Exploring 'extreme' physics with an inexpensive plastic toy popper

David R Lapp

Tamalpais High School, 700 Miller Avenue, Mill Valley, CA 94941, USA

E-mail: drlapp1@sbcglobal.net

Abstract

This article describes an activity that can be performed with an inexpensive plastic toy popper. The activity builds skill at analysing motion and results in the calculation of a surprisingly extreme acceleration.

The plastic toy popper is a fun novelty that is often used as a party favour. A set for class can be purchased for a few dollars [1–3]. This article will discuss an activity that strengthens students' motion analysis skills and provides for a direct and safe investigation of 'extreme' physics.

This activity has been successfully done using either a 1 inch or 1.5 inch popper; measurements and calculations in this article were done with a 1 inch popper. Inverting the popper (figure 1) puts it into an unstable condition and it restores itself quickly after being placed on the floor or a tabletop. During the short time it restores itself (that is, during the 'pop'), it applies a force to the surface upon which it is resting. This causes a brief, but very high, upward acceleration. The popper typically rises to a bit over a metre and then falls back to the surface. Students usually look at the action as one motion—freefall. They see, correctly, that throughout its rise and fall, only gravity acts on the popper. It is freefalling and therefore accelerating at 9.8 m s^{-2} downward. What they miss is that to get the popper to initially rise, an upward acceleration had to first occur for a short period. I challenge students to make measurements that lead to calculations, which ultimately result in a value for the rate of acceleration during the pop and the period of the pop.

Students work in pairs to measure the average maximum height of their popper. From this maximum height, they are asked to calculate the initial speed of the popper as it leaves the surface, the time to rise to its maximum height, and the position of the popper 0.20 s after the pop. To calculate the initial speed of the popper, they consider that it is freefalling all the time it is rising (after it leaves the table) and that, at its maximum height, its speed has been reduced to zero. For a typical average maximum height of 1.25 m, the calculation for initial speed is

Figure 1. Two 1 inch plastic toy poppers. The one on the left is in its stable condition. The one on the right has been inverted. This causes an instability which will lead to it restoring itself to its stable condition. The restoration leads to a force being applied to the surface which leads to a 'pop' off the surface.

$$v_f^2 = v_i^2 + 2ad$$

$$0 = v_i^2 + 2\left(-9.8 \text{ m s}^{-2}\right)(1.25 \text{ m})$$

$$v_i = 4.95 \text{ m s}^{-1}.$$

 0031-9120/08/050492+02$30.00

The calculation for the time to rise to its maximum height is

$$a = \frac{v_f - v_i}{t}$$

$$-9.8 \text{ m s}^{-2} = \frac{0 - 4.95 \text{ m s}^{-1}}{t}$$

$$t = 0.505 \text{ s}.$$

The calculation for the position of the popper after 0.20 s is

$$d = v_i t + \tfrac{1}{2} a t^2$$

$$d = (4.95 \text{ m s}^{-1})(0.20 \text{ s}) + \tfrac{1}{2}(-9.8 \text{ m s}^{-2})(0.20 \text{ s})^2$$

$$d = 0.79 \text{ m}.$$

The preceding calculations are good practice in using various kinematics equations to analyse motion. Most students are surprised at how much information can be gleaned from making only a measurement of the maximum height of the popper. However, the biggest surprise for students is the magnitude of acceleration for the popper during the pop. As the popper restores itself, the force it exerts against the surface acts over a distance approximately equal to its radius (1.25 cm). The acceleration of the popper over this short distance is found using:

$$v_f^2 = v_i^2 + 2ad$$

$$\left(4.95 \text{ m s}^{-1}\right)^2 = 0 + 2a\,(0.0125 \text{ m})$$

$$a = 980 \text{ m s}^{-2}.$$

Finally, students calculate the time of the pop:

$$a = \frac{v_f - v_i}{t}$$

$$980 \text{ m s}^{-2} = \frac{4.95 \text{ m s}^{-1} - 0}{t}$$

$$t = 0.005\,05 \text{ s}.$$

My students have been encouraged to judge whether a particular result seems reasonable. Consequently, they frequently question the magnitude of the acceleration of the toy popper. They are impressed that they can calculate such a high acceleration from the simple data they have collected. This acceleration of two orders of magnitude above the freefall acceleration qualifies as 'extreme' physics. The calculation of the very small increment of time for the pop also gives students pause when they consider that the ability to do this calculation was fully the result of their measurement of something as simple as the maximum height of the popper.

Analysing the motion of the toy poppers is a fun activity for students. They enjoy the action of the poppers and are impressed with the high acceleration and very short time they are able to calculate. Those who finish a bit earlier than the rest invariably continue to play with their poppers and will often discover that the popper goes far higher if launched from the tip of a finger rather than a flat surface. The first time I used this activity, a student discovered this and asked me about it. I realised that when launched from the tip of the finger, the force applied during the restoration of the popper acts over a greater distance. When the popper rests on a flat surface, the force applied to that surface begins when the popper is halfway through its restoration, but when it rests on a fingertip, the force is applied at the beginning of the restoration. This gives twice the time and therefore twice the initial speed. Asking students to explain why the poppers rise to a higher maximum altitude when launched from a fingertip gets them to think more deeply about the physics of the popper. I have since included this question as an extension to the calculations in the activity.

The plastic popper gives students an opportunity to analyse the physics of a simple toy. Toy poppers can also provide teachers with an inexpensive activity that gives students practice at analysing motion as well as safe and direct access to extreme physics.

Received 21 June 2008
doi:10.1088/0031-9120/43/5/004

References

[1] www.windycitynovelties.com/EPaysoft/Cart/product.asp?ITEM_ID=6495&CatID=0
[2] www.centurynovelty.com/detail_306_209-231.html
[3] www.craftpacks.co.uk/#prod1725

David Lapp has 22 years of high school physics teaching experience. The last 18 years he has taught at Tamalpais High School in Mill Valley, California. He is also an occasional lecturer in the Department of Physics and Astronomy at Sonoma State University. His interests are in physics education and specifically in developing methods for making physics accessible to all students.