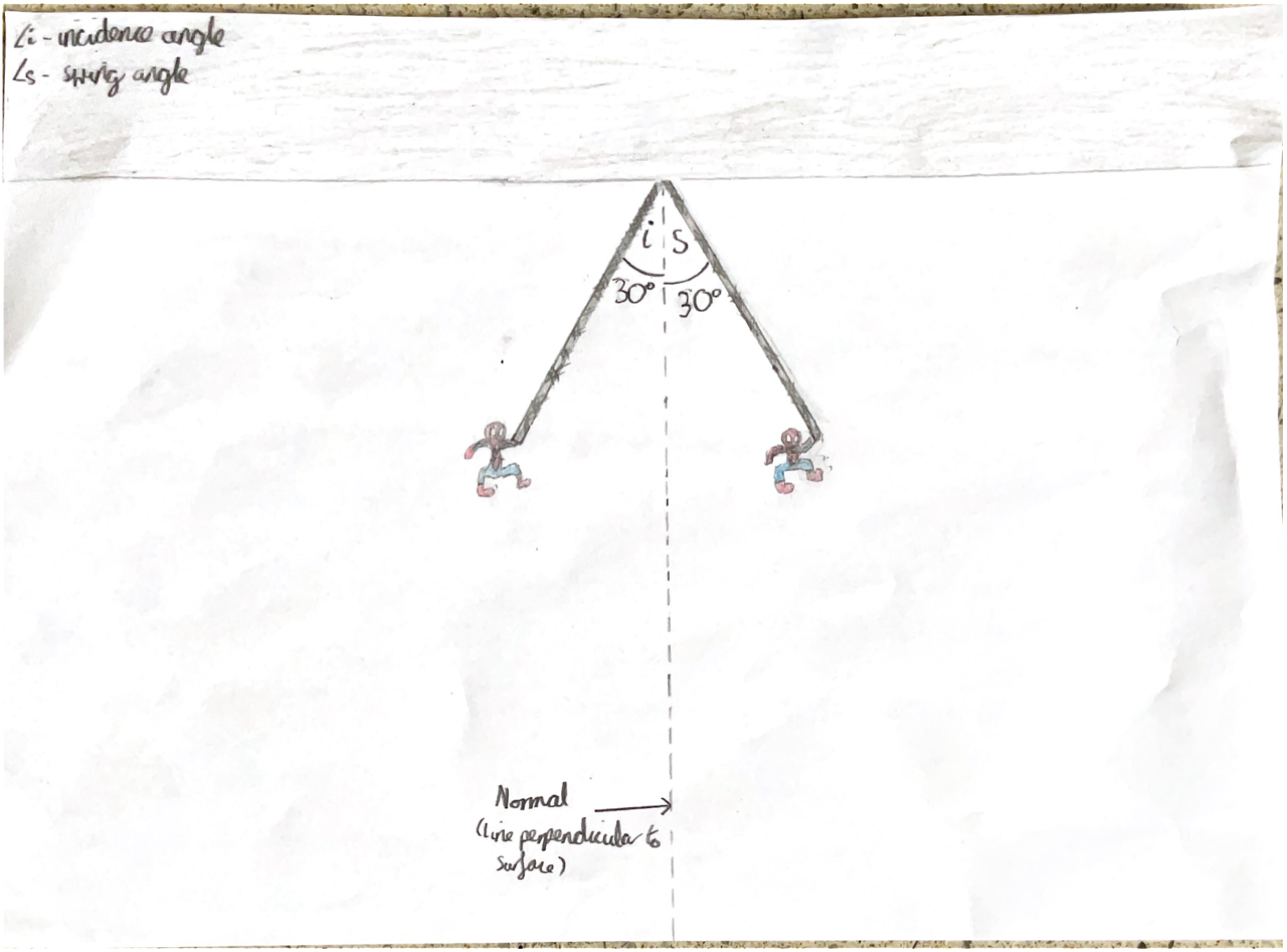
The Maths of Spider-Man's Web-Swinging

I'm sure you've seen Spider-Man swinging from webs between buildings, but how much calculation actually goes through his mind as he does this? In this essay, I will be exploring the geometry that must go into Spider-Man's mind as he does this, and is there more than what really meets the eye?

