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P3_7 Spider-Man! Spider-Man! Does whatever a spider can?

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Abstract

"Spins a web, any size! Catches thieves, just like flies! Look out, here comes the Spider-Man!" [1] In a world of reboots and sequels, this article looks back to Spidey's silver screen debut, in Sam Raimi's nostalgic 2000's masterpiece, in order to break down the web-slinging, high-octane, laws of physics abiding action which inspired a twenty year-long fascination and box office mania with superhero films. In the film, our hero has microscopic hooks grown onto his fingers that keep him attached to walls which he climbs. In this paper, we explore the idea of removing these hooks and instead have Spider-Man cling to a wall via frictional forces alone. The force which would need to be applied to keep a body still against a wall is calculated for a range of different substances. For $Al_3Mg_3B_{56}$ (BAM), the material with the lowest coefficient of friction in the world, the necessary force was found to be 37,300 N.

Introduction

In this scene, three key pieces of athleticism present themselves for analysis: Clambering up a vertically standing wall, jumping in large, arcing motions between buildings and swinging through the NYC skyline via the use of high tensile strength webbing projected from the wrists. Here, the force acting towards the wall comes from Spider-Man's webbing, which acts to connect him and the wall together. By examining these wonders, we can assess if the abilities shown hold true to human reality, or whether Spider-Man can really do whatever a Spider can!

Theory

First, let's look at the physics underpinning a scenario where a grown man is suspended on a vertical wall. This model is visualised in Fig. 1 [2].

Assuming that the forces responsible do not need to be resolved into angular components allows for a simpler calculation to be made, a reasonable assumption to make based on Fig. 1. What needs to happen for Spider-Man to remain static? The net force in both the x and y directions must equal zero, as any net force would result in acceleration. The incredulous nature of this scenario is emphasised here, showing the amount of force that would typically need to be applied upon a body against the wall in order for it to remain suspended.

$$F_f = mg \tag{1}$$

Where the frictional force (F_f) equals the weight of the body in question (mg).

$$N = F \tag{2}$$

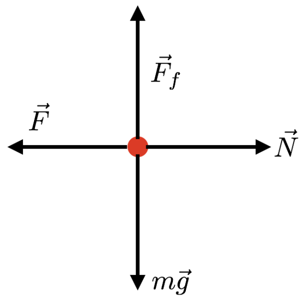

Figure 1: Free-body diagram for a body hanging suspended on a vertical wall lying exactly perpendicular to the ground[2].

Where the normal force (N) equals the force applied to Spider-Man onto the wall via his webbing (F).

$$F_f = N\mu_s \tag{3}$$

The frictional force equals the product of the normal force (N) and coefficient of static friction (μ_s).

$$F_f = F\mu_s \tag{4}$$

The frictional force (F_f) is equal to the product of the force applied onto Spider-Man (F) and the static frictional coefficient (μ_s).

Assuming a mass of 76 kg, Spider-Man's weight close to the surface of the earth is (76×9.81) 745.56 N. Looking at the fantastically varied and ever-evolving architecture of New York City, we can construct a table of materials, each one with a unique static friction coefficient [3], in order to calculate the force that would have to be applied onto Spidey, as his rubbery suit contacts each substance, in order to remain still.

It is clear that a lower coefficient equates to a higher necessary force application in order for the resulting force acting upon the body to remain null. This explains why most humans do not have the ability to cling to walls freely, without the use of external appendages.

BAM is the material with the lowest coefficient of static friction currently known [4]. The necessary applied force to prevent slipping, if

Material Contacting Rubber	μ_s	F(N)
Asphalt	0.90	828
Concrete	0.60	1240
Stainless Steel	0.64	1160
Tool Steel	0.86	867
Urethane	0.67	1110
Wood	0.95	785

Table 1: Necessary force application and friction coefficients for various materials. Values taken from [3].

Spider-Man were making contact with a surface composed wholly of this substance, can be calculated:

$$mg = F\mu_s \tag{5}$$

$$F = (76 \times 9.81)/0.02 = 37,300 \text{ N} \tag{6}$$

This applied force is significantly greater than any of the values found previously, a testament to the capabilities on display. Of course Peter Parker not only remains static, but climbs higher and higher comfortably, by applying extra force up the wall.

Conclusion

Overall, the force required to suspend a fully-grown human against walls made of varying substances has been calculated, and emphasised within the context of a superhero performing this action. Using the latest scientific understanding about static friction coefficients, the force required for a body to remain still when pressed up against BAM has also been calculated. Further scenarios are considered in the follow-up paper!

References

[1] `https://bit.ly/3dntd42` [Accessed 1 December 2021]

[2] `https://bit.ly/3DGdDvj/` [Accessed 1 December 2021]

[3] `https://bit.ly/3lGdDVF` [Accessed 1 December 2021]

[4] `https://bit.ly/3DyzHaN` [Accessed 1 December 2021]