

A thought experiment indicates that a classic physics demonstration is invalid

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Abstract:

The classic ball-on-a-string demonstration of conservation of angular momentum is shown to produce results inconsistent with generally accepted principles. The law of conservation of angular momentum does not apply to this classic demonstration.

1. Introduction

In an effort to produce experimental prototypes for a project, a fault was exposed. Current understanding of this demonstration is that if the radius is reduced, the momentum must increase in order that angular momentum remain conserved. Prototypes indicate no increase in momentum. My research altered direction in an attempt to understand why not. What I found is a simple oversight.

2. Thought Experiment

A professor provides a classic demonstration of conservation of angular momentum in a lecture hall during which he swings an object on a string which is fed through a small hole in a tube held in one hand while the string is held, below the tube, in the other hand. He then holds the tube steady and pulls the string down to reduce the magnitude of the radius to one tenth of its original value.

Applying conservation of angular momentum, the angular velocity must increase one hundred fold ¹.

If we assume a conservative initial angular velocity of two revolutions per second, the end result must be two hundred revolutions per second.

Two hundred revolutions per second when converted to revolutions per minute is **12 000 rpm**.

Since an angular velocity of this magnitude has clearly never been attained in any presentation of this demonstration and mere observation suggests an order of magnitude in the discrepancy, a rational person must conclude that this is inconsistent with reality.

3. Conclusion

The application of the law of conservation of angular momentum does not apply to the classic ball-on-a-string demonstration.

4. Discussion

Claims that conservation of angular momentum in a variable radii system has been verified time and time again via rigorous scientific experimentation are simply false. There is no famous experiment which verifies that angular momentum is conserved in a variable radii system. When pressed to supply any reference to any experiment to back up this claim, all detractors have become silent.

The evidence currently provided during the teaching of conservation of angular momentum is generally limited to a demonstration or example of an increase in angular velocity experienced when a radius is reduced. This does not however indicate the conservation of angular momentum. The increase in angular velocity is obvious since reducing the radius means the circumference and hence the distance the mass traverses to complete a revolution is also reduced. It will therefore complete a revolution in less time and consequently revolve faster without requiring an increase in velocity predicted by conservation of angular momentum.

I can offer very little explanation for the fact that this issue has been overlooked by so many for so long. Humans make mistakes.

The many derivations which suggest that angular momentum is conserved in this demonstration must contain flaws. It is not necessary for me to point out any of these flaws. I have provided a valid argument. The burden of proof has been fulfilled.

The ball on a string demonstration has been claimed by various detractors to be deficient despite the fact that it was most likely the original demonstration used by Newton himself to convince that angular momentum is conserved. It was perfectly acceptable when he used it and has been mainstream for centuries. To claim that it is all of a sudden not a valid demonstration in a weak attempt to defeat my argument is simultaneously defeating Newton's original claim which simply supports my argument. In any event, to claim this demonstration does not demonstrate conservation of angular momentum is to agree with my conclusion.

Friction, air resistance, uncontrolled torques and other less than significant factors have been mentioned by various detractors. It is claimed that in an ideal frictionless world angular momentum would be conserved in this demonstration. To make this claim however, one would have to account for the application of sufficient torques and resistances to prevent the system from achieving the calculated 12000 rpm. Ten fold increase in velocity means a hundred fold increase in kinetic energy which is an increase of ten thousand percent. The claim is that this huge energy gain is lost to the environment. A braking effect must produce heat and there is no significant heat to be found in any of these demonstrations. No professor has ever complained of burned fingers. This claim defeats the law of conservation of energy.

References

1. D. Halliday & R. Resnick. Fundamentals of Physics, 2nd edition, extended version (John Wiley & Sons, Inc., New York, 1981) (page 195).