Name: Partner: Teacher:

Batman The Ride

QUALITATIVE QUESTIONS

1. In terms of forces, explain why Batman The Ride uses a long shallow first incline.

2. When you enter Batman The Ride, you walk the first 7.2 meters vertically to get on. What is the advantage to Six Flags St. Louis of having <u>you</u> do this?

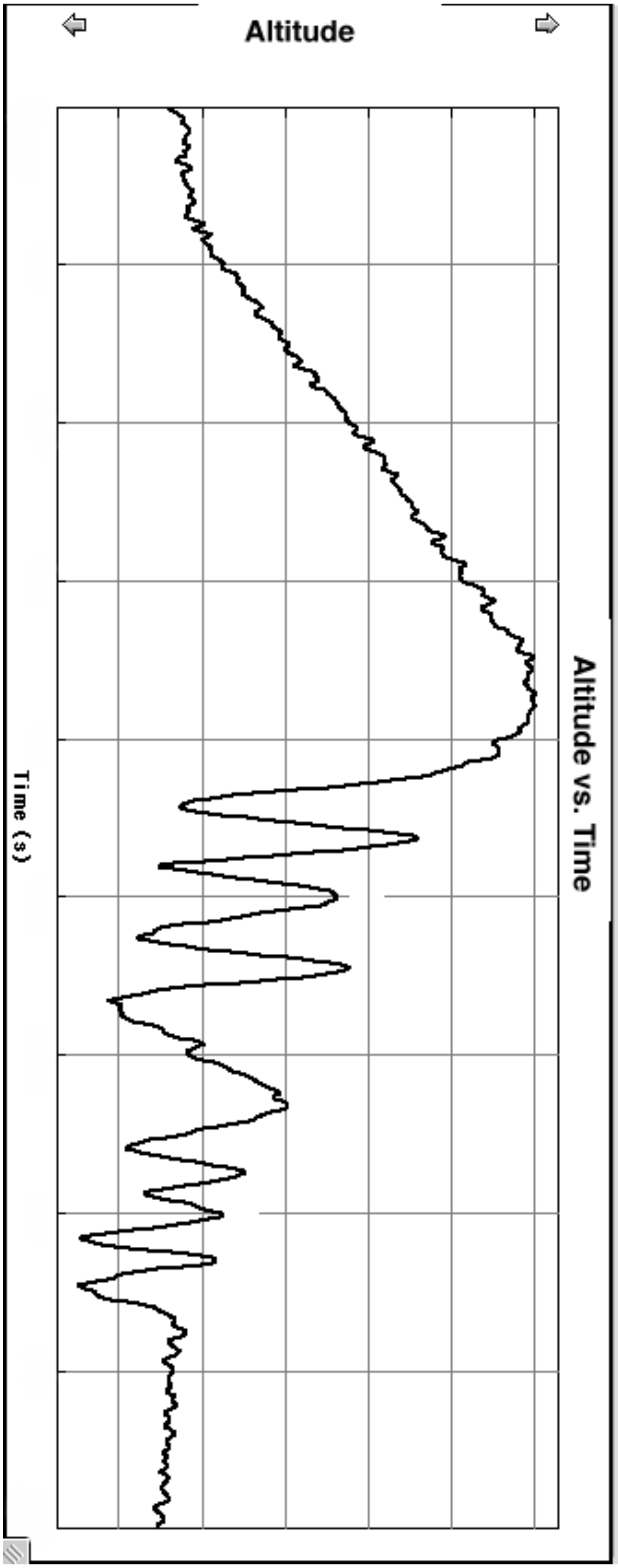
3. If the time to go uphill were shorter, what would happen to the power needed to move the train to the top of the first incline?

