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Spidey Motion

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Abstract
In this paper we test the accuracy of the film makers by calculating the maximum velocity Spiderman is able to swing in a typical situation. We will also use the calculated speed of Spiderman to assess his effectiveness at reaching an urgent crime on the other side of New York City. Our calculations show that Spiderman typically travels up to 68.83 mph and he does so safely.

Introduction
Throughout the Spiderman films, Spiderman is often shown to be swinging through the streets of New York at a velocity greater than that of the flowing traffic on the roads [1], the speed limit on the roads in the centre of New York is 30 mph [2]. We will also calculate the tension in the silk to see if it is within the bounds of the tensile strength of spider silk.

Investigation
We will first construct a very simple model to calculate the absolute maximum velocity of Spiderman. To construct this model we must first make a few assumptions:

- When swinging Spiderman moves with uniform circular motion.
- Air resistance and other frictional forces are negligible.
- Spiderman being a superhero is strong, athletic and capable of running at speeds upwards of $8 ms^{-1}$ and weighs 75kg.
- All gravitational potential energy is converted into kinetic energy.

Spiderman will be travelling at maximum velocity at the midpoint in his swing when his gravitational potential energy is at its lowest. Spiderman is standing at the top of a 100 metre skyscraper, using $E_p = E_k$ where E_p is gravitational potential energy and E_k is kinetic energy we calculate the velocity of Spiderman assuming all of the gravitational energy lost is converted into kinetic energy and friction is negligible. Shown in equations 1-3. [3]

$$E_P = mgh \quad (1)$$

$$E_k = \frac{1}{2} mv^2 \quad (2)$$

$$v = \sqrt{2gh} \quad (3)$$

Spiderman takes a run up and leaps off the building with an initial velocity (v_i) and shoots a web of length l. He swings in an arc and so the change in elevation that Spiderman experiences can be calculated using:

$$h = l(1 - cos\theta) \quad (4)$$

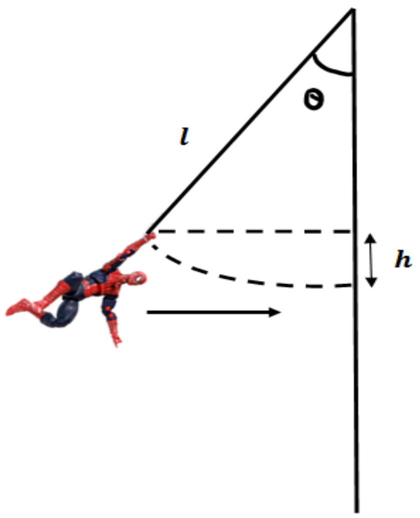

Figure 1 : Diagram explaining the change in elevation of Spiderman.

The final velocity (*v_f*) is calculated from the total kinetic energy of Spiderman which is the sum of the gravitational potential energy and the initial kinetic energy.

$$E_{k\,final} = mgh + \frac{1}{2}mv_i^2 \quad (6)$$

Rearranging equation 6 to find v_f we get [4]

$$v_f = \sqrt{(2gh + v_i^2)} \quad (7)$$

Spiderman runs and jumps off the building with an initial velocity of 8 ms^{-1}; before he begins his descent he shoots a web 90 metres in length 60^0 to the vertical. Using equation 4 to calculate h we sub the value obtained into equation 7 to calculate Spiderman's maximum velocity at the midpoint of his swing. The velocity calculated was 30.77 ms^{-1} which is equal to 68.83 mph more than double the speed of the flowing traffic on the roads.

Another thing we must consider is the tension in Spidermans web. When swinging, Spiderman is moving with an angular motion and so therefore experiences a centripetal force. The tension in Spidermans web is what keeps Spiderman moving with circular motion. To calculate the tension in the web we must first consider the forces acting on Spiderman and the web. The centripetal force acting on Spiderman is calculated using

$$F = mv^2/r \ (8).$$

The circular motion of Spiderman means that he is constantly accelerating as he is changing direction (magnitude stays the same) meaning the forces are unbalanced.

Spiderman must also experience the force of gravity pulling down on him (W=mg). Therefore we can calculate tension in Spiderman's web at any point using: [3]

$$T = \frac{mv^2}{r} + mgcos\theta \quad (9)$$

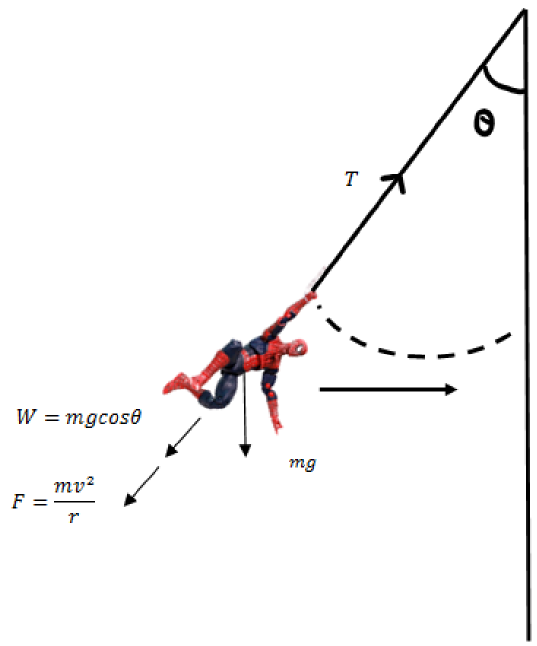

Figure 2: Calculating tension in spider web

Tension is greatest at $\theta = 0$ and when Spiderman is travelling at the greatest velocity. Thus, the maximum tension in the rope is at the midpoint of the swing. The tension was calculated to be 1524.74 N. A piece of spider silk of just 1cm in diameter is able to withstand forces of up to 8.64 x 10^4 N [5]. As you can see the tension of Spiderman's web is much smaller than the maximum force the 1cm diameter spider web is able to withstand therefore Spiderman is very secure when swinging from high rise buildings.

Conclusion

As established above Spiderman can travel at over double the speed limit of the traffic on roads making his mode of transport very efficient. Guided by his spider-senses he is capable of instinctively swinging through the air way above ground level meaning there are less obstacles in his path. He is capable of swinging over rooftops and so is not restricted to the route taken by the roads allowing him to make shortcuts and so the distance to a destination will be the shortest possible distance (as the crow flies).

One key thing we do not consider is the effect of air resistance and so it is unclear how long Spiderman is able to maintain these high speeds. However when swinging Spiderman often tucks in making him more aerodynamic reducing the effect of air resistance. Spiderman may also use pumping (shifting the bodies centre of mass) to increase the height of his swing and therefore maintaining or even increasing velocity.

References

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