



BY HOWARD JOHNSON, PhD

## Unified electrodynamic force

**F**ire two charged particles at the same moment, with the same initial velocity, into a perfect vacuum (**Figure 1**). The two particles, having the same electric charge, repel one another. This repelling electric force,  $F$ , makes the particle tracks diverge.

Given the magnitude of the electric force and the masses and internal velocities of the particles, you can, if you know a little college

physics, predict the rate of divergence—but you'd be wrong. The actual particle tracks diverge at a slower rate than electric-field considerations alone predict.

If French physicist and mathematician André-Marie Ampère were alive today, he would explain the diminished divergence as the result of magnetic forces. Ampère's laws describe a mechanical force that pulls together parallel wires carrying current in the same direction. Simplified to the case of only two charged particles moving in space, the pull of Ampère's magnetic force partly counteracts the electric repulsion to produce the actual trajectories shown in **Figure 1**.

Case closed? Hardly. Follow me to the next level.

Place yourself in a chair moving alongside the two particles. From your perspective, as the electron guns recede leftward, the two particles appear stationary. The only movement you perceive is their gradual vertical divergence. From your perspective, the particles have no horizontal motion, so there is no magnetic force. From your perspective in the chair, the particles diverge at a rate that solely their electric-field interactions determine.

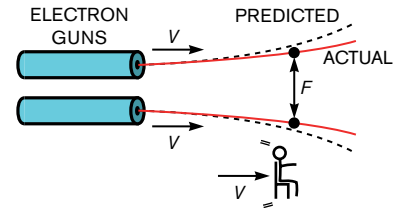
Yet, from my perspective standing on the ground beside the electron guns, a magnetic force indeed seems to exist, and it slows the divergence of the two particles. Which of us is right?

The key to this paradox may shock you because it sounds like the theme of a science-fiction novel: My time and your time are different. Your velocity induces a tiny dilation of your scale of time relative to mine. From my perspective, that time dilation slows your predicted rate of divergence just enough so that your rate precisely matches mine.

In this experiment, the choice of reference frame modulates the existence of the magnetic force. You can turn it on or off depending upon where you stand or sit. It is therefore not a "real" force. It is nothing more and nothing less than a direct consequence of Einstein's theory of relativity.

Standing on the ground observing the experiment, I can view the result in three ways:

- using the reference frame of your chair, computing a purely electric-field interaction, and adjusting the results to account for the relativistic time dilation between us;
- accepting at face value Ampère's



**Figure 1** The electric force between two charged particles makes their trajectories diverge.

fictional magnetic force as apparent from my perspective; or

- in full realization that only one force, the electric force, is in play, with its magnitude modified according to the relative velocities of the particles and observers involved.

**Reference 1** outlines the third method. It makes interesting reading for those ready to embrace the full brilliance of relativity and the true meaning of the unified electrodynamic force. The treatment is highly mathematical.

The characterization of magnetic force as a relativistic effect in no way diminishes the importance of magnetic-field calculations in ordinary circuits. The magnetic-field illusion is an extremely useful means of understanding and designing all sorts of things—from motor-generators to high-speed transmission lines.**EDN**

### REFERENCE

1 Fukai, Junichiro, *A Promenade Along Electrodynamics*, Vales Lake Publishing, 2003.

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