The Special Theory of Relativity has not been used to analyze rotating objects because rotating reference frames are not inertial. But relativity can be extended to rotating reference frames if creative methods are found for the analysis.

The Rotating Disk

Consider a circular disk rotating about an axis passing through it's center and perpendicular to the plane of the disk. See Figure 31.

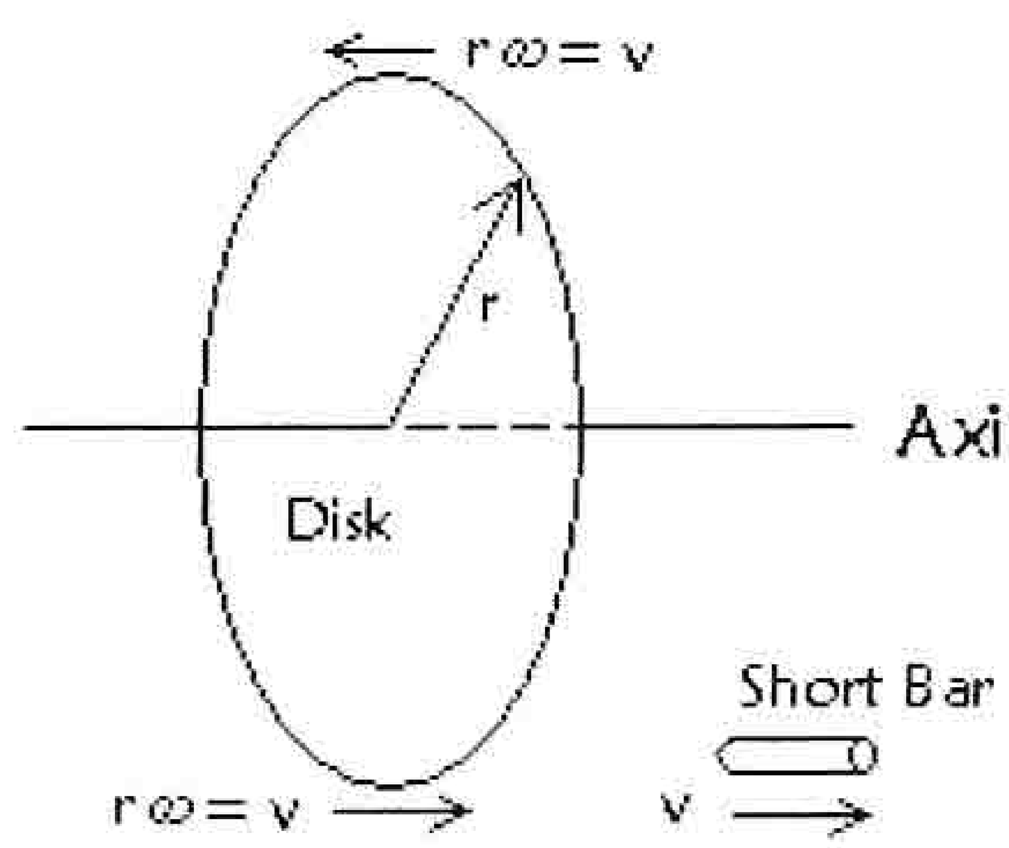

Figure 31. A disk rotating about an axis.

The circumference of the disk, drawn by the tip of the radius r, has a velocity $r\omega$ where ω is the angular velocity of the rotation. This tangential velocity $r\omega$ could be equal to the velocity of a short linear bar passing nearby. The bar will undergo length contraction, time dilation and failure of simultaneity at a distance. It would therefore be expected that the circumference of the disk would also experience those effects.

The Simultaneity Paradox

Failure of simultaneity at a distance is one of the three inertial principles of relativity. It always occurs on "Short Bars" such as illustrated in Figure 31. Paradoxically, it cannot possibly occur on a rotating disk. This result comes by pure deduction. All points on the circumference of a disk must show the same time to stationary observes next to the disk because all points on that circumference are functionally identical. It is not possible to decide why one specific clock on the moving circumference should have a reading ahead or behind any other clock. All points on the circumference have the same history, so all points on the circumference must have the same clock reading when viewed at any instant by the stationary frame (assuming all clocks are synchronized before they were accelerated to velocity ω).

For the same reason, all circumferential observers must also agree that the clocks in the stationary frame opposite them have the identical readings at all times.

The Length Contraction Paradox

Length contraction is another principle of relativity that occurs on all inertial reference frames. However, the circumference of a spinning disk cannot experience length contraction because the radius of the disk does not experience length contraction. The radius is perpendicular to the velocity and must retain the value it had before the rotation started. The paradox is that the circumference (being a function of the radius) cannot experience length contraction, even though it moves in the direction of the velocity (in other words, even though it looks like a circular string of "Short Bars").