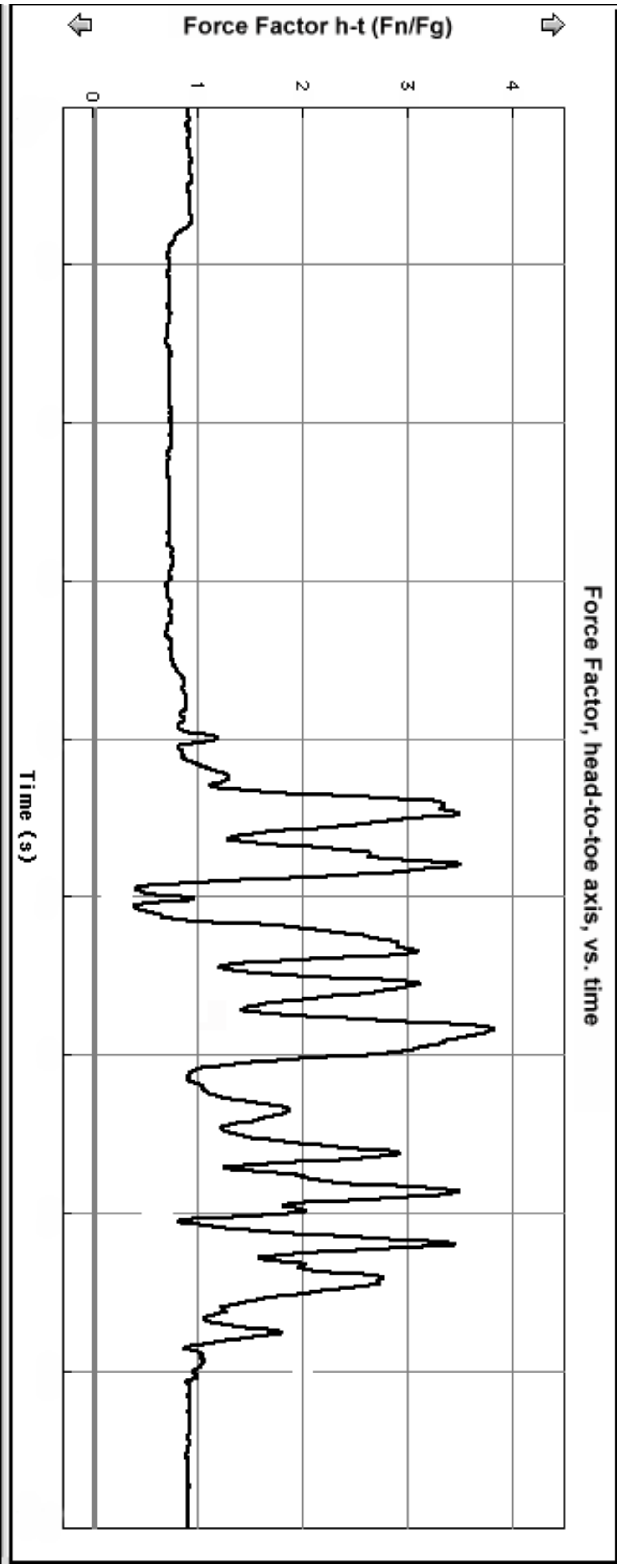
4. Why is the first hill of Batman The Ride the highest point on the ride?

5. Does each hill after the first hill have to be lower than the first hill? Explain.

QUALITATIVE QUESTIONS (continued)

The graphs below were made from data collected by carrying a Force Factor meter and an altimeter on the ride.

