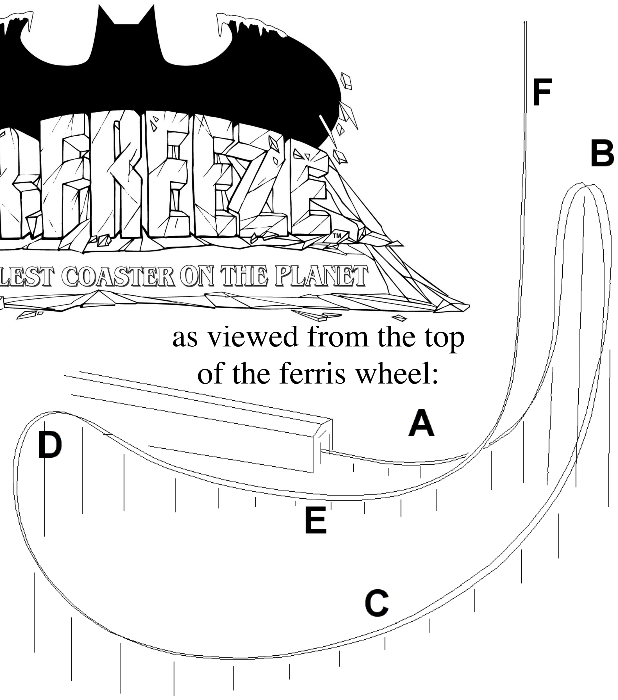
Name: Partner: Teacher:

Mr. Freeze

QUALITATIVE QUESTIONS

Many of the questions that follow refer to the graphs of data collected when riding Mr. Freeze with high tech data collection vests. With your I.D., you can borrow a vest without charge just before you get on the ride. The graphs will be printed for you as you return the vest and claim your I.D. at the exit of the ride.

as viewed from the top of the ferris wheel:



1. Label your printout of the altitude vs. time graph to correspond with the lettered sections in the diagram of the ride.

2. a. Make force diagrams for a rider as the train starts and stops.

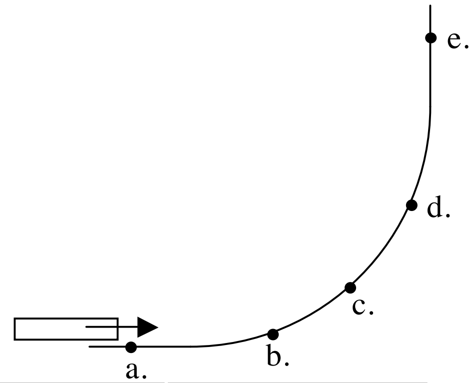
Starting – speeding up to the right   Stopping – slowing down to the left

b. The graph of Force Factor vs. time (front-to-back axis) shows that acceleration at the beginning and end of the ride are in the same direction. Why is this so? Show your answer with a motion map of the train starting and a diagram of the train stopping that show the directions of the velocity, acceleration, and net force.

Starting – speeding up to the right   Stopping – slowing down to the left

QUALITATIVE QUESTIONS (continued)

3. Immediately after the train comes out of the horizontal tunnel, it makes one-fourth of a circular turn until the train is moving vertically. The diagram shows five positions during the transition from horizontal to vertical motion. Draw and label a force diagram that includes each of the forces the rider experiences at each position.



a.	b.	c.	d.	e.
before entering the curve	entering the curve	halfway through the curve	exiting the curve	moving vertically after the curve

4. The net force at points b, c and d can be separated into radial and tangential components. how does the radial net force affects the rider's motion.

5. Explain how the tangential net force affects the rider's motion.

6a. At the peak of the loop, when you are upside down (Point B), the lap bar doesn't exert any force on you. Why do you stay in the train? Explain (Think about your body's orientation and the direction of your acceleration at B).

b. Under what circumstances might the lap bar be necessary at point B. Explain.

