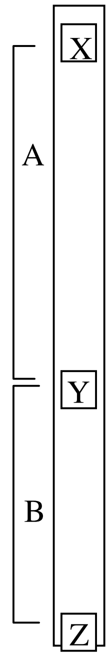
QUALITATIVE QUESTIONS



SUPERMAN
Tower of Power

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:

   a. speed the greatest? _____

   b. gravitational energy the greatest? _____

   c. gravitational energy the least? _____

   d. kinetic energy the greatest? _____

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

   a. acceleration the greatest? ______

   b. normal force greater than the gravitational force on a rider? ______

   c. gravitational force greater than the normal force on a rider? ______

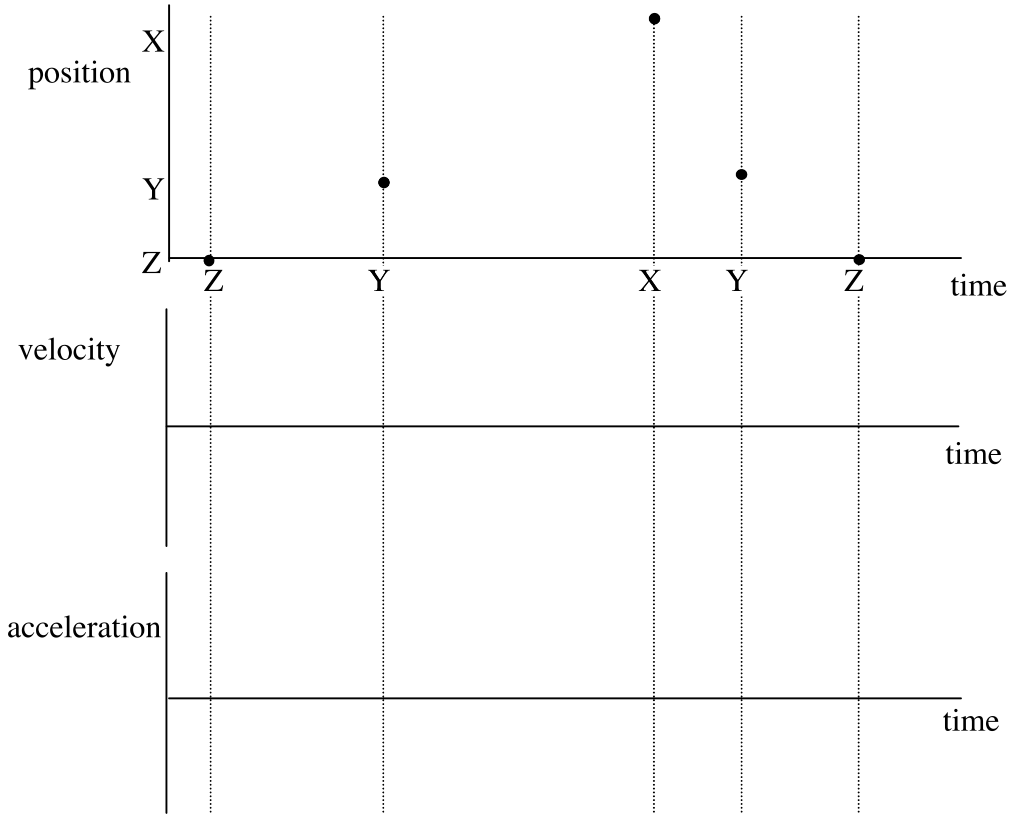
3. A foam ball has been attached to the restraint. Hold the ball in your hand as the car rises. When the ride falls, release the ball in front of you. Describe the behavior of the ball as you fall.

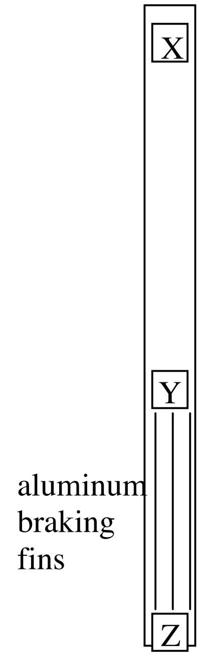
4. The braking system on Superman is passive and requires no friction or input of power. Long aluminum fins are attached to the lower portion of the tower. The back of each car has very strong magnets that straddle the aluminum fins and stop the falling car. How does this passive braking system work?

5. 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?