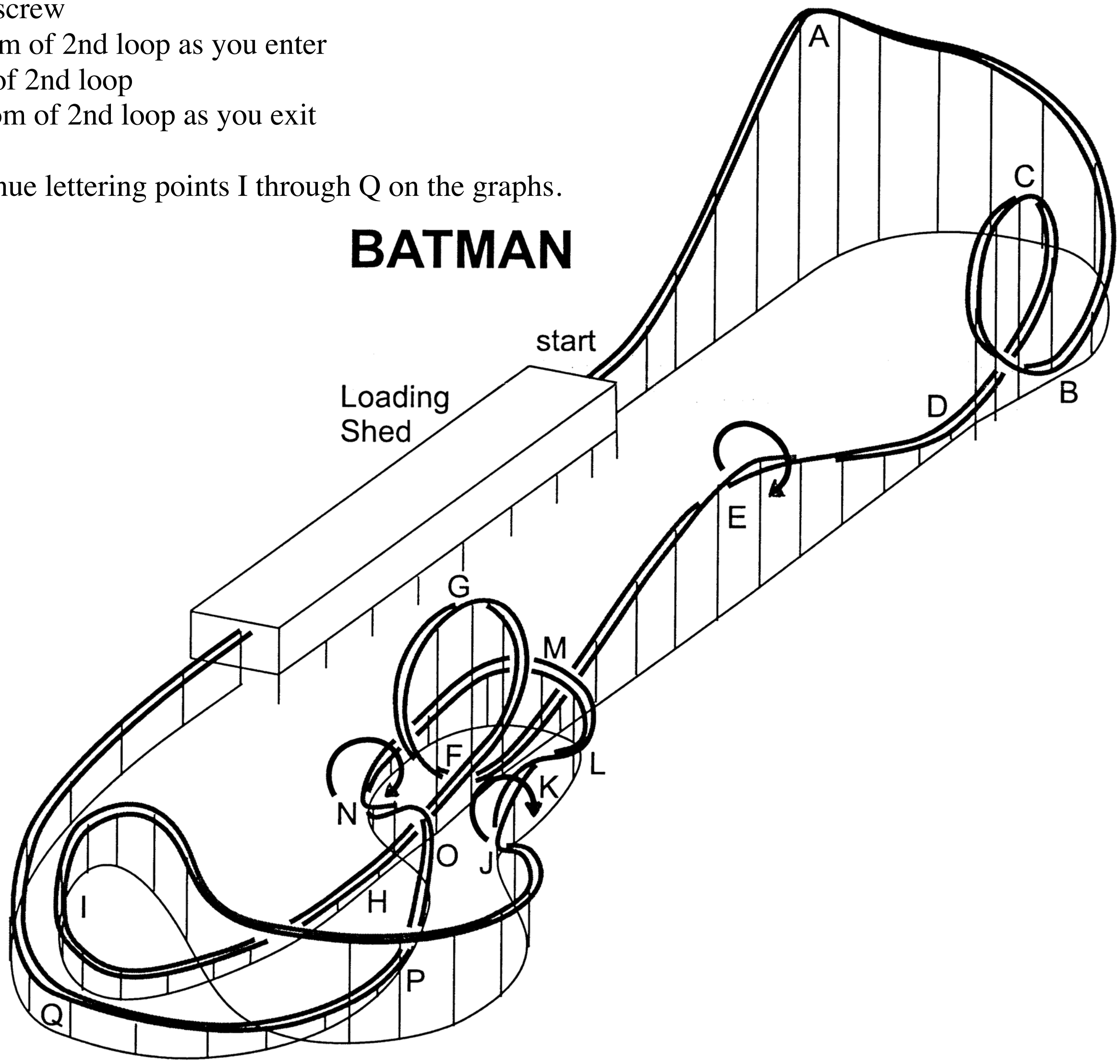




QUALITATIVE QUESTIONS (continued)

6. Label both graphs with the following positions along the ride.
   a. Top of incline
   b. Bottom of first drop
   c. Top of first loop
   d. Bottom of first loop as you exit
   e. Corkscrew
   f. Bottom of 2nd loop as you enter
   g. Top of 2nd loop
   h. Bottom of 2nd loop as you exit

   Continue lettering points I through Q on the graphs.



7. Justify your labeling choices for at least three of points A through H using only the data from the Force Factor vs. time graph.

QUALITATIVE QUESTIONS (continued)

8. At what point on Batman The Ride does the Force Factor meter give its maximum reading? Why is it a maximum at that point?

9. Find the portion of the Force Factor vs. time graph that corresponds to the first loop (Points B, C, and D).

   a. Does the sign of the reading change during any portion of the loop?

   b. Does the direction of the normal force change during the loop? Explain.

