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Question 12: Do Newton's laws hold true in accelerating frames?

Ethan Skyler:
It seems to me that Newton's Laws are not the whole answer since they only hold true in frames where acceleration is absent. After reading through your site, I get the feeling that you think otherwise. If so, please explain why. J.W., Boston, MA, USA

Hello J.W.:
As is generally accepted, I do recognize that Newton's laws always hold true in frames of reference where acceleration is absent. For example, using Universal Physics terms, in a non-accelerating frame of reference, LAW I and Newton's formula for acceleration, F=ma (Absolute Force = mass x acceleration rate) indicate the following:

Non-accelerating Frame of Reference

(a) In the absence of an acceleration/Action force, an object's motion within the non-accelerating frame will remain unaccelerated.

(b) When an object in a frictionless environment experiences an acceleration/Action force, acceleration for the object within the reference frame will occur at the rate predicted by Newton's formula a=F/m which is the acceleration rate = the impressed acceleration/Action force (expressed in Absolute units for force such as the Poundal or Newton) divided by the quantity of the object's matter (expressed in units for mass such as lb.mass or kilograms).

But do I think Newton's Laws hold true in frames of reference that are undergoing acceleration? The answer is most definitely not "never" as one might initially think but instead is "sometimes but not always." It has been my experience that frames of reference are often attached to a single large object. Then the movement of a smaller object within the frame is tracked or plotted using the frame as a reference. Now if the large object to which the frame is attached is itself experiencing acceleration, then the smaller test object thought to be in rest-motion within the frame by an accelerating observer is also experiencing acceleration at some rate greater than zero.

Why not acceleration at the same rate as the large object? If the acceleration is a linear event with rotation absent then all objects thought to be in rest-motion by an accelerating observer within the accelerating frame will be experiencing acceleration at the same rate and in the same direction as the large object to which the frame of reference is attached. But if the acceleration involves some degree of rotation of the large object, then an axis for this rotation exists so the degree of acceleration for the smaller object will be affected by both the distance the smaller object resides from this axis along with the rate at which the smaller object is rotating if it resides at the axis or orbiting if it is positioned elsewhere within the frame.

So, as you can see, the acceleration associated with a rotating frame of reference adds a degree of complexity to the accelerational event. Do Newton's laws, as written, hold true when the observer accepts the rotating frame as a basis for observation? The answer is no. But "the thing is not altogether desperate" to quote an ever-hopeful Newton. If the frame's rate of rotation is known and this rate is accounted for in the calculations applied to the smaller object's behavior within the rotating frame, then Newton's laws will work just fine. By this technique, the smaller object's behavior is really being compared to an even larger frame that is not experiencing acceleration. But if this translation to a larger non-accelerating frame is not done, as is often the case, then Newton's Laws will most-likely not be correct in predicting the forces present nor the paths followed by objects within the rotating frame as noted below.

Accelerating Frame of Reference (Rotation)

(a) The presence of an acceleration/Action force of one type or another (internal or external) is required to force the smaller test object to maintain the required rate of absolute acceleration so that the test object will appear to remain in rest-motion to the accelerating observer. Newton's LAW I does not apply since here a force is required to make the test object appear that its motion is unchanged or unaccelerated. I shall refer to this acceleration/Action force that is causing the test object to accelerate at the same rate as is its position within the rotating frame as the test object's "rest-force".

(Please note that when an object is observed by an accelerating observer to be in "rest-motion" within an accelerating frame of reference, the object is not actually in the non-accelerative state of rest-motion where its velocity remains constant. Instead its velocity is changing which always indicates the presence of acceleration. It is the accelerating observer's failure to recognize this truth that makes it seem as though Newton's laws have gone awry. Thus, while comparisons of an object's behavior are commonly made to accelerating frames of reference, any such event that seems to indicate to the observer the existence of a flaw in Newton's laws is really indicating the existence of a flaw in the observation.)

