b)], the current continues to flow in the same direction until the motor has completed one-quarter turn [Fig. 2(c)]. After that point is reached, it is the insulated part of the half-stripped arm that makes contact with the cradle and so the current ceases (were it to continue, the resulting magnetic forces would hinder the rotation). There is no current in the coil until after the motor has rotated [Figs. 2(c)–2(g)] through 270°. At that point the current resumes [see the arrowhead and N, S labels in Fig. 2(g)], and there is again a torque on the coil that maintains the rotation in the same direction.

The key element in the self-starting motor is the half-stripped arm of the rotor, which must be placed in the ◓ position when the rotor coil is positioned horizontally in the cradle (Fig. 1).

Our method of making a self-starting electric motor was tested with sixth-grade students who were learning about simple electric motors for the first time. The percentages of self-starting, manual starting, and fail were 80%, 17% and 3%, respectively. For our control group (students who were unaware that the initial orientation of the coil is important), the corresponding percentages were 6%, 30%, and 64%.

References

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3. P. G. Hewitt, *Conceptual Physics,* 3rd ed. (Addison-Wesley, New York, 1997), pp. 142-144.
4. It is worth mentioning that even if both arms of the rotor are completely stripped, the motor can work due to self-commutation caused by rotor imbalance. See A.F. Klittnick and M.J. Rickard, "Mystery motor demystified," *Phys. Teach.* **39**, 174-175 (March 2001).

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