Powerball Physics: How does a powerball work?

By Graham Rangel-Sharp

Many thousands of Powerballs are presently being used right across the globe and yet most people would be unable to tell you just why or how they actually work! So, here is my basic explanation of the physics behind the operation of the splendid spheres;

1) Gyroscopic action - Precession

Surely everyone has experienced the actions of a gyroscope sometime in there lives, from a spinning top to a holding a rotating bicycle wheel by its axle. As you should know, weird things happen when you try to turn a high velocity rotating object about any of its axes other than in the plane of rotation. If your holding a spinning bicycle wheel out in front of you with one side of the axle in each hand and try to twist the wheel then you feel a pull in a direction right angles to the direction you apply the force. This changing of direction is called precession.

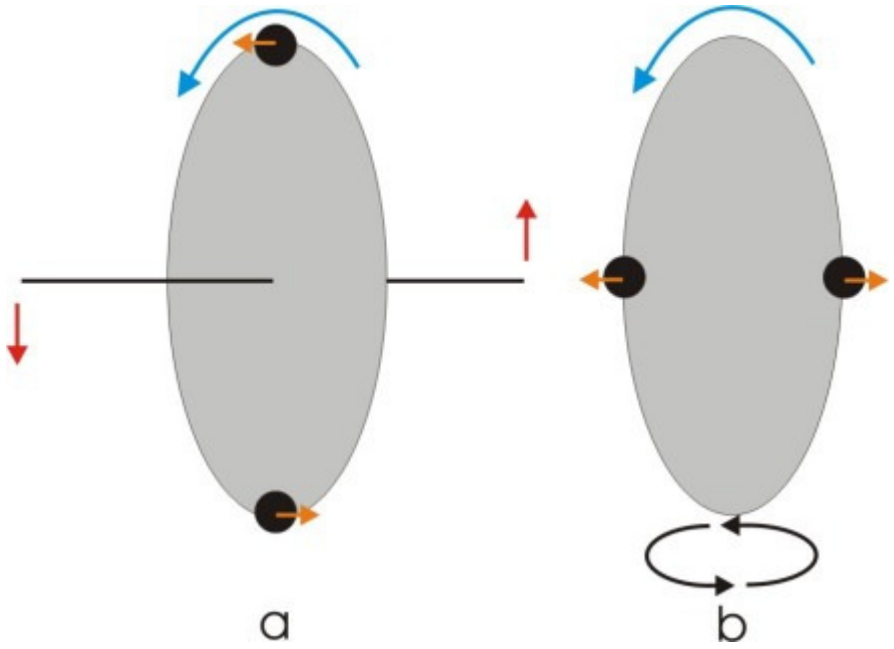


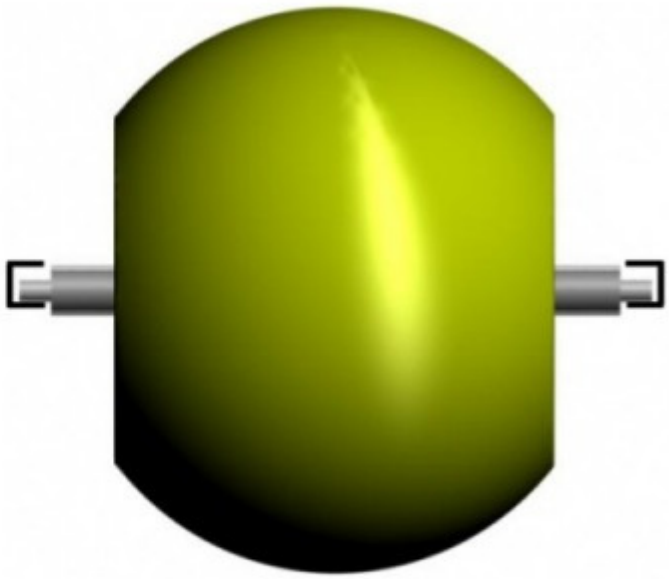
Figure (a) shows a wheel rotating in the direction of the blue arrow on an axis denoted by the black axle lines. If the axle is then tilted, in the direction of the red arrows you can imagine how the force is applied to the mass of the object, for now reduced to two black balls on the circumference of the wheel. Mass on the upper half of the wheel feels a force pulling it to the left whilst mass on the right hand side feels a force to the right.

