

The Rattleback and the Centrifugal 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 at the expense of the rotation. The rotation axis will then precess 180 degrees until the rattleback is rotating in its preferred direction. It seems that 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. Rolling 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 to dynamic (sliding) friction during the rocking stage of the motion, but static friction doesn't do any work and so it 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 centre of rotation. 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 [1].

Conclusion

III. 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 [1]. 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.

References

- [1] Tombe, F.D., “*The Reality of Centrifugal Force*” (2021)
<https://www.researchgate.net/publication/350060937> The Reality of Centrifugal Force