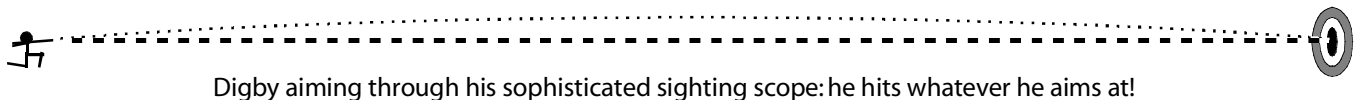


PhyzGuide: The Monkey Gun

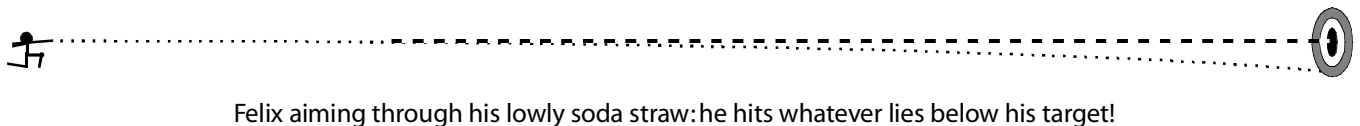
Shock the monkey!

Once upon a phyztime, Felix and Digby were on safari in the jungles of Africa. They were hunting the dreaded “vorpal monkey” (a distant genetic cousin of the infamous vorpal bunny). The vorpal monkey had terrorized many villages and had evaded scores of hunters. A reward of 6 million kabukies was placed on the monkey’s head, and so Felix and Digby set out on their dangerous quest.

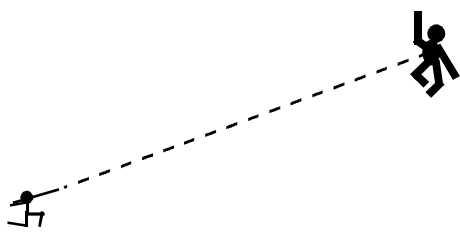
Digby invested in an expensive, high-power rifle with a sophisticated aiming scope. The gun was highly accurate at distances up to 1000 yards, since the scope corrected for gravitational effects:



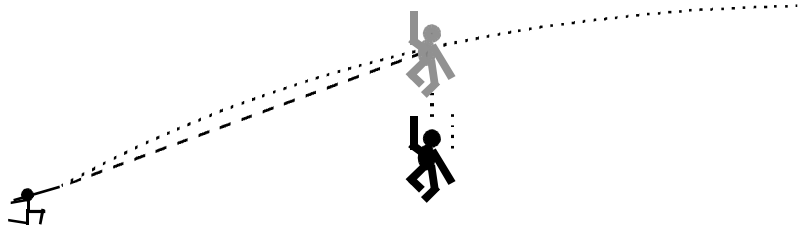
Felix, however, had a simple rifle with only a lowly soda straw mounted where the scope *should* be. If he didn’t aim above his target by the right amount, he would always miss:



After several days and nights of sweltering heat, blood-thirsty mosquitoes, and swarming locusts, the pair came across the vorpal monkey. The monkey hung from a tree and taunted Felix and Digby as the two stared in amazement. Digby quickly took aim and fired. But when he fired, the monkey let go of the tree, dropped to the ground, and ran away screeching in victory.



Digby takes aim: the dashed line indicates his target sighting.



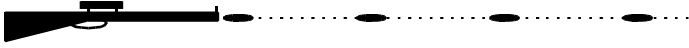
Digby fires, but the monkey lets go. Digby's bullet follows the dotted line: it passes through where the monkey used to be. Digby misses: he was outfoxed by a monkey, so he felt like an ass!

No wonder the monkey had survived so many hunters! Several days later, the duo caught up with the monkey again, and again the monkey hung from a tree, sneering at the two as they stalked him. But this time, Felix aimed through his lowly soda straw and fired at the vorpal monkey. With a “CHEEP,” the monkey again let go of his branch. But this time, it was the monkey that was outfoxed. Felix’s bullet nailed the vorpal monkey straight through the heart, killing it instantly. Felix was awarded the 6 million kabukies and felt like the king of the jungle. Digby still felt like an ass. I mean a donkey. Sorry about that.

How did Felix do it? Read on...

