1-2019

Holy High-Flying Hero! Bringing a Superhero Down to Earth

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Bringing a Superhero Down to Earth

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I am always looking for ways to bring current events into my introductory physics classroom or laboratory. I am especially interested in finding examples where basic principles of physics can be used to cast skepticism on assertions made by celebrities, politicians, or professional athletes.The other day, one such example literally fell into my lap.

While watching television with my 13-year-old daughter, a commercial aired that showcased both the 2018 Lexus® LS 500 sedan and Marvel Studios' blockbuster superhero movie, "Black Panther." The Lexus/Marvel spot starts with the Black Panther employing a variety of astonishing acrobatics to take down a handful of thugs. At the conclusion of the fight, the superhero realizes that his alter ego is late for an important social engagement. Using a communication device built into his mask, he asks his sister to dispatch his car to pick him up, saying: "Is my ride ready?" The sister responds: "Yes … but you have to hurry!" Apparently, the superhero is so late for his social engagement that the car cannot even stop to pick him up. At this point, a remote-controlled 2018 Lexus LS 500 sedan starts screeching its way through city streets to pick up the superhero. The car speeds down a street at 54 mph (the commercial actually shows the car's speedometer at 54 mph) where the Black Panther awaits atop an overhanging bridge. At just the right instant, the Black Panther stands, drops from the bridge, free falls through the car's fully opened sunroof, and comes to rest comfortably in the driver's seat of the car. The commercial can be seen by simply Googling "Lexus LS 500 Commercial" or visiting YouTube.[1]

My daughter has seen her fair share of superhero movies, so I expect her to be somewhat immune to the unbelievable, physics-defying, CGI-generated special effects often saturating these movies. However, this commercial grabbed my attention because the instant it aired, she protested out loud: "That's totally impossible!" Her reaction caused me to wonder if my college students would likewise find the commercial "impossible" to believe. Here was an excellent opportunity to incorporate current events into my classroom. Could my students use basic principles of physics, covered in our introductory classical mechanics course, to cast doubt on the events portrayed in the commercial?

POW! It's a bird … it's a plane … it's the Hooded Llama!

To avoid any references to actual car brands and superheroes, I cast the problem using a fictitious superhero, "The Hooded Llama," and his equally fictitious sports car, "The Nexus 500." My daughter has drawn the Hooded Llama performing the same exact stunt, from the same points of view, as depicted in the commercial: We see the Hooded Llama awaiting atop an overhanging bridge [Fig. 1(a)], dropping from the bridge [Fig. 1(b)], free falling towards the car [Fig. 1(c)], and falling through the car's fully opened sunroof [Fig. 1(d)]. In this problem, the Hooded Llama is simply trying to jump through the opened sunroof of his Nexus 500 sports car (Fig. 2).

Our superhero, of height $H_{\text{Hooded Llama}}$ and mass $M_{\text{Hooded Llama}}$, stands atop a bridge of height H_{Bridge}. At the correct moment, he drops from a bridge so that he falls directly into his speeding Nexus 500, traveling at constant velocity V_{Car}. The sunroof has an opening along the direction of motion of D_{Roof}. Note that the dimension of the sunroof, along the long axis of the actual Lexus LS 500, depends on the style (standard or panoramic), but a typical value is 18.7 in. Also, the headroom of the car (i.e., the distance from the floor of the car to the interior ceiling) is listed as 37.3 in.[2] Assume

Fig. 1. (a) The Hooded Llama awaits his ride from an overhanging bridge.

Fig. 1. (b) The Hooded Llama prepares to jump.

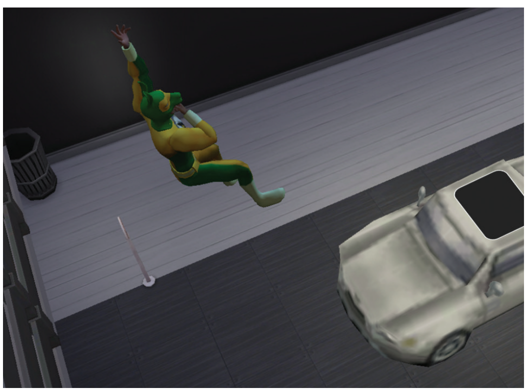


Fig. 1. (c) The Hooded Llama free-falls.

Fig. 1. (d) The Hooded Llama passes through the sunroof of his remotely controlled car.

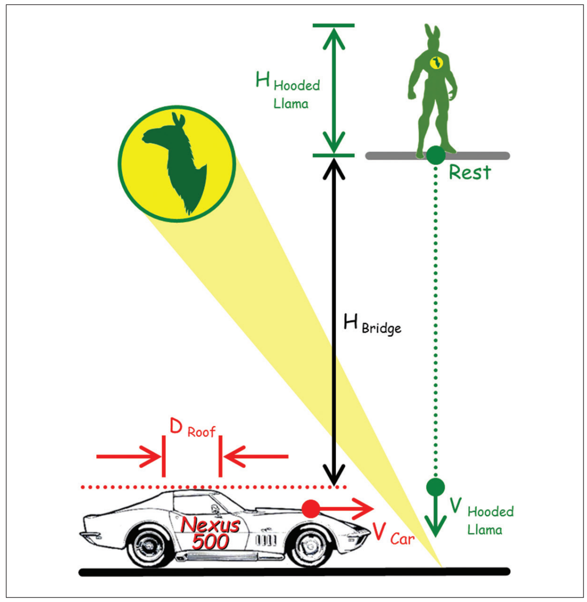
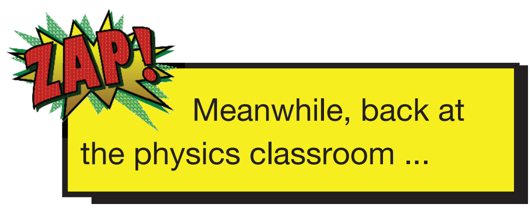


