The Spider and the Van de Graaff Generators

Take the point directly at the midpoint of the two spheres as the origin, and describe the vertical direction with the “y” co-ordinate and the horizontal direction with the “x” co-ordinate. A spider who was working at the proton factory didn’t clean himself properly, and accidently left work with an extra $6.25 \times 10^{10}$ protons sticking to his back. He then decided to take a shortcut home, which involved descending between two powerful Van de Graaff generators. These generators each create a charge of $40.0 \mu$C on two perfectly conducting spheres whose centers are 1.00 m apart. The spider (with protons) has a mass of 3.00 g, and is initially 80 cm above the origin. At $t = 0$ he cuts his silk, and descends directly downward under the force of gravity. For this problem, you may treat the conducting spheres as point charges.

1. What is the initial charge that the spider is carrying? (3 pts)

2. Given an expression for the electrostatic potential due only to the two spheres at any point $P$ (outside the spheres) as a function of that point’s location vector $\vec{r}$ from the origin — the only variable in your answer should be $\vec{r}$. (5 pts)
3. Give an expression for the electrostatic force the spider would feel due to the spheres everywhere along the $y$-axis (as a function of $y$). (5 pts)

4. Where along the vertical line describing the spider’s (attempted) trajectory will the electrostatic force in the upward direction be at a maximum? *Hint: When a function is at a maximum, its derivative vanishes.* (5 pts)

5. Will the spider make it past the Van de Graaff generators by taking this shortcut? Why or why not? *Hint: Think about the total potential energy — gravitational and electrostatic combined.* (2 pts)