The first factor that he must consider is the pendulum of his swinging, but, what exactly is a pendulum? Basically, it's like that thing on all those old clocks that swings from side to side. This helps Spider-Man as he must calculate the initial angle, pass directly under the anchor point (this is the lowest point) and then swing back up. But, it's not this simple. The initial angle is labelled 'i' on the diagram below, and, Spidey must calculate this angle, as this is always equal to the swing angle, labelled 's' on the diagram, so that he can swing up and move forward as he desires.

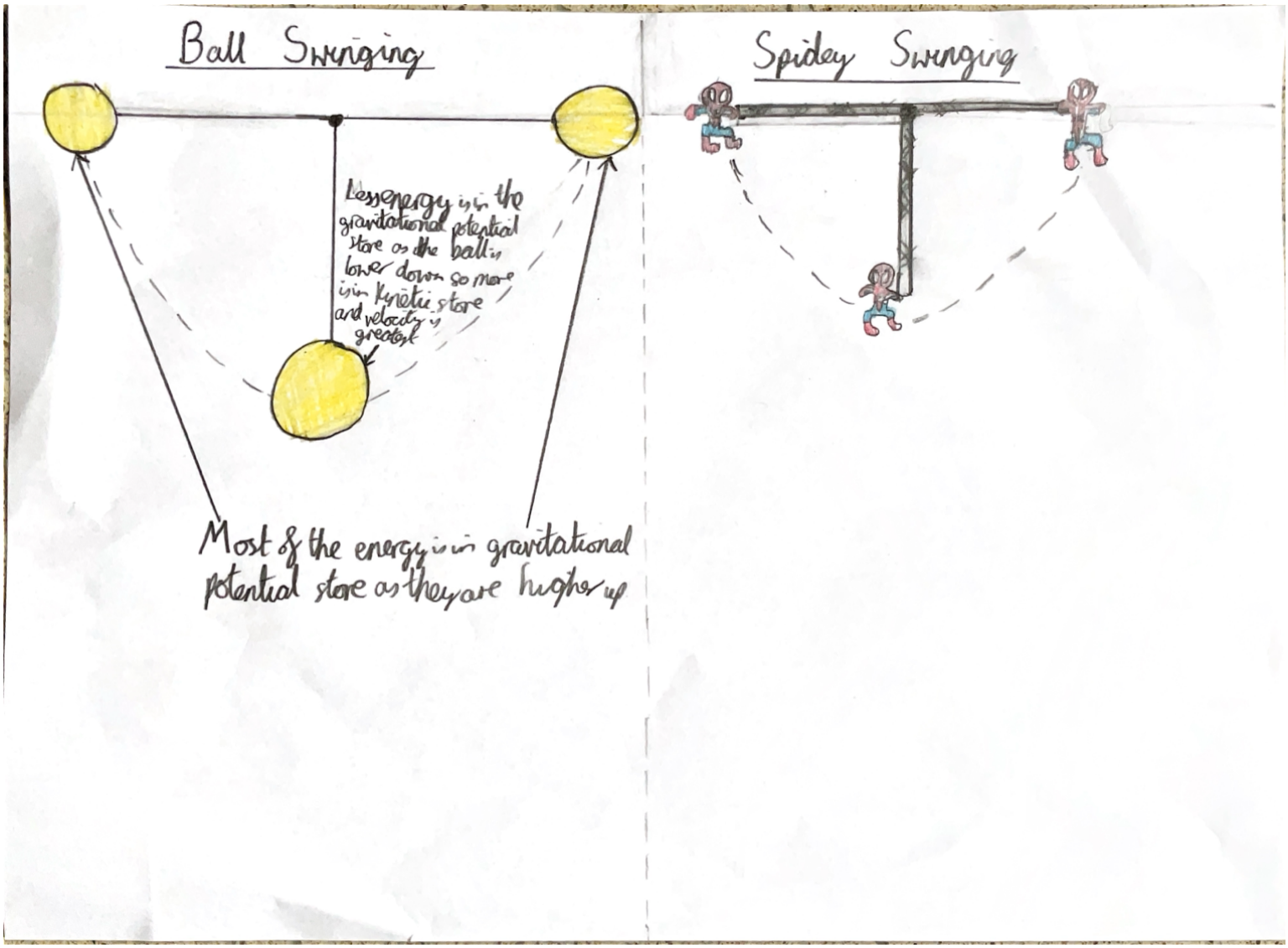


The second factor he ought to consider is when he must release his web to maintain the most momentum. Think of it like this - imagine swinging a ball on a rope. The ball doesn't just keep going forward and upwards forever, it eventually starts swinging backwards, in the opposite direction, and starts losing his forward momentum. This means that Spider-Man must know when to release his web so that he does not move backward to maintain the most momentum. Also, notice that, on the ball on a string it stops as it becomes horizontal at each side, meaning that Spidey would have to release before this to try and keep the momentum. Spider-Man would have to release himself at the lowest point (also known as 'equilibrium'), as this is where his momentum would be greatest. His momentum would be greatest here as momentum is equal to mass x velocity (velocity is just speed in a direction) and, as his mass remains constant, his momentum is greatest where his velocity is

greatest, which is at the equilibrium.

But, what exactly is the proof that Spidey's velocity is greatest here? Well, have you ever heard of the Principle of Conservation of Energy? Well, that's just a fancy way of saying that you can't make or get rid of energy. You may have also heard of different types of energy stores, and the main 2 that Spider-Man would need to consider are his kinetic store, and his gravitational potential store. To put it simply, imagine a ball bouncing. It moves upwards, briefly stops at the highest point, and then moves back down. This means that the energy in its kinetic store increases (as kinetic energy is basically movement energy) as they move upwards, and, as they get higher and higher more of this energy is transferred to its gravitational potential store. But, what exactly is the gravitational potential store? Basically, it's the energy that increases the higher up you go. So, this is why the ball slows down as it moves higher, as it's kinetic energy (movement energy) decreases, as it goes to its gravitational potential store, and, there is a brief moment when the ball stops at the top, as there is no more kinetic energy as it has gone to the gravitational potential store. But, the ball starts moving again back down as this gravitational potential energy goes back to its kinetic store.