Fig. 2. The Hooded Llama is late for a social engagement and jumps into his Nexus sports car while it is moving at constant velocity.

the Hooded Llama drops from rest and remains upright as he passes through the sunroof, using his legs to halt his fall. In reality, our hero would have to bend his waist to properly land in the driver's seat. Thus, our hero's buttocks, and not his legs, would stop his fall.

However, in the interest of simplifying our calculations, and to save our hero the indignity of further discussing his buttocks, we assume the car has enough room so that the Hooded Llama stops his fall by using his legs against the floor of the car, after which he smoothly settles into the driver's seat.



The following three questions were posed to students: (a) With what minimum speed must our hero reach the sunroof in order to pass safely through its opening? (b) From what height must he have started his fall? (c) What force would his legs have to absorb in order to come to rest in the driver's seat? Assume a mass of 200 lb for our hero.

The problem combines simple applications of kinematics, uniformly acceleration motion and the work-energy principle. To answer (a), we start by calculating the time needed for the Hooded Llama to pass through the sunroof. Obviously, the superhero accelerates as he free falls through the sunroof; thus, we should take into account his acceleration over the length of the fall (i.e., the height of the superhero). However, this acceleration makes such a negligible contribution to the Hooded Llama's final velocity (it is well below a 1% contribution), we can assume a constant velocity as he passes through the sunroof. Thus, his final velocity is computed as: $t_{\text{through sunroof}} = (H_{\text{Hooded Llama}}/V_{\text{Hooded Llama}})$, where $V_{\text{Hooded Llama}}$ is the downward velocity of the hero when his feet reach the front edge of the sunroof. However, the sunroof will only pass underneath him for a maximum time of $t_{Max} = (D_{Roof}/V_{Car})$.

Therefore, the condition under which Hooded Llama can pass safely through the sunroof is $t_{\text{through sunroof}} < t_{Max}$, or

$$\frac{H_{\text{Hooded Llama}}}{V_{\text{Hooded Llama}}} < \frac{D_{Roof}}{V_{Car}}.$$

This expression gives us the hero's minimum speed when he reaches the sunroof as

$$V_{\text{Hooded Llama}} > \frac{H_{\text{Hooded Llama}} * V_{Car}}{D_{Roof}}.$$

Plugging in the values: $H_{\text{Hooded Llama}} = 6$ ft, $V_{Car} = 54$ mph (or 79.2 ft/s), and $D_{Roof} = 18.7$ in, we see our hero has to enter the opening of the sunroof at a speed of at least 208 mph (or 305 ft/s). **"Holy high speed hazard, Hooded Llama!"**

To answer (b), we assume the Hooded Llama jumped from rest from the bridge, thus making his downward velocity when he arrives at the roof of the car:

$$V_{\text{Hooded Llama}} = \sqrt{2 * g * H_{Bridge}} \quad .$$

Combining this result with our safety condition, we get:

$$H_{Bridge} > \frac{\left(\dfrac{H_{\text{Hooded Llama}} * V_{Car}}{D_{Roof}}\right)^2}{2g},$$

and the height from which our hero had to drop as approximately 1446 ft. The height of the Willis Tower (formerly the Sears Tower) in Chicago is 1450 ft. **"Holy highrise headache, Hooded Llama!"**

Finally, we answer (c) by employing the work-energy principle. As our hero came to rest in the driver's seat, his legs had, <u>at most</u>, the distance of the headroom of the car over which to exert a force to stop his fall. In this small distance, his legs must have done work equal to his kinetic energy as he entered the sunroof. We use an average force over the distance of the headroom of the car to derive:

$$F_{avg} * d_{Headroom} = \left(\frac{1}{2}mV^2\right)_{\text{Hooded Llama}} .$$

Using a mass of 200 lb and headroom distance of 37.3 in, we get a value of F_{avg} of 413,915 N (or 93,051 lb)—that corresponds to a vertical deceleration of 4563 m/s^2 (or 466 *g*'s)! Typical aircraft pilots, using modern *g* suits, can only handle 9 *g*'s; but we are talking about the Hooded Llama, not some ordinary human. **"Holy high-flying hospitalization, Hooded Llama!"**

Acknowledgments

The author gratefully acknowledges his daughter, Carmela, for creating the images in Fig. 1 and for knowing a physics-defying commercial when she sees one. The author also acknowledges the reviewers of this manuscript and the editors of *The Physics Teacher*, who significantly strengthened the presentation of this work.

BAM! References

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2. "The 2018 Lexus® LS 500," http://www.lexus.com/models/LS/specifications, accessed on Feb. 21, 2018.

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