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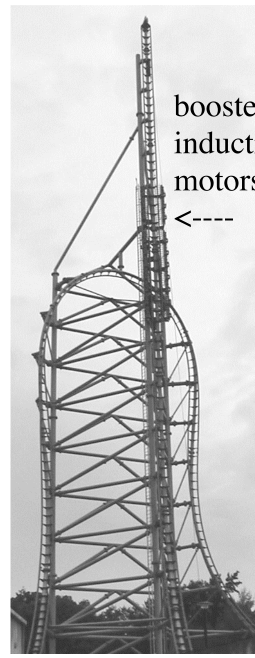
QUALITATIVE QUESTIONS (continued)

7. According to the graphs, during what lettered portion of the ride are you in free fall? What properties of the graph indicate free fall? Make sure to examine both of the Force Factor vs. time graphs.

8. The designers of this ride found it necessary to install booster motors that briefly push the train up while ascending the vertical section of the track, section F. (See the picture to the right.) Why do you think they did this?



QUALITATIVE QUESTIONS (continued)

9. Complete the table below. Use the graph of Force Factor (front to back axis) vs. time to find the Force Factor for each section indicated. Then indicate which of the following interactions is occurring for each portion of the ride.
   I. The seat is pushing up on you.
   II. The harness is pulling down on you.
   III. The seat and harness are exerting little or no force on you.

Portion of Ride	**Force Factor** (values from graph)	**Interaction** (I, II, or III)
a. During the boost on the way up.		
b. After the boost on the way up.		
c. When your velocity is zero at the top.		
d. On the way down (before you get to the curved part).		

11. Draw free-body diagrams for a passenger at the four positions in the previous question.

a. During the boost on the way up.	b. After the boost on the way up.	c. When your velocity is zero at the top.	d. On the way down.

12 a. Determine the time to go from C to E forward and the time to go from E to C backward.

b. Explain why the times are different.

QUALITATIVE QUESTIONS (continued)

13 a. What are the Force Factor values along the head to toe axis for valley E before the vertical section F (while moving forward) and after the vertical section F (while moving backward).

b. Draw force diagrams for the rider at valley E for each of the two times you are at that position (forward and backward). Explain why the Force Factor readings are different in these two instances.

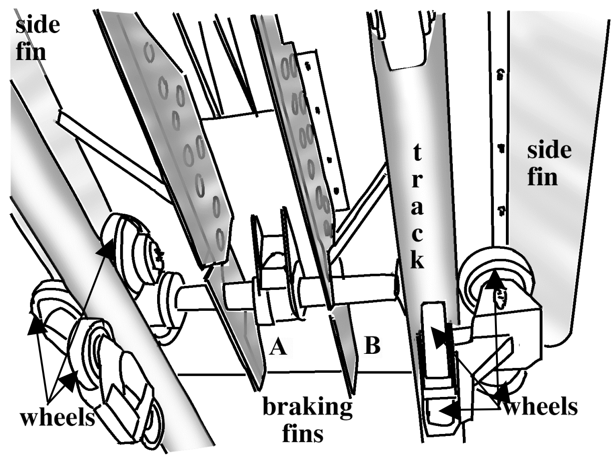
How Mr. Freeze Starts and Stops

To accelerate the Mr. Freeze train, the side fins of the train car (top diagram) fit into the slot in the linear induction motors (bottom diagram) that line both sides of the track. The linear induction motors are electromagnets that induce electric currents in the aluminum side fins of the train. The currents in the side fins produce opposing magnetic fields. By precisely timing the oscillation of the north and south poles of the electromagnets, the train is propelled down the track.

