

# Spider-Man “Newton’s Laws”

1. What bit Peter Parker, to give him a plethora of formidable spider-like superpowers?
2. At a pivotal point in the early part of the movie, even though he could have prevented it, Parker allows a criminal to escape from justice. Ironically this leads to the murder of somebody. Who was this somebody?
3. Who has Parker been secretly in love with?
4. Who is Harry?
5. Who was Harry dating?
6. What was Norman Osborne’s profession?
7. Who was the real Green Goblin?
8. In scene 8, Spider Man is still only mild-mannered Peter Parker, just discovering his powers. After accidentally knocking some food on the school bully, Flash, Spider-Man is forced to defend himself from being beaten up. At this moment we get a glimpse into the “Zen of the Spider” as Peter Parker’s awareness goes into overdrive. He easily evades Flash’s attacks, and in a very satisfying turnabout he punches the frustrated Flash so hard he knocks him across the room with his feet flying out from underneath him? You can see in the scene that Flash’s trajectory is essentially straight for about five to eight feet before he falls to the ground and slides several more feet. This basic scenario is repeated in a more extreme case later in the movie, at the “Unity Day Festival”, when the Green Goblin kicks Spider-Man so hard he is projected at least 50 meters in a straight line before finally coming to a stop when he smashes into a metal post.
  - a. We know that from the instant a projectile is launched, it has a downward acceleration equal to  $9.8 \text{ m/s}^2$ . Therefore, it is clear that anybody or anything that is launched will accelerate towards the ground and eventually hit it. The faster something is moving horizontally, the less far the object will fall as it moves a particular vertical distance. Maybe the guys taking the punches, (the punchees), in all of these scenes are punched so hard and are moving so fast that they just don’t fall far enough downward for us to notice. In the “Unity Day Festival” scene, it takes Spider-Man about 3 seconds to fly into the light post. Calculate how far he should of fell in this time: (Use  $(Y-Y')=V_y't + (1/2)at^2$  where  $V_y' = 0 \text{ m/s}$ ;  $a = -9.8\text{m/s}^2$ )

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- b. Based on the fact that Spider-Man flies horizontally for 50 meters in about 3 seconds, what was his horizontal velocity. Use:  $V_x = d/t$

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- c. Newton's third law of motion tells us that when an object (such as the puncher's fist) exerts a force on another object (such as the punchee's face), the other object will exert an equal force back. In the "Unity Day Festival" scene, the impact time of a punch is somewhere in the neighborhood of 0.1 second. Calculate Spidey's acceleration: Use  $a = (V_x - V_x')/t$
  - d. Calculate the force of the punch: Use  $F_{net} = F_{punch} = ma$   
(Assume that  $m = 75 \text{ kg}$  for a average sized person)
  - e. This force must be equal to the force that Spider-Man exerts back on the Green Goblin as a reaction. How will this force affect him? (Hint: Goblin's mass is pretty close to that of Spider-Man)
  - f. How would their accelerations compare? (Hint: It does not matter how strong he is and there are no other forces to anchor him, except for static friction on the ground).
9. Spider-Man has netted a 75 kg criminal in the act of attempting a bank heist and is dragging him along the ground with his web. The pulling force = 250 N, and there is a 100 N friction force on the ground opposing the motion. Draw a "free-body diagram" showing the forces that are acting on the criminal, and determine his acceleration.

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- a. What is the net force?
  - b. What is the acceleration? Hint:  $F = ma$
10. The Green Goblin has pulled off a bank job, and he accelerates upward on his nifty glider at a rate of  $4 \text{ m/s}^2$ , hauling a 30 kg sack of unmarked twenties with a rope. If the rope can withstand a maximum tension of 400 N, will it be strong enough to hold the sack? (Hint:  $F_{net} = ma$ ;  $Weight = mg$ ;  $g = 9.8 \text{ m/s}^2$ ; and  $F_{net} = F_{rope} - Weight$ )

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11. Spidey is presumably able to scale walls because those little hairs on his fingertips give him a better grip on the brick than normal fingers would.
- a. His costume covers him completely, do you think this might be a problem with scaling walls.
  - b. In the "bully scene", make approximate count of his fingertip hairs. (I'll say 300 for each finger tip). Check on this.