Now, one of Newtons laws states that an object will continue to move with the same speed and direction unless acted on by another force. That is the upper mass will continue to move left whilst the bottom will continue to move right. However, these masses are rotating and after some time these masses will have rotated round to the positions in figure (b). Since they want to carry on moving to the left/right they will do so, however after the rotation this causes a resulting twisting force about an axis perpendicular to the original force applied.

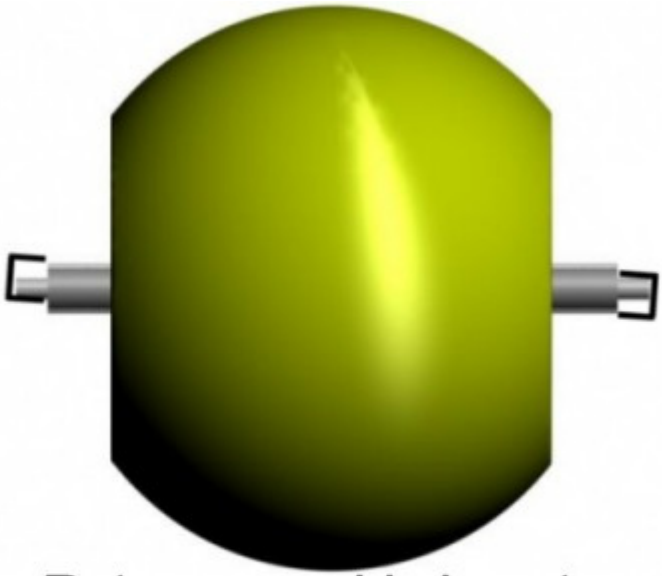
2) Powerball Structure

In a powerball, the wheel is now a mass of plastic with some metal in there to add some mass. The rotor is free to spin and is attached to a support band that sits in a groove in the powerball casing. The rotor is fixed to an axle that fits through holes in the support band and then rests on the groove in the casing, first 2 figures below.

Rotor and support assembly (TOP)



Rotor assembly resting in outer groove of case (SIDE)



Rotor assembly in outer groove as case is twisted (SIDE)

Once the rotor is spinning, a twisting force applied by the hand, as with the bicycle wheel above, causes a rotating force perpendicular to it and since the rotar assembly is free to rotate inside the casing, it does so until it is the rotor is spinning the in same plane as the applied force. If the direction is then changed the rotor assembly will once again rotate until facing the direction on the applied force. If the direction of the twist keeps changing, as in an ideal circular motion then the assembly will continue to rotate. The speed of the rotation is dependant on the applied force and the speed of the spin. These rotations are termed - inner rotations.

With the assembly at rest the axle sits on the bottom of the casing groove. If the rotor is spinning then each side of the axle will try to drive the assembly around, however as it sits they will be driving in opposite directions, no movement occurs and the

friction slows down the spinning rotor. If the case is twisted however, the axles tend to resist the twist, due to precession, and as such now make contact with the groove, one with the upper side, one with the lower side. The inner rotations caused also by precesssion are in the same direction as the rotation caused by the axles running on the upper and lower surface of the groove. If the precessed rotation speed is greater than that caused by the driving force of the axles, friction will lead to acceleration of the rotor spin. If it is less then it will tend to slow down as if at rest.

From this theory, the relationship between the speed of the rotor and the assembly rotations can be calculated by the relationship between the circumference of the axles and the circumference of the the groove it runs around in. The axle diameter is approximatly 2mm, giving a circumference of 6.28mm. The diameter of the case groove is approximatly 60mm, giving a 188.5mm groove circumference, a ratio of 188.5/6.28 = 30. That is there are 30 spins of the rotor for one complete inner assembly rotation.

This explains why the device should not be oiled - ever!!! It just will not give enough friction to speed up the rotor.

It also explains why the metal version will most likely run at higher speeds. Greater precessional force due to extra mass gives faster inner rotations however greater force will be felt in the hands of the user!

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