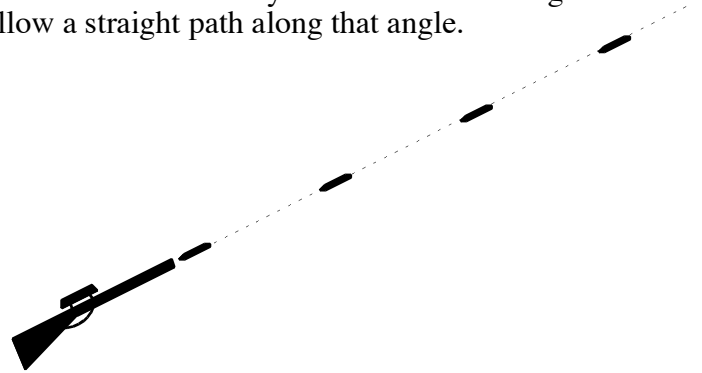
To understand why Felix with his lowly soda straw succeeded where Digby and his sophisticated scope failed, we must recall the effect of gravity on projectiles.

Consider a gun fired in a gravity-free environment. A bullet fired horizontally would follow a straight horizontal trajectory; a bullet fired at an angle would follow a straight path along that angle.

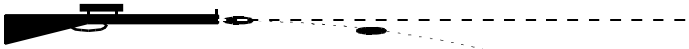


ABOVE A bullet fired horizontally travels horizontally with no downward acceleration when there is no gravity.

RIGHT A bullet fired at an angle travels along that angle with no downward acceleration when there is no gravity.

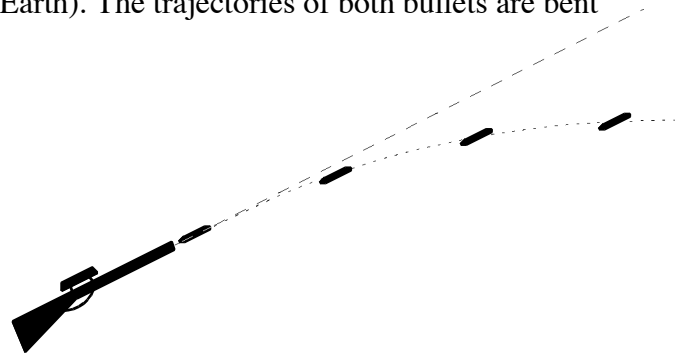


Now let's add the effect of gravity. Gravity has the same effect on all projectiles: it accelerates them downward at an acceleration of g (10m/s^2 or 32ft/s^2 on Earth). The trajectories of both bullets are bent into parabolas by gravitational acceleration.



ABOVE A bullet fired horizontally falls away from the straight-line path with increasing speed due to the acceleration of gravity.

RIGHT A bullet fired at an angle falls away from the straight-line path with increasing speed due to the acceleration of gravity.



The distance that the bullet falls away from the straight-line path increases geometrically: it is proportional to the square of the amount of time the bullet has been in flight. If the bullet fell 5cm below the straight-line path after 0.1s, it will be 20cm below (four times as far) the straight-line path after 0.2s, and 45cm below after 0.3s. The equation is

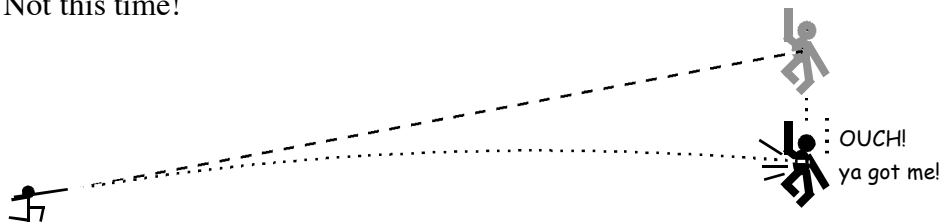
$$\Delta y = \frac{1}{2}gt^2$$

y is the distance below the straight-line trajectory
 g is the acceleration due to gravity
 t is the amount of time the bullet has been in the air

Notice that the deviation from the straight-line path depends only on acceleration due to gravity and time—there is no dependence on horizontal speed. (Recall that a bullet fired horizontally stays in the air *no* longer than one dropped from the same height!)

Finally, consider the path of the vorpal monkey. The monkey is a projectile without any initial horizontal velocity. Therein lies the secret of Felix's success: **BOTH FELIX'S BULLET AND THE MONKEY ARE PROJECTILES AND ARE AFFECTED THE SAME WAY BY GRAVITY!**

By aiming through his lowly soda straw, Felix cannot hit his target—his bullet is pulled downward by gravity. But so is the vorpal monkey! Usually, this gravitational effect took the monkey out of the bullet's path. Not this time!



Felix fires and the monkey lets go. The bullet falls away from the straight-line trajectory, and would miss the monkey if the monkey remained in the tree. But the monkey fell due to acceleration of gravity. **THE MONKEY AND BULLET FALL AT THE SAME RATE** and the monkey is hit!