

**QUALITATIVE QUESTIONS**

Observe the motion of the cars as they are pulled to the top of the tower and dropped. The labeled points in the diagram are X at the top, Y at the point braking begins when going down, and Z at the bottom.

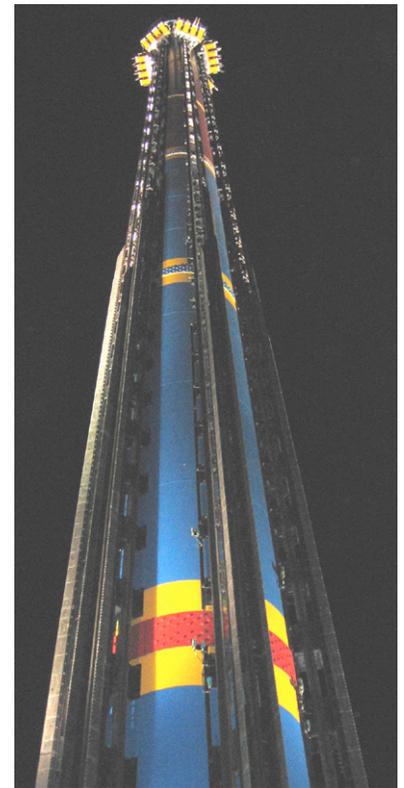
1. At which of the following points is the ride's:

- speed the greatest? \_\_\_\_\_
- gravitational energy the greatest? \_\_\_\_\_
- gravitational energy the least? \_\_\_\_\_
- kinetic energy the greatest? \_\_\_\_\_

2. During which lettered section is the ride's:

- acceleration the greatest? \_\_\_\_\_
- normal force greater than the gravitational force on a rider? \_\_\_\_\_
- gravitational force greater than the normal force on a rider? \_\_\_\_\_

3. A foam ball has been attached to the restraint. Hold the ball in your hand as the car rises. When the ride falls, release the ball in front of you. Describe the behavior of the ball as you fall.