But, how does all of this fit in with Spider-Man? Well, remember how I mentioned that he would need to release his web at the lowest point, as his velocity was greatest here. This is because, this is the point where there is the most kinetic energy, as, as it moves higher as it becomes horizontal, this kinetic energy decreases as its gravitational potential store will increase, and energy can't be created so this must come from the kinetic store Spider-Man, which decreases. This means that Spidey's kinetic energy is highest at the lowest point, so his velocity will be highest here.



Another factor that Spidey must consider is wind and air resistance. Remember that momentum that was so important to Spider-Man before? Well, if there was wind, as wind is a force in the opposite direction of his movement, his momentum would decrease in what is known as a damped pendulum motion, basically just meaning that the momentum is decreased compared to what it would be like with no wind resistance. This can have a negative impact on Spidey's swinging as this momentum is essential for him to keep moving forward. But, how could Spider-Man deal with this?
Well, remember gravitational potential energy from before (the one that increases with height)? Spidey could take advantage of his height, with a high gravitational potential store, and use it to dive downwards. This would cause him to increase his kinetic store (as his gravitational potential store decreases) causing him to move faster and accelerate, and, as momentum is equal to mass x velocity, he could increase his velocity, and then increase his momentum by doing so.

The final factor that would help Spider-Man is his turning moment. A turning moment is what causes something to rotate, and is equal to force x distance. For example, have you ever noticed that longer spanners are more useful than shorter ones, and make loosening bolts much easier. This is because, by increasing the length of the spanner, this would increase the distance, and would then increase the turning moment. So, for Spider-Man, he would want to increase his turning moment, as he swings and rotates about a point. This means that he would need to shoot longer webs to buildings further away, to maximise his turning moment by increasing distance.

So, there is loads of maths that Spidey has to consider as he swings through the streets of New York every day, and he's got to fight so many villains on top of that! It really does make you wonder, why doesn't he just take the bus?