

# The Rattleback and the Gyroscopic Force

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**Abstract.** The rattleback (Celtic stone) is the most mysterious phenomenon in classical mechanics. It freely undergoes a complete reversal of its angular momentum without the involvement of any apparent external torque. This mystery will now be investigated.

## Introduction

**I.** A rattleback is a special kind of spinning top, usually semi-ellipsoidal in shape, which when placed on a horizontal surface and rocked, will begin to rotate in a preferred direction. If we rotate the rattleback contrary to this preferred direction, any slight rocking will escalate and the rotation axis will precess until the rattleback is rotating in its preferred direction. An external torque of some kind must be acting on the rattleback. Gravity acts vertically downwards and so this cannot be what is supplying the torque. Sliding (dynamic) friction is involved and it serves to dissipate the motion, but this is merely a resistive force which couldn't possibly cause a reversal torque. Static friction is also involved, and indeed without static friction a rattleback will not work. Static friction is necessary in order to avoid dissipation during the rocking stage of the motion, but static friction just like dynamic friction is only a resistive force which could not possibly cause a reversal torque.

## Centrifugal Force

**II.** When an object is rotated, an inertial centrifugal expansion is induced, which in the case of solids is resisted by a reactive centripetal force that is in turn caused by the inter-molecular bonds. When a rattleback rocks or rotates, the centrifugal force will act through the centre of mass in each limb. The position of the centre of mass in each limb is what will define the natural plane of rotation. If an object is force rotated about an asymmetrical axis such that the centre of mass in each limb lies outside the plane of the forced rotation, the reactive centripetal force will not then be in line with the inertial centrifugal force. This means that only the component of the centrifugal force that is in line with the reactive centripetal force will be

cancelled, and there will remain a residual component of centrifugal force acting transversely to the polar origin. During the rocking mode of a rattleback, this transverse component of the centrifugal force acts out of the plane of the rocking motion, hence causing the rattleback to precess into a preferred horizontal plane of rotation. It's also possible to have two-directional rattlebacks so shaped asymmetrically such that the centre of mass in each limb always lies outside the plane of rotation, and as such they just continue to-ing and fro-ing in a precessional cycle until friction damps the motion out altogether.

Centrifugal force is a real force despite the fact that modern textbooks claim otherwise, and this reality is the vital ingredient that is missing from all the standard analyses on rattlebacks.

## **The Magnus Effect and the Coriolis Force**

**III.** The Magnus effect in aerodynamics, which causes the *p-factor* on a rotor blade or a propeller, is closely related to *Bernoulli's Principle*. Due to the relative speed of a current being different on either side of a spinning object, the pressure differs too, so as to cause a net torque. In the case of a spinning object such as a rattleback, the background luminiferous medium [1], will circulate inside the object, passing through the interstitial spaces between its constituent molecules as like water passes through a basket. The Magnus effect will then cause the molecules to align with their spin axes parallel to this aethereal wind, as this will be the equilibrium alignment. The tendency of the spinning rattleback to expand due to inertial centrifugal force will be resisted by a reactive centripetal force which is supplied by the inter-molecular bonds. This centripetal interaction will cause a re-orientation of the spin axes of the molecules, hence inducing an additional Magnus effect. If the centre of mass in each limb of the rattleback lies in the plane of the forced rotation, the additional Magnus effect will cause the centripetal force to be directed through the two centres of mass in direct opposition to the inertial centrifugal force. However, if the centre of mass in each limb lies outside the plane of forced rotation, as occurs during the rocking stage, the additional Magnus effect will act transversely out of the plane of forced rotation towards the two centres of mass. This transverse component of the centrifugal force causes precession, hence exhibiting some of the characteristics of a Coriolis force, particularly as observed where the Coriolis force acts to counter gravity in a pivoted precessing gyroscope.

## The Weight of a Precessing Gyroscope

IV. Although there are conflicting reports regarding whether or not a pivoted precessing gyroscope loses weight, the general consensus is that it doesn't. If this is the case, an explanation is still nevertheless required as to why its weight is transferred from the centre of mass to the pivot. It's an observed fact that a Coriolis force does cancel gravity at the centre of mass of a spinning pivoted gyroscope, preventing it from toppling. This Coriolis force however comes as part of an action-reaction pair, and so an equal and opposite Coriolis reaction force presses down on the pivot. Therefore if the Coriolis force is equal in magnitude to the gravitational force, the weight at the pivot will be unchanged. What will have changed however is the fact that the weight will no longer be caused by gravity, but rather by Coriolis force [2].

### Conclusion

V. The rattleback is mysterious because it is observed to reverse its angular momentum in the absence of any apparent external torque. Friction is only resistive and never produces a recoil effect, while gravity only acts vertically downwards, so neither of these can be the cause. The inertial forces would appear to be the most obvious contenders but mainstream dismiss these as being merely fictitious artefacts that only arise when we make observations from a rotating frame of reference. However, unless conservation of angular momentum has broken down or there is a new force acting which has not been officially identified in physics, we must draw the conclusion that mainstream have got it badly wrong in claiming that the inertial forces are fictitious. The inertial forces are as real as Newton's laws of motion from which they follow, and they are described in polar coordinates in an inertial frame of reference. Once we accept this reality, then the rattleback mystery is solved.

The precessional torque that acts on a rattleback is caused by centrifugal force acting through the centre of mass on each limb. The two centres of mass are what define the natural plane of rotation. When the rattleback is forced to rock or rotate such that the centres of mass are outside the plane of the forced rotation, the reactive centripetal force will then be out of line with the centrifugal force, and so it will only cancel with the component of the centrifugal force that it is in line with. The resultant centrifugal force acting out of the plane of the forced rotation is the mysterious force in question that causes the reversal of the rattleback's

rotation. It acts through each of the two centres of mass hence causing a torque.

In an earlier paper on this subject written in 2008 [3], it was pointed out that the reversal effect observed in a rotating rattleback appears to be caused by a force which possesses the hallmarks of both centrifugal force and Coriolis force, and that it may be some kind of hybrid. The Magnus effect on the molecular scale is in fact a variation of the magnetic force,  $\mathbf{F} = q\mathbf{v} \times \mathbf{B}$ , differing only in that the former is induced by spinning molecules moving through the luminiferous medium, whereas the latter is induced by the spin of the tiny particles that comprise the luminiferous medium itself. In the latter case the spin axes are mutually aligned to produce a solenoidal magnetic field. The tiny spinning particles that comprise the luminiferous medium are electron-positron dipoles which are striving to dilate [1], and these press with centrifugal force against atoms and molecules on all sides. When a spinning molecule moves through the luminiferous medium, the Magnus effect causes a differential centrifugal force to exert a torque on the molecule. If that molecule is constrained to a particular orientation, it will then experience a deflection. Likewise the magnetic force is a differential centrifugal force arising from the solenoidal alignment of the rotating electron-positron dipoles that comprise the luminiferous medium. A differential centrifugal force acting on either side of a moving object is a *compound centrifugal force*, this being the name which GG Coriolis applied to the transverse inertial force that acts in a rotating system. The rattleback force is therefore in some respects a Coriolis force just like the gyroscopic force.

However, so long as mainstream physicists continue to deny the reality of centrifugal force, Coriolis force, the aether, and the electron-positron sea, the rattleback will forever remain a mystery, as will the linkage between the inertial forces and the electromagnetic forces.

## References

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