**SUPERMAN**

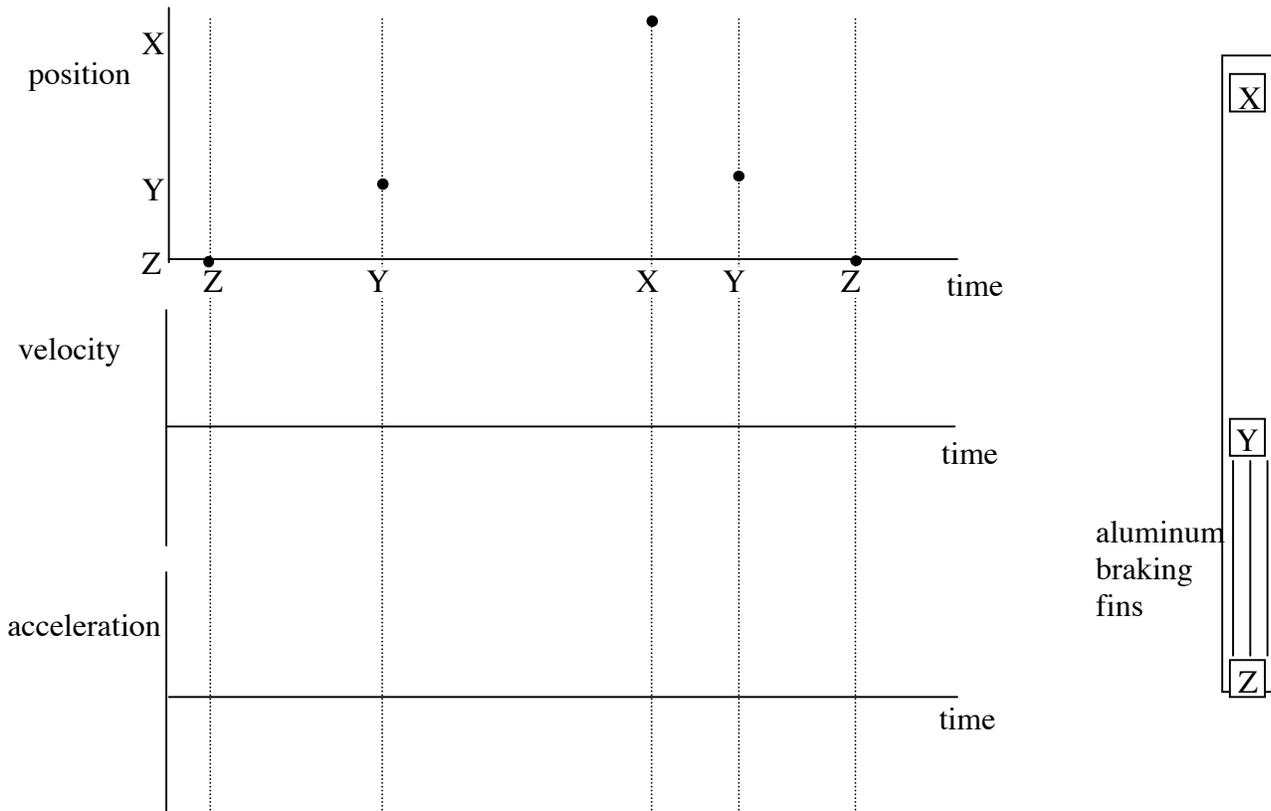
Tower of Power

The braking system on Superman is passive and requires no friction or input of power. Long aluminum fins are attached to the lower portion of the tower. The back of each car has very strong magnets that straddle the aluminum fins and stop the falling car.

4. Carefully observe the motion of the car on the way up. Does the velocity increase, decrease, or stay the same when the car leaves the aluminum fin region of the tower? What would account for this change?

# Superman

5. Sketch qualitative position-time, velocity-time, and acceleration-time graphs for one complete cycle of the ride. The letters indicate the times the ride reaches the indicated positions. Treat upward as the positive direction.



6. Draw qualitative force diagrams for a rider at each of the points indicated.

The figure shows a vertical rectangular diagram of a roller coaster car on the left, with points X, Y, and Z marked. To its right is a table with six columns, each representing a different stage of the ride. The text 'aluminum braking fins' is written to the left of the car diagram.

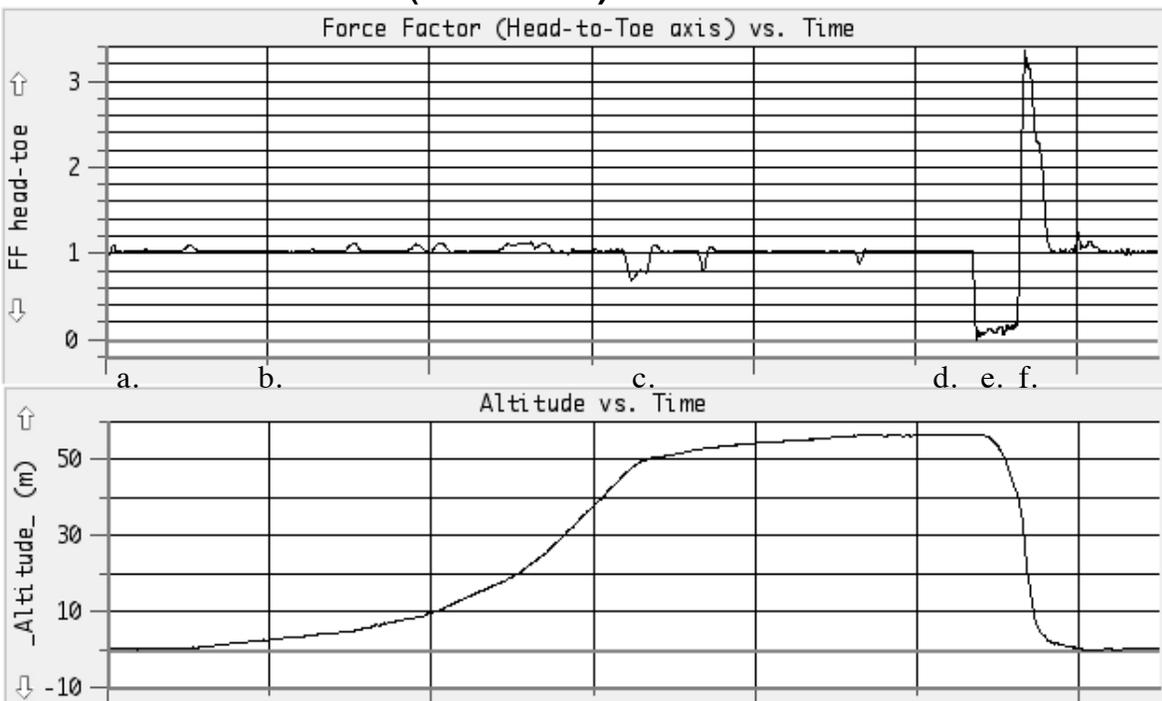
<p>point Z <math>v=0\text{m/s}</math></p>	<p>point B getting faster moving up.</p>	<p>point A constant speed up</p>	<p>getting slower moving up to pt. X</p>	<p>A falling down</p>	<p>point B getting slower moving down</p>
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**QUANTITATIVE QUESTIONS****Kinematics Analysis:**