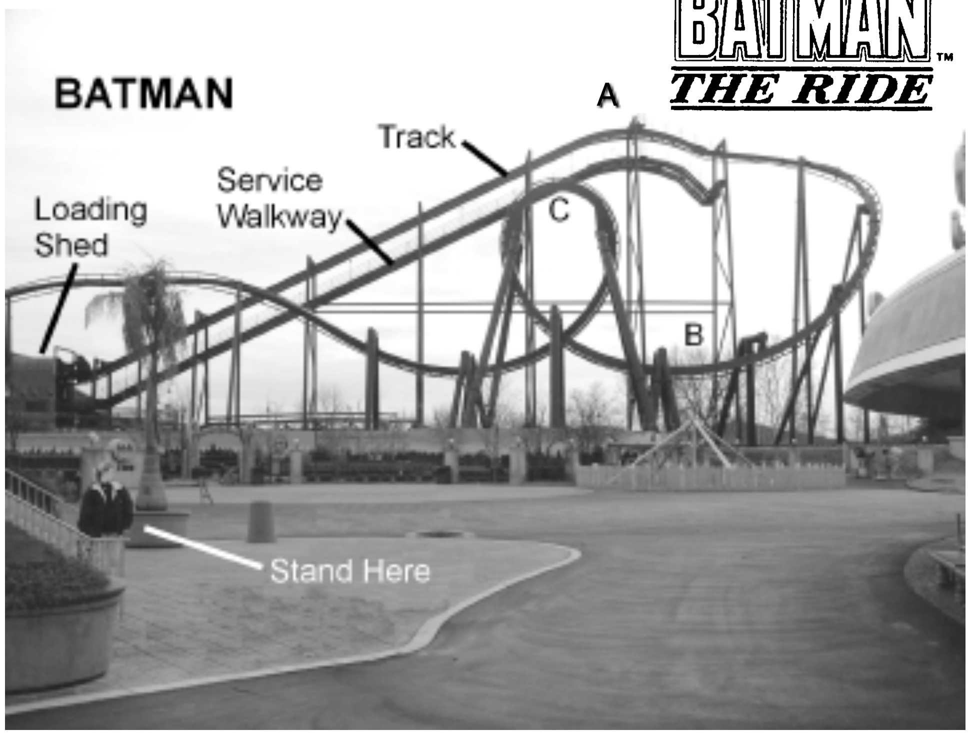
   c. What is the sign of the Force Factor when you are upside-down?

   d. What is the direction of the normal force at that point?

   e. Compare your answers for c and d and explain.

QUANTITATIVE QUESTIONS

For the questions that follow, refer to the photo below that shows the first incline, the first drop and the first loop of Batman The Ride. Point A in the diagram is at the top of the first incline after the train has been pulled to the top. Point B is at the bottom of the first drop as the train enters the first loop. Point C is at the highest point on the first loop.



1. Look across the plaza from the Batman entrance and you will see an iron railing that has steps at one end. It is 87 m from the end of the iron railing by the steps to the point on the ground directly below point A. It is 69 m, horizontally, from the railing to the place on the ground below both points B and C. Use these distances and your ability to measure angles to find:

   a. The vertical distance from the ground to the rider at position A. Note that at some positions the rider is above the track and below the track at other positions.

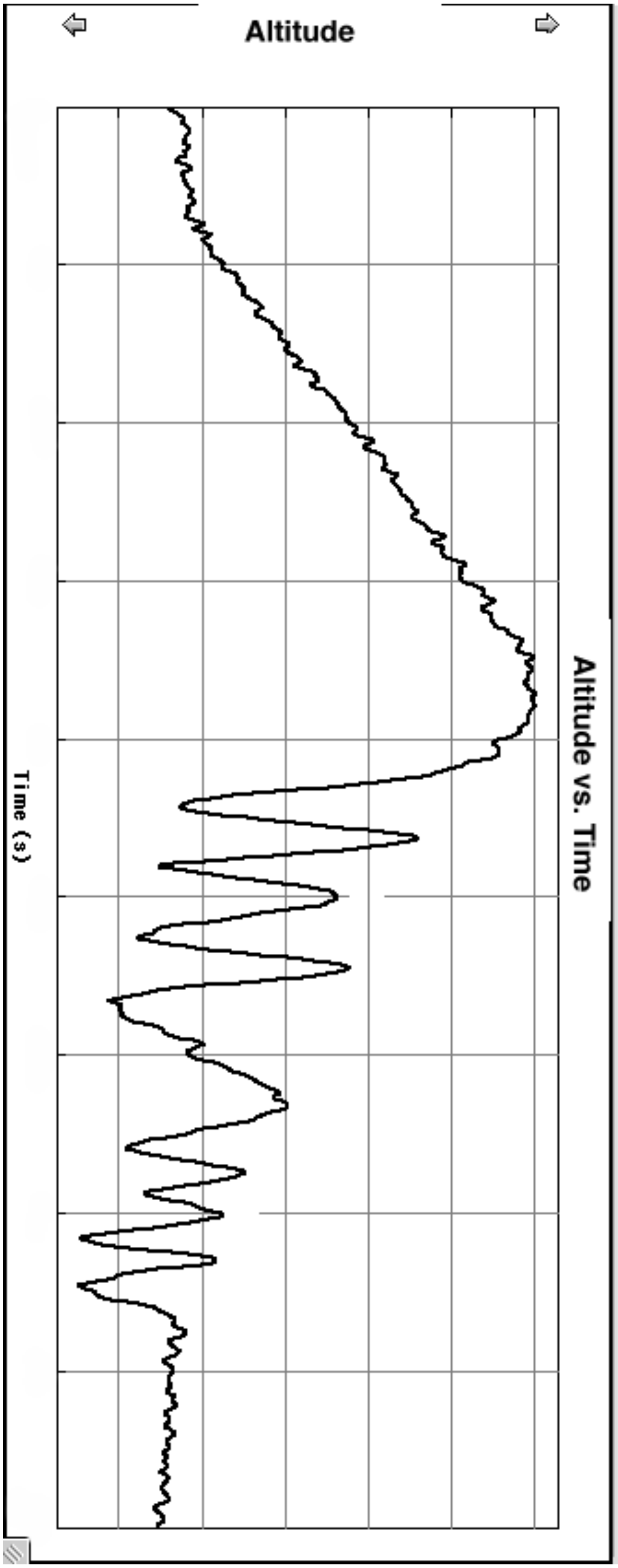
   b. The vertical distance from the ground to the rider at position B.