So, how about circumferential length contraction on a spinning hoop? A hoop would be a spinning disk that is hollow in the middle and has no inner radial material that needs to 'contract'. Length contraction still cannot occur. This is a result of the Law of Conservation of Energy. Suppose you had two hoops and the inside diameter of the larger one was slightly smaller than the outside diameter of the smaller one. The smaller hoop could not fit inside the larger hoop. Assume both hoops are initially stationary. Now spin the smaller hoop with a velocity such that length contraction would reduce it's outside diameter. In would then easily fits inside the larger hoop. Now, with the smaller hoop inside the larger hoop, bring the velocity back to zero. Assume the surfaces of both hoops are frictionless.

The energy expended to give the smaller hoop a velocity would be equal to the energy recovered as that velocity was brought back to zero. But once the smaller hoop was no longer moving, it's outer diameter would be pressed tightly against the inner diameter of the larger hoop. Now the hoops have a compressive-tensile energy (potential energy) that was created by the experiment. This is contrary to the Law of Conservation of Energy, so the smaller hoop cannot fit inside the larger hoop while it is spinning. Length contraction of the spinning hoop cannot occur.

The Time Dilation Paradox

Time dilation is a principle of relativity, but paradoxically cannot occur on a spinning disk. To explain why, consider the three simple experiments shown in Figure 32.

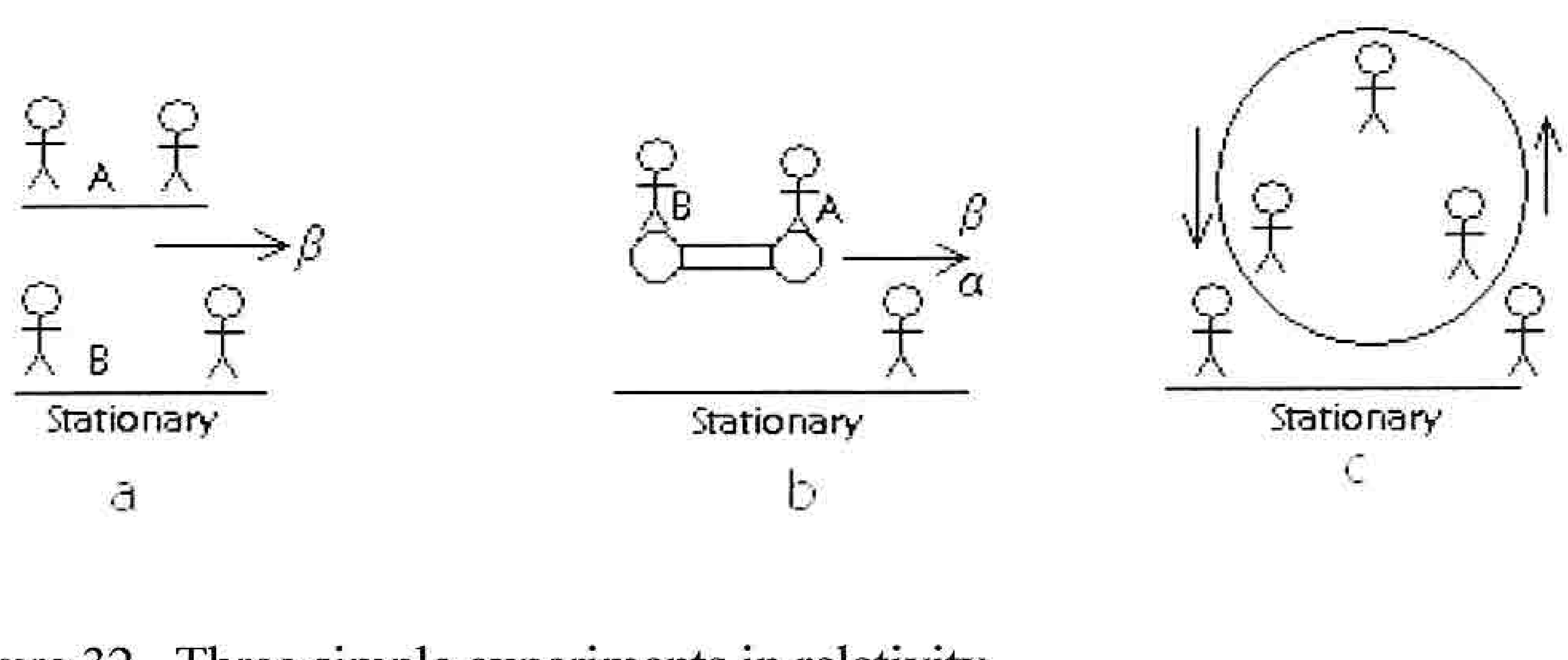

Figure 32. Three simple experiments in relativity.

