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A1_1 Gwen Stacy's Death, Physics or Just Storytelling?

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Abstract

In this paper, we examine the physics behind one of the most iconic scenes from Spider-Man comics, the death of Gwen Stacy. For Gwen to survive her fall without suffering from the whiplash effect, her body needs to experience a force no more than 6G. This is possible if the web string acts like a spring system that extends 16.7 meters beyond its original length and has a young modulus of 294 MPa, which is within the range of spider silk (100MPa-10GPa) allowing it to withstand the forces.

Introduction

The death of Gwen Stacy is a famous and iconic moment in Spider-Man universe. The scene is depicted in many comics, where during the fight against Green Goblin who has kidnapped Gwen Stacy, Green Goblin lets Gwen fall from the bridge to distract Spider-Man to make his escape. In this article we will be analysing this scene to figure out whether Gwen died due to story telling or if she had a chance to survive based on physics.

Setting Up The Fall

Let's start with setting up the parameters of Gwen Stacy's fall, thanks to Stan Lee we know that the scene takes place on top of the Brooklyn bridge. The height she falls from is $H_0 = 84m$ above ground. Now this scene is depicted in many different comics and in each comic the fall distance differs so we will use a fall distance $H = 42m$ which is mid way the total height of the bridge. Assumptions are made for mass of Gwen Stacy $m = 50kg$ and surface area of spiderweb $A = 2.5$ x $10^{-5}m^2$. A good deceleration for eyes upward(with eyes facing in opposite direction of the fall) falling for humans is 6G, so in order to calculate Gwen's survival we will use that to be our maximum acceleration $a = 6g$

$$v^2 = 2gH \tag{1}$$

Using Eq (1) and assuming constant acceleration we can calculate the falling velocity of Gwen Stacy when she was at 42 meters to be $v = 28.7ms^{-1}$.

Method and Calculations

There are many forums that have discussed and calculated using the velocity and using the assumption that she came to an almost instantaneous stop that would make her body experience a fatal G force. This would be the scenario if the spider web was fully rigid but with Spider-Man webs, being very similar to the actual spider silk, they can stretch and can experience high amount of strain before reaching the deforming limit. Now to set up the forces, as Gwen would be caught in her fall two forces would be acting upon her, the upward force being the tension in

the spiderweb $T = kx$ and the downwards force due to gravity. $W = mg$. The net force acting on Gwen would be

$$T - W = F \tag{2}$$

$$F = ma = kx - mg \tag{3}$$

where k is the spring constant and x is the distance the spider web would stretch. To make sure that Gwen stays alive as she decelerates, her acceleration should be 6g or lower. Using that value in Eq(3) we can find a value for $kx = 7mg$

Finally we know that the energy when the web attaches to Gwen E_i

$$E_i = \frac{1}{2}mv^2 + mgH \tag{4}$$

is equal to energy the first instance after being caught when velocity reaches zero E_f

$$E_f = \frac{1}{2}kx^2 + mg(H - x) \tag{5}$$

$$\frac{1}{2}mv^2 + mgH = \frac{1}{2}kx^2 + mg(H - x) \tag{6}$$

By substituting the value of kx in Eq(6) we can work around the unknown value of k to find $x = 16.7m$. Using the value of x in Eq(3) we can calculate the value of the spring constant, $k = 204.5Nm^{-1}$. After obtaining the value of k and x, we can check if the values obtained are indeed correct by using the value of k in Eq(6) and using the quadratic formula to work out the value of x to be $x = 16.7m$ and $x = -11.9m$, where the negative value is discarded. Making sure the Spider-Man web can actually withstand the forces we can calculate the young modulus of the web using the equation where L is the length of the web string which is equal to H and x is the amount the string was stretched.

$$Y = \frac{FL}{AX} = 294MPa \tag{7}$$

Discussion

Before discussing the results, it should be kept in mind a few assumptions had to be made during the calculations due to the absence of data on Spider-Man's webs both online and across the Marvel Universe. Spider silk which is the closest natural substance to Spider-Man's web can be used to compare how the web string would react under the given circumstances. Through studies it is know that spider silk can be stretched up to 40 percent of its length while keeping its toughness[1]. The Young's modulus of the string was calculated to be $294MPa$. Using the information available on spider silk, we can compare that the young modulus value falls with in the range of the spider silk which ranges from 100 MPa to 10 GPa[2]. Not only that but the string stretches up to 39 percent of its original length staying with in the limit before it starts losing its toughness.

Conclusion

From the data obtained through calculations and assumptions, under perfect conditions it can be deduced that Gwen Stacy had a chance to survive her fall. If the web string with the young modulus of 294MPa would stretch to 16.7 meters, the upward force from the web string would keep the force at 6G making sure not to cause a whip lash effect and withstand the forces acting on it, keeping Gwen Stacy alive. In conclusion, Gwen Stacy would have survived the fall based on physics, but unlucky for her the storytelling had another fate for her.

References

[1] http://web.mit.edu/mbuehler/www/SIMS/Deformation%20of%20Spider%20Silk.html

[2] http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.541.2873&rep=rep1&type=pdf