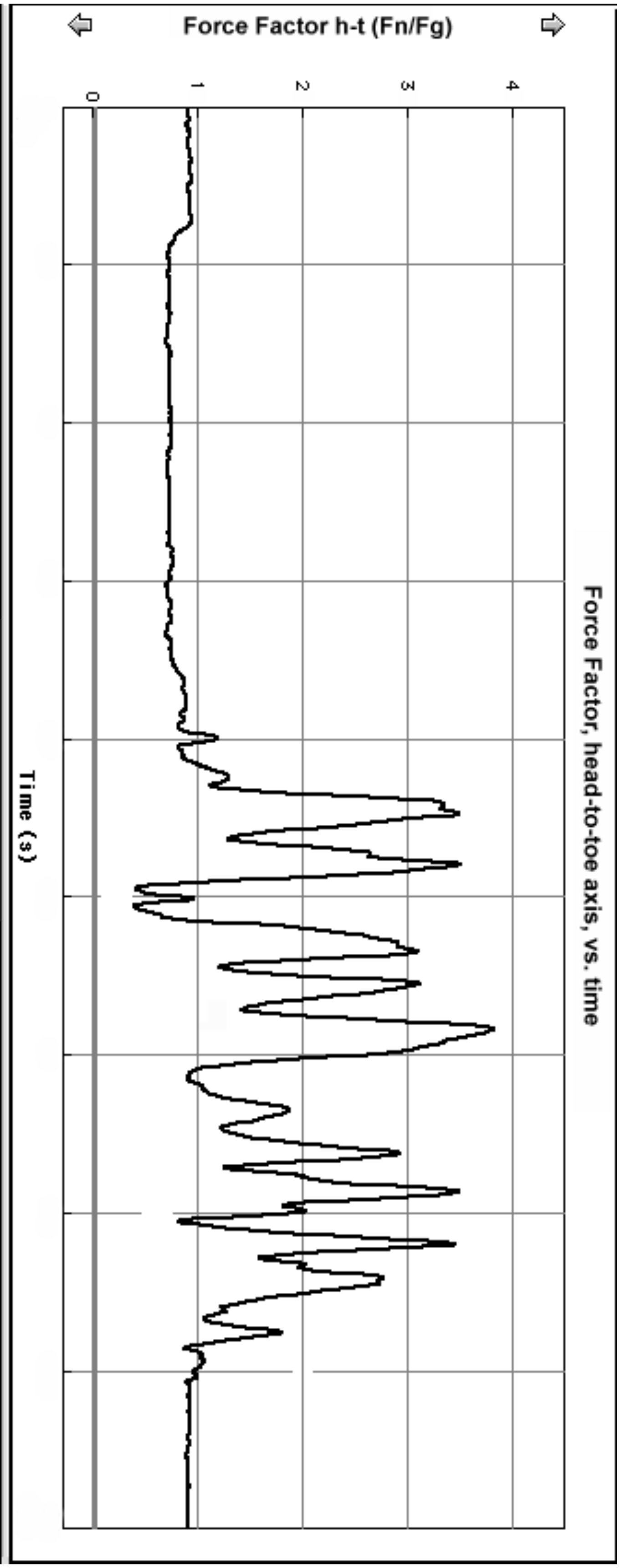
   c. The change in height from position A to position B.