- c. Since he has ten fingers, how many hairs total for both hands. (Note: At the very minimum, these hairs must be able to support Spider-Man's weight. Remember, he'll need a little extra force to accelerate himself upwards)
- d. Assume Spider-Man has a mass of about 75 kg, then calculate the overall hair force. (Hint:  $F_{\text{hairs}} = \text{weight} = mg$ )
- e. With your estimated number of hair, calculate the force for each hair.
- f. Is this reasonable for one hair to hold up? Remember that 1 N = weight of an average apple.
12. Spider-Man is a very good jumper. If we look at the jumping scene and compare Spider-Man's launch velocity to the horizontal distance he covers, it looks like he can jump at least 50 feet (18m) horizontally (almost twice as far as the long jump world record), and his initial angle of launch looks to be pretty close to 45 degrees.
- a. Calculate his velocity of launch:  
 Use  $Y - Y' = V_y t + (1/2)at^2$  where  $Y - Y' = 0$ ; and  $V_y = V' \sin 45$ ; and  $a = -9.8 \text{ m/s}^2$   
 Solving for t:  
 Gets:  $t = (V' \sin 45) / 4.9 \text{ m/s}^2 = (0.707 V') / 4.9 \text{ m/s}^2$   
 Horizontally:  $(X - X') = V_x t = V' \cos 45 (0.707 V') / 4.9 = 18 \text{ m}$   
 or  $18 = (V')^2 (\cos 45)(0.707) / 4.9$   
 Solve for  $V'$
- b. Solve for  $V_y'$ : (Note:  $\sin 45 = V_y' / V'$ )
- c. Find his weight: (Weight = mg; where  $g = 9.8 \text{ m/s}^2$  and  $m = 75 \text{ kg}$ )
- d. Find the force (F) that depends on the time of contact his foot has with the ground during his leap. (Use:  $F_{\text{net}} = F - \text{Weight} = ma$ )  
 (Note:  $a = V_y' / t$ ; where  $t = 0.25 \text{ sec}$ )
- e. If 4.45 N = 1 lb; then how many lbs. would part (d) be:
- f. Is this realistic for one leg?
- g. There is no force in the horizontal direction. Therefore, there is no acceleration and his initial horizontal velocity will remain the same throughout the entire jump.  
 Calculate his  $V_x$ : (Use  $V_x = V' \cos 45$ )
- h. The last element of this scene that we need to address involves Spider-Man sticking a tricky landing. He apparently lands within 2-3 feet from the edge of the building.  
 Calculate his deceleration: (Use:  $(V^2 - V_x^2) = 2 a (X - X')$ )  
 (Note:  $V = 0 \text{ m/s}$ ; and  $(X - X') = 3 \text{ feet} = 1 \text{ m}$ )
- i. Calculate the force needed to stop during the deceleration of part (h).  
 (Use:  $F = ma$ )
- j. This is the amount of the kinetic friction force necessary to bring Spider-Man to a stop:  $f = (\text{coefficient of friction})(\text{Normal Force})$ . Since this incident occurs on a level

horizontal surface then the Normal Force equals the Weight. From this information, and the force calculated in part (i), calculate the coefficient of friction.