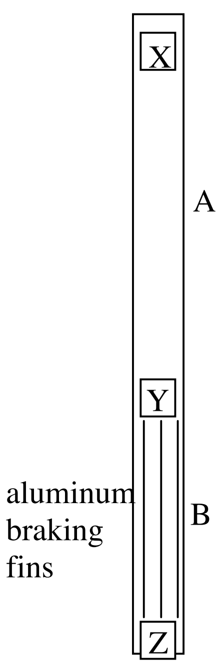
Superman

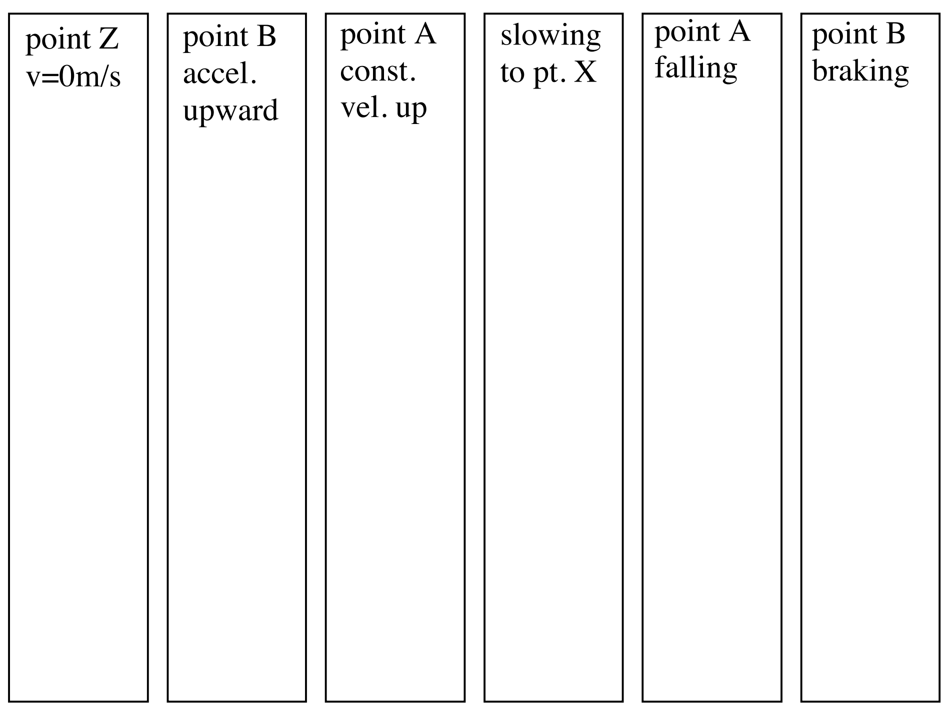
6. Sketch qualitative position-time, velocity-time, and accleration-time graphs for one complete cycle of the ride. The letters indicate the times the ride reaches the indicated positions. Treat upward as the positive direction.





7. Draw qualitative free body diagrams for a rider at each of the points indicated.





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.

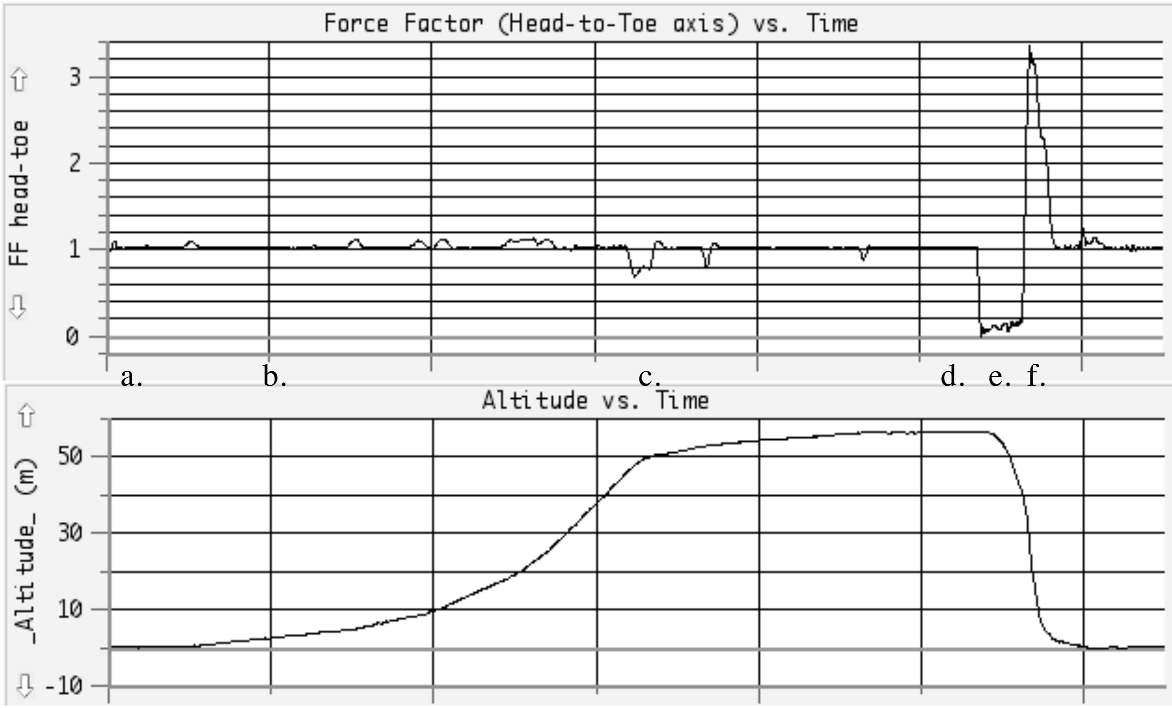
6. Calculate the velocity of the car at the moment braking begins.

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, quantitatively determine the magnitude of all forces acting on a 70 kg rider at each of the indicated points. (*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. Free body diagram for a 70 kg rider, v=0, at point a.

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

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

QUANTITATIVE QUESTIONS (continued)

d. Free body diagram for a 70 kg rider waiting to drop at point d.	e. Free body diagram for a 70 kg rider falling at point e.	f. Free body 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.

Impulse-Momentum Analysis

13. This is one of the few rides in amusement parks in which the average stopping force can be found by using the impulse-momentum theorem: $m\Delta v = F_{net}\Delta t$.
    a. Calculate the change in momentum of a 700 kg car and riders during braking.

    b. Calculate the average braking force on the car and riders. (Hint: The braking force is not the same as the net force.)

QUANTITATIVE QUESTIONS (continued)

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.

14. Calculate the gravitational potential energy of the car and riders at the top of the ride relative to the ground.

15. 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.

16. Calculate the maximum kinetic energy of the car.

17. Calculate the gravitational energy of the car relative to the ground at the moment braking begins.

18. 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 ______________

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