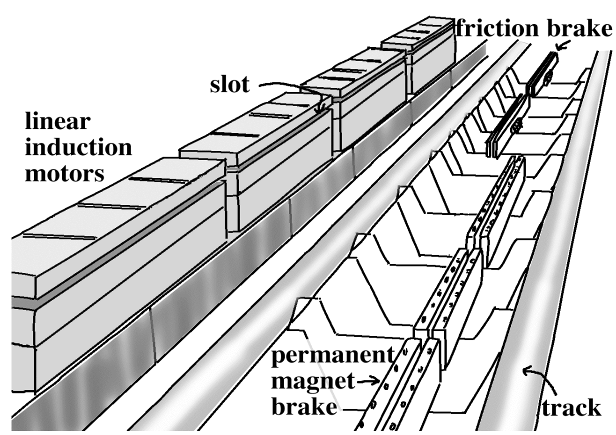
There are two braking systems on Mr. Freeze. A double row of permanent magnets is located between the rails (bottom diagram). When the train reenters the tunnel, braking fin B (top diagram) passes between the permanent magnets, producing opposing magnetic fields that slow the train. The friction brake consists of pairs of plates that pinch braking fin A.

For safety, both sets of brakes are normally in their active position. When the ride is ready to start, pressurized air separates the friction plates and lowers the permanent magnets so that the car's braking fins will pass over the magnets and not between them.

15. Why do the friction brakes use air pressure to *release* the brakes rather than to *engage* the brakes?



The bottom of a Mr. Freeze train car



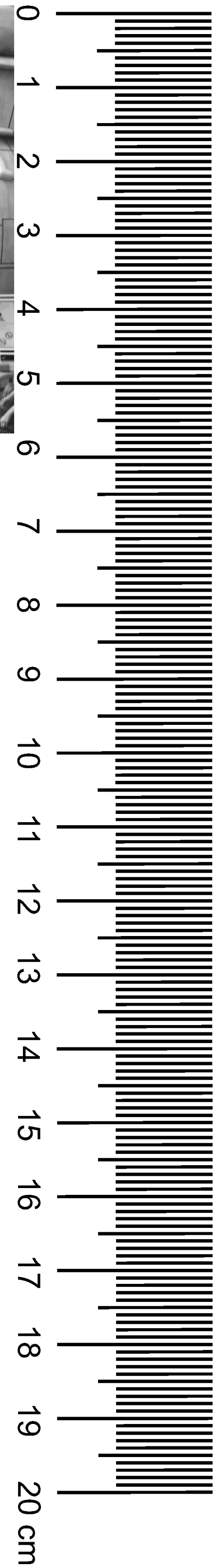
A section of the Mr. Freeze track inside the building. From this position, the loading platform is in front of you and the outside part of the ride is behind you.

Mr. Freeze FP

QUANTITATIVE QUESTIONS

The entrance to "Mr. Freeze"

1. Carefully determine the distance the train travels before exiting the tunnel. Entering the ride, you will cross a bridge. Stand just beyond the bridge at the position marked on the diagram below. The words "ENJOY THE ONE" on the Mr. Freeze building are 11.4 meters long. Hold the ruler at arm's length to determine how many times "ENJOY THE ONE" fits across the distance from the front of the train to the end of the tunnel.



Train displacement while in the tunnel: ___________

2. The front of the train reaches the end of the tunnel 4.4 seconds after starting. Calculate the **average speed** of the train while in the tunnel.

QUANTITATIVE QUESTIONS (continued)

3. Assuming that the train is accelerating uniformly while in the tunnel, use your answer to question 2 to determine the velocity of the train when its front end reaches the end of tunnel. (Hint: What was the initial velocity of the train?)

4 a. Calculate the average acceleration of the train while speeding up in the tunnel.

b. Draw a force diagram for a rider while in the tunnel.

c. Determine the Force Factor value for the period of time the rider was in the tunnel using the Force Factor (front to back axis) vs. time graph.

d. Calculate the acceleration of the train using the Force Factor data, your force diagram, and Newton's 2^{nd} Law. (Hint: You might not need to know your mass if you save substitutions for last)

e. How do the two acceleration values calculated in 4a and 4d compare?