(b) If the direction and magnitude of the test object's rest-force is not taken into account along with the frame's rate of acceleration, then it is unlikely that application of yet another acceleration/Action force in another direction will cause the object to behave as predicted by Newton's formula a=F/m when viewed by the accelerating observer.

Now let us consider frames of reference that are exclusively experiencing acceleration along a straight line. It is important here to recognize the type of acceleration/Action force that is causing the large object's linear acceleration and therefore the acceleration for the attached frame of reference. If the large object is a positively accelerating spacecraft and the acceleration/Action force is the external contact force being applied by rocket motors, then the following will occur:

Accelerating Frame of Reference (Linear Acceleration - External (contact) a/A Force)

(a) The presence of an acceleration/Action rest-force of one type or another (internal or external) is required to force the smaller test object to maintain the required rate of absolute acceleration so that the test object will appear to remain in rest-motion to the accelerating observer. Once again Newton's LAW I does not apply.

(b) If the direction and magnitude of the test object's rest-force is not taken into account along with the frame's rate of acceleration, then it is unlikely that application of yet another acceleration/Action force is another direction will cause the object to behave as predicted by Newton's formula a=F/m when viewed by the accelerating observer. Thus if two astronauts in the accelerating spacecraft decide to play catch using a baseball, the acceleration/Action force required from the astronaut at the rear of the accelerating spacecraft to cause sufficient positive acceleration so the ball will even reach the other astronaut at the front may approach the impossible, while any force greater than just letting go of the baseball by the front astronaut may result in too great a difference in velocity for the rear astronaut to effect a catch without injury.

Yet hope still exists for Newton's laws to hold true in an accelerating frame of reference. If the large object's acceleration is strictly linear and being caused solely by an internal acceleration/Action force such as gravitation, then the following will apply.

Acceleration Frame of Reference (Linear Acceleration - Internal a/A Force)

(a) In the absence of any additional (local) internal acceleration/Action forces and also in the absence of any external (contact) acceleration/Action forces, an object's apparent rest-motion within the accelerating frame will cause the object to appear as unaccelerated to the accelerating observer. If a modest sized spacecraft, with its rocket motors off and with no orbital motion whatsoever, is experiencing acceleration caused by the internal acceleration/Action force of gravitation with this internal a/A force being directed toward a large body in space while the spacecraft itself is traveling directly toward or directly away from this large body, then Newton's LAW I will hold true for events performed within this accelerating spacecraft. Thus to the observer an (additional) acceleration/Action force will need to be impressed upon the object before any changes to the object's apparent rest-motion can occur (acceleration).

(b) When an object in a frictionless environment inside the accelerating spacecraft experiences an additional and local internal acceleration/Action force or an external (contact) acceleration/Action force, apparent acceleration for the object within the accelerating reference frame will occur at the rate predicted by Newton's formula a=F/m. When our two astronauts again decide to play catch, if each astronaut impresses the same magnitude and duration of external (contact) force to the ball then the ball's relative velocity at the time of reception will essentially be identical regardless of which direction along the ship's centerline the ball is thrown. Here Newton's Laws hold true within the accelerating frame of the spacecraft for once the ball is thrown in either direction inside the spacecraft, any velocity granted to the ball by either astronaut relative to the spacecraft will not be reduced or increased by the internal gravitational acceleration/Action forces that continue to remain present during the ball's flight for the simple reason that these internal a/A forces will continue to cause equal rates of acceleration for the spacecraft and all objects within. (See Question 11 regarding why objects initially fall at the same rate of acceleration.)

(Please allow me to ignore any minor differences in the ball's gravitational rate of acceleration at each end of the spacecraft when compared to the spacecraft's overall average rate of gravitational acceleration.)

I owe you a debt of gratitude, J.W.. Your question has prompted the development of the concept of rest-force. I am sure it will come in handy many times in future-presents. Thanks for asking!

Your friend in understanding the nature of Physics,

Ethan Skyler
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