Electromagnetic forces and time dilation in special relativity

Figure 1.

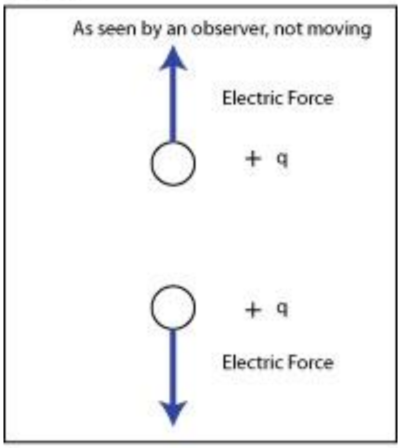


Figure 2.

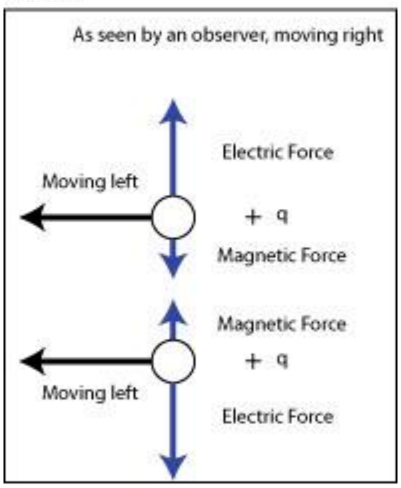
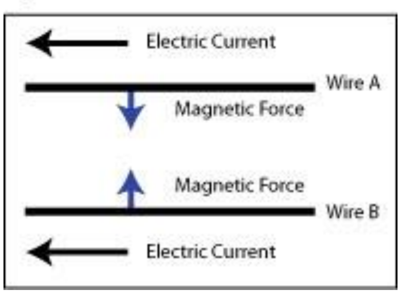


Figure 3.



Think of two identical particles with charge +q as in figure 1. They are separated by a certain distance and not moving at this instant. But in the view of an observer not moving relative to these two particles, an electric force is being exerted upon each of them, so they will begin to move away from one another.

Now, let's say that there is another observer who is moving to the right relative to these two particles. This observer will see that these two particles are moving left as in figure 2. Surprisingly, this observer will see that a magnetic force, in addition to the electric force as in figure 1, is exerted upon each of the particles; this is because this second observer will see the charges as electric currents, or equivalently moving electric charges. (I hope that you are familiar with the fact that the two electric wires through which electric currents are passing are attracted to each other by magnetic forces as in Figure 3. Recall that an electric current on wire A creates a magnetic field at wire B, and because there is an electric current in wire B, this magnetic field creates a magnetic force upon wire B. And, vice versa.)

Therefore, the observer in figure 2 will see that smaller forces act upon the two particles than the observer in figure 1 sees, because the magnetic forces diminish the effect of the electric forces. For this reason, the observer in figure 2 will witness that the two particles move apart each other with smaller velocities than the observer in figure 1 witness.

This implies that the time flows more slowly for the observer in figure 2 than the observer in figure 1; it would take more time for the observer in figure 2 to see the distance between the two particles increase by a certain amount than it takes for the observer in figure 1 to see this happen. This is one of the main results of Einstein's theory of special relativity. The time of a moving observer, as in figure 2, flows more slowly than the time of an observer at rest, as in figure 1.

You might wonder, if the observer in figure 2 moves very fast, then could he witness that the magnetic force is bigger than the electric force (since the bigger the speed of the electric charge, the bigger the electric current and the magnetic field, and therefore, the bigger the magnetic forces)? In this hypothetical case, might the observer in figure 2 witness that the two particles are pulling each other, rather than repelling each other as in figure 1? This should not be the case, because if this were, the observer in figure 2 would see these two particles clash into each other after a finite amount of time, while the observer in figure 1 would never see any collision. Two observers in different frames of reference must agree on facts such as whether or not two particles ever crash into each other. Let me explain why this is so. Let's say that you make a bomb explode if two particles crash into each other. It's impossible that some see the bomb explode while the others never see it explode no matter how long they wait. Whether the bomb explodes or not is an ambiguous fact that cannot depend on observers. What can depend on observers is when and where if the bomb explodes.

However, if you calculate the speed of observer in the figure 2 at which he sees the magnetic force being bigger than the electric force, you will find that the speed of the observer would have to be greater than the speed of light; when the speed of the observer is exactly equal to the speed of light, the magnitude of the magnetic force and that of the electric force will be the same.

The conclusion one must draw from this situation is that, in order to prevent contradictory observations by different observers, it must not be possibly to move faster than light.

As a side note, from this example, you can see that the speed of light can be calculated from the ratio between the electric force and the magnetic force. This is indeed true. Maxwell calculated the speed of an “electromagnetic wave,” and found that it coincided with the speed of light experimentally known at the time, proving that the “electromagnetic wave” is the same thing as light. Of course, his formula for the speed of “electromagnetic wave” depended on the ratio between the electric force and the magnetic force.

Let me conclude this article with a comment. Many of those who do not understand Einstein’s theory of special relativity think that you go to the past, if you travel faster than light because you will see the image of past. But, this is a wrong reason. Say, you are in a swimming pool. If you travel faster than the speed of light in water but slower than the speed of light, you will see the image of past, but you won’t go to the past.

Summary

- Even though an observer observes only electric force being applied to an object, it is possible that another observer observes magnetic force being applied to an object as well.
- It is impossible to travel faster than speed of light, because it leads to contradiction.