1. Use the graph on the next page to find the maximum height the car reaches.
2. Find the height of the car when braking begins. (Use the graph on the following page.)
3. Determine the distance the car falls before braking.
4. With a stopwatch, measure the time the car falls freely before braking.
5. Based on your measurements, calculate the acceleration of the riders while falling.
6. Calculate the velocity of the car at the moment braking begins.
7. With a stopwatch, measure the time from the moment braking begins to the time the car stops at the bottom.
8. Calculate the average acceleration while braking.
9. Is the acceleration while braking uniform? How do you know?



QUANTITATIVE QUESTIONS (continued)



**Force Analysis:**

10. Using the Force Factor vs. time graph, draw quantitative force diagrams showing the magnitude of all forces acting on a 70 kg rider at each of the indicated points. You can use  $g=10 \text{ N/kg}$ . (The head-to-toe Force Factor is the ratio of the head-to-toe normal force to the gravitational force. In other words, the head-to-toe Force Factor times the gravitational force equals the head-to-toe normal force.)

a. Force diagram for a 70 kg rider,  $v=0$ , at point a.

b. Force diagram for a 70 kg rider ascending with constant velocity at point b.

c. Force diagram for a 70 kg rider slowing while ascending at point c.

Name:

Partner:

Teacher:

**Superman**

**QUANTITATIVE**

**QUESTIONS (continued)**

d. Force diagram for a 70 kg rider waiting to drop at point d.

e. Force diagram for a 70 kg rider falling at point e.

f. Force diagram for a 70 kg rider at the point of maximum braking, point f.

11. Use Newton's second law and your force diagram above to calculate the rider's acceleration just after being dropped from the top.
12. Use Newton's second law and your force diagram above to calculate the rider's acceleration at the point of maximum braking.

**Energy Analysis**

For the purposes of the questions that follow, let us estimate that the mass of the car carrying four riders is 700 kg.

13. Calculate the gravitational potential energy of the car and riders at the top of the ride relative to the ground.
14. Explain why the energy supplied by the ride to lift the car to the top is greater than the gravitational energy of the car at the top.

## Superman

15. Calculate the maximum kinetic energy of the car.
16. Calculate the gravitational energy of the car relative to the ground at the moment braking begins.
17. Use your previous calculations to find the total energy of the car at the top and when braking begins.  
How should these values compare?

Total Energy at top \_\_\_\_\_ Total Energy as braking begins \_\_\_\_\_

18. What ultimately happens to all of the energy of the system?