- k. The coefficient of friction for rubber and smooth cement is about 0.6. Does your answer in part (j) agree to 0.6.
  - l. However, since the friction force acts at the soles of his feet, what would happen to the inertia of the upper half of his body? What would Spidey do?
13. In one of the last scenes of the movie, the Green Goblin is holding MJ in one hand and a cable car in the other, with both suspended over a precipice. He's being extremely mean and intimidating, but whether or not he can hold everything depends not so much on his attitude and how strong he is.
- a. Draw a free body diagram of the forces on the Green Goblin: (Note: There are 4 forces on the Green Goblin and MJ. Assume  $M_{total} = M_{gg} + M_{mj} = 100 \text{ kg} + 55 \text{ kg}$

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- b. From your force diagram, we see that there is a horizontal force acting on the Green Goblin due to the cable car that he holds. The cable is connected to the cable car over a pulley, and the tension force that the cable exerts on the car is essentially the same as the force that the cable exerts on the Goblin. How big is the tension force acting from the cable? (Use  $F_t = mg$ ; where  $m = 2000 \text{ kg}$  and  $g = 9.8 \text{ m/s}^2$ )
- c. What is the only opposing horizontal force to the tension force calculated in part (b).
- d. Does this opposing force matter how strong he is?
- e. What is the weight for both the Green Goblin and MJ?  
Use:  $\text{Weight} = M_{total} g$
- f. If this opposing force is friction, then the formula we use is:  
(static friction) = (coefficient of friction) (Normal Force)  
Since they are standing on a level horizontal surface then the Normal Force equals the weight. Using the maximum coefficient of friction of 1, calculate the static friction that will oppose the tensional force of the cable car.

- g. How many more times is the force tension from the static friction.
  - h. The system, (the cable car, the Green Goblin, and MJ), must accelerate together over the edge. Calculate their acceleration: (Use  $F_{total} = F_t - \text{friction} = (M_{total}) a$ )
  - i. How does calculated acceleration compare with freefall acceleration?
14. In this last scene of the movie, the Green Goblin releases MJ and the cable car. Spider Man is able to catch both and stop their fall while hanging from a strand of web. How strong does the web have to be to support the weight?
15. In the same scene as #13 & #14, MJ falls out of Spider-Man's grasp but is able to catch herself by barely grabbing a ledge with her fingers as she falls past it.
- a. Is this possible?
  - b. MJ appears to have dropped a distance of 30-40 feet, (10-13 m), before catching herself. How fast was she going? (Assume that all bodies will 5 meters in 1 second) (Remember:  $g = 9.8 \text{ m/s}^2$  and  $9.2 \text{ m/s} = 20 \text{ mph}$ )
  - c. How much force will be exerted on MJ's fingers in bringing her to a stop? (Use  $F = m ((V-V')/t)$  where  $V = 0 \text{ m/s}$  ;  $m = 55 \text{ kg}$ ; and  $t = 1.1 \text{ sec}$ )
16. When Spider-Man first learns to use his web he swings off of the top of a building and into a solid wall.
- a. His potential energy ( $mgh$ ) turns to kinetic energy ( $(1/2)mV^2$ ). Estimate his velocity just before his impact.
  - b. Estimate his force of impact: (Use  $F = m ((V-V')/t)$  where  $V = 0 \text{ m/s}$  ;  $m = 75 \text{ kg}$ ; and  $t = 0.25 \text{ sec}$ )
17. In the movie, Spider-Man finds that he can shoot strands of spider web from his wrists. These web strands adhere instantly to objects like tall buildings, and enable Spider-Man to swing Tarzan-like while traveling great distance at fairly high speeds. Unfortunately, the web strands would also require a great deal of matter that seems to come from nowhere.
- a. A web strand would probably need to be at least 0.005 meters is diameter to support Spider-Man's web-swinging antics. If such a strand were 100 meters long, what would the volume of this cylinder? (Use Volume of Cylinder =  $(3.14) r^2 (\text{length})$ )
  - b. How does this volume compare with Spider-Man's estimated volume of  $0.07 \text{ m}^3$ .
  - c. If the web volume was manufactured from his volume, then what percentage would be taken away every time Spider-Man shot a 100 meter strand.
  - d. What if Spider-Man needs to shoot a mere mile of this stuff to travel downtown. What percentage of his body volume would he use up. (Note 1 mile = 1600 meters)
  - e. Assuming that the volume of web-producing chemicals stored in Spidey equals the volume of web produced. This volume would need to come from energy converting to mass and volume. Where does the energy come from?