Figure 32a shows two inertial reference frames passing each other with speed β. This familiar experiment is the fundamental experiment used to derive the three inertial principles of relativity. Figure 32b is the fundamental experiment used in the article *The Acceleration Law*. It shows a bar connecting two masses that are accelerating relative to a stationary reference frame. Figure 32c shows a disk spinning next to a stationary reference frame.

What the first two of these experiments have in common is that all the observers, whether stationary or moving, have the ability to determine their velocity relative to the opposite reference frame. They measure things carefully, take notes and then get together after the experiment is over so that they can calculate their velocity. Whether they are stationary, or have a velocity or acceleration, all observers can still know and agree on their velocity at all times during the experiment.

It is therefore hypothesized that all the observers in Figure 32c must also be able to calculate their relative velocity at all times during the experiment. If this is true, then the absence of length contraction and "failure of simultaneity at a distance" dictates that there cannot be time dilation on the disk clocks. Velocity is just measured length divided by measured time. With no length contraction or failure of simultaneity at a distance to provide relativistic factors in the calculation, time cannot have a relativistic form (dilation) either. Both stationary and disk observers must see the same time (clock readings). Note: if clocks were slowed by the disk circumferential velocity, then there would be a failure of simultaneity at a distance in the radial direction. How could that be explained?

The "Other Things" Paradox

If the three principles of inertial relativity don't apply to a spinning disk, can the circumferential speed of the disk exceed the speed of light? Logically, even though relativity appears to be void in this case, exceeding the speed of light does not seem possible. What if an observer on a spinning disk dropped a ball off the disk? The ball would retain the disk velocity, but cannot go faster that the speed of light as a separate inertial object. The Law of Conservation of Momentum would appear to limit the velocity of the ball when still part of the disk.

Another question would involve the energy of a spinning disk. $E = mc^2 / \sqrt{1-\beta^2}$ is based upon the three inertial principles of relativity, but it is hard to see how it would not apply to the mass of a spinning disk. If an observer on a spinning disk dropped a ball off the disk, wouldn't the ball have the above energy after being dropped? Isn't this the same energy it would have before being dropped?

Another question: If disk clocks do not run slow, would there be a red shift of photons hitting the circumference of the disk? There are many questions that might be asked of non-inertial reference frames and the only way to determine if relativistic effects are operating is to use a deductive process (logic). The paradox here is that some parts of relativity theory appear to be void on a spinning disk and other parts do not.

Philosophy

In the beginning, relativity dealt only with inertial reference frames. This was a necessary simplification at the time, as development of a new theory that included everything would be a difficult task. Gradually, acceleration became incorporated into relativity theory. In a continuation of this progression, the discussion of this article seeks to further expand the boundaries of relativity.

Including accelerated reference frames into the original relativity theory was avoided because there was a suspicion that these frames might behave in strange ways. Each individual type of non-inertial frame might even have it's own unique problems. In the case of spinning disks and hoops, the three principles of inertial relativity do not apply. But, why would there be such a dramatic difference between inertial and non-inertial reference frames? The opinion offered here is that the presence of force is responsible for these exceptions to normal relativity theory.

From the articles *Force and Geometry* and *Force and Time*, it is now known that there is a fourth principle of relativity - force enhancement. One of the peculiar characteristics of this principle is that force is absolute, not relative. Apparently, the existence of force in an experiment can influence the activity of the other three principles of relativity.

But the presence of force in an experiment does not guarantee that the other three principles will be affected. In the article *The Acceleration Law*, masses at the ends of an accelerating rod behaved with all the inertial relativistic principles in effect. The same can be said for the experiments in *Force and Geometry* and *Force and Time.* Yet, in the case of spinning things, the three principles are nullified. Could it be the nature of the force that is having an effect in spinning experiment? Perhaps it is not force itself that is causing the other three principles to be modified, but the situation that the force is changing? Each piece of a spinning disk or hoop has a centripetal force that is constant in magnitude, but constantly changing in direction. There appears to be no other significant difference between the spinning disk experiment and the acceleration experiments in the other articles.

Conclusions

This article gives some rough guidelines for the analysis of non-inertial experiments. When force is changing within an experiment, standard relativistic ways to analyze the experiment need to be carefully evaluated. Innovative methods must be found to discover how the three principles of inertial relativity will react. This also includes other aspects of relativity theory (energy, speed of light, etc.). With some of the characteristics of force revealed, it is now possible to analyze many more types of experiments. The existence of centripetal force in an experiment somehow voids many of the effects of inertial relativity theory.