   d. The vertical distance from the ground to the rider at position C.

Batman The Ride

The graphs below were made from data collected by carrying a Force Factor meter and an altimeter on the ride.





QUANTITATIVE QUESTIONS (continued)

2. **<u>Analysis of the train while being pulled from the station to the top of the first hill, point A.</u>**

a. Measure the time it takes for the train to be pulled from the station to the top of the incline (point A).

b. Measure the time for the train to pass any point on the incline.

c. Determine the speed of the train as it is lifted to the top of the incline. The train is 12.0 m long.

d. The mass of a fully loaded train is about 8,000 kg. How much kinetic energy does the train have at point A?

e. How much gravitational potential energy does the loaded train have at the top of the incline (point A)?

f. How much power was required to raise the train to the top of the incline at the speed you calculated? Remember that the train was at rest and 7.2 meters above the ground when it left the station.

3. **<u>Analysis of the train at the bottom of the first valley, point B.</u>**

a. Use conservation of energy to determine the speed of the train at the bottom of the first drop (point B) assuming no frictional losses.

b. Use the Force Factor vs. time graph to determine the **normal** force on a 60.0 kg person at the bottom of the first drop (point B).

QUANTITATIVE QUESTIONS (continued)

c. In the margin to the right, draw and label a quantitative free body diagram for a 60.0 kg rider at point B. What is the value of the **net** force on the rider?

d. Based on your answer to question part c, what is the **magnitude** of the acceleration of the 60.0 kg rider at point B?

e. What is the **direction** of the acceleration of the rider at the bottom of the drop (point B)?

f. Based on your answers to questions 3a and 3d, determine the radius of the rider's path at the bottom of the first drop (point B).

4. **Analysis of the motion of the train while upside down at the top of the loop, point C.**

a. The short crossbars that hold the track together are 1.0 m apart. The top half of the first loop is a circle. Find the circumference of the top half of the loop and calculate the radius of a rider's path as they go around the loop.

b. Explain why the radius calculated in 4a is intentionally different from the radius calculated in 3f.

c. Use conservation of energy to determine the speed of the train at the top of the first loop (point C). Assume no frictional losses.

QUANTITATIVE QUESTIONS (continued)

d. Use the length of the train and the time for the train to pass point C to determine the “actual” speed of train at the top of the first loop.

e. Compare the speed you predicted in part 4c with the speed calculated in 4d. Explain any differences.

5. **<u>Analysis of the forces on a rider while upside down at the top of the first loop, point C.</u>**

a. Using the “actual” speed of the rider and the radius at the top of the first loop, find the magnitude and direction of the **net** force on a 60.0 kg rider at point C.

b. In the margin to the right, draw and label a free body diagram for a rider at the top of the first loop.

c. Predict the force exerted **by the seat** on a 60.0 kg person at the top of the first loop.

d. Use the Force Factor vs. time graph to determine the <u>normal</u> force on a 60.0 kg person at the top of the first loop.

e. How should your forces for 5c and 5d compare? Explain any differences.

QUANTITATIVE QUESTIONS (continued)

f. Determine the magnitude of the acceleration of the rider at the top of the loop.

g. What is the direction of the acceleration of the rider at the top of the loop?

6. **Analysis of frictional effects.**

a. Calculate the total energy of the train at the top of the first loop using the "actual" speed calculated in question 4d. How does this energy compare to the energy at the top of the first incline? Explain any difference.

b. How much energy was dissipated due to friction between points A and C?

c. Using the fact that the crossbars are 1.0 m apart, determine the length of the track from point A to point C.

d. Calculate the average frictional force opposing the motion of the train from point A to point C.