Bungee Jump Accelerations

In this experiment, you will investigate the accelerations that occur during a bungee jump. The graph below records the acceleration *vs.* time for an actual bungee jump, where the jumper jumped straight upward, then fell vertically downward. The positive direction on the graph is upward.

For about the first 2 seconds, the jumper stands on the platform in preparation for the jump. At this point the acceleration is 0 m/s^2. In the next short period of time, the jumper dips downward then pushes upward, both accelerations showing up on the graph. Between about 2.5 seconds and 4.5 seconds, the jumper is freely falling and the acceleration is near –9.8 m/s^2.

When all of the slack is out of the bungee cord, the acceleration begins to change. As the bungee cord stretches, it exerts an upward force on the jumper. Eventually the acceleration is upward although the jumper is still falling. A maximum positive acceleration corresponds to the bungee cord being extended to its maximum.

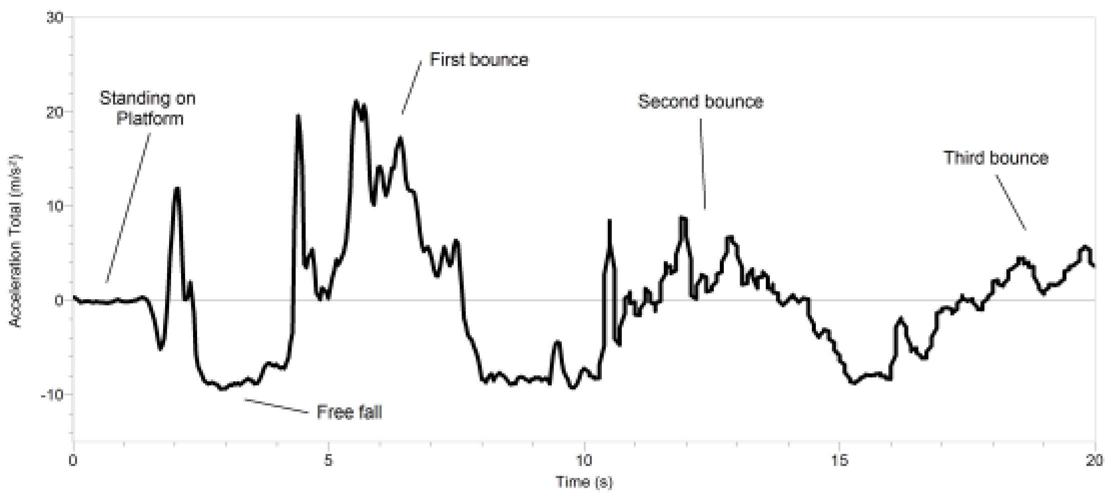

Figure 1

In your experiment, a block of wood or a toy doll will substitute for the jumper, and a rubber band will substitute for the bungee cord. An accelerometer connected to the “jumper” will be used to monitor the accelerations.

OBJECTIVES

- Use an accelerometer to analyze the motion of a bungee jumper from just prior to the jump through a few oscillations after the jump.
- Determine where in the motion the acceleration is at a maximum and at a minimum.
- Compare the laboratory jump with an actual bungee jump.

MATERIALS

LabQuest
LabQuest App
Vernier Low-g Accelerometer **or** Wireless Dynamics Sensor System (WDSS)
bungee jumper[1] (wooden block **or** small doll)
bungee cord (long, flexible rubber band **or** elastic cord)
ring stand

PRELIMINARY QUESTIONS

1. Consider the forces acting on the bungee jumper at the lowest point of the jump. Draw a free-body diagram indicating the forces acting on the jumper. Longer arrows should represent the force vectors with greater magnitude. Label the force vectors.

2. Study the graph of the acceleration during an actual bungee jump (see Figure 1). On the graph, label the time corresponding to the lowest position during the jump. How do you know this point corresponds to the lowest position?

3. What was the acceleration at that point? Was the direction of the acceleration up or down?

4. Label the time where the jumper reached the highest position during the first bounce. How do you know this point corresponds to the highest position?

5. What was the magnitude of the acceleration at that time? Was the direction of the acceleration up or down? Explain why this is so.

6. How long was the bungee cord used in the real bungee jump? Explain. **Hint**: Consider how long the jumper fell before the cord started to apply a force.

PROCEDURE

Part I The Jump–Step by Step

1. Set up the sensor and LabQuest for data collection.

   Using Low-g Accelerometer

   a. Connect the Low-g Accelerometer to LabQuest and choose New from the File menu.
   b. Attach a block of wood or small doll (your jumper) to the Accelerometer. Verify the arrow on the Accelerometer is pointed upward (toward the hook if using a block, or toward the feet of the doll).
   c. Tie the rubber band to the hook on the wooden block or to the feet of the doll. Tie the other end of the rubber band to a rigid support, such as a large ring stand. Adjust the length of the cord so that the block or doll does not hit the floor when dropped.

   Using WDSS

   a. Turn on the WDSS. Note the name on the label of the device.

[1]The bungee jumper is needed if collecting data with the Low-g Accelerometer, not if using the WDSS.

   b. Choose New from the LabQuest App File menu. Choose WDSS Setup from the Sensors menu.
   c. Tap Scan to look for WDSS devices.
   d. Select your WDSS and select OK.
   e. Select Accel-X to enable the sensor you need for this experiment. Select OK.
   f. Verify the x-axis accelerometer arrow is pointed upward.
   g. Tie the rubber band to the force hook on the WDSS. Tie the other end of the rubber band to a rigid support, such as a large ring stand. Adjust the length of the cord so that the WDSS (your jumper) does not hit the floor when dropped.
2. The accelerometer must be zeroed so that it reads, only for the vertical direction, zero acceleration when at rest and –9.8 m/s^2 when in free fall.
   a. Rest the bungee jumper stationary on the table, with the Accelerometer arrow (or x-axis accelerometer arrow on the WDSS) pointing directly upward.
   b. Choose Zero from the Sensors menu. The readings should be close to zero.
3. Verify your jumper is oriented properly (arrow pointed up). Start data collection. Hold the jumper motionless while data are being collected.

4. When data collection has finished, a graph is displayed. To examine the displayed graph, tap any data point. As you tap each data point, acceleration and time values will be displayed to the right of the graph. Identify a flat portion of the graph and tap and drag your stylus across to select a region. Choose Statistics from the Analyze menu. The mean acceleration should be near zero. This value represents the acceleration of the jumper prior to jumping. Record the value in the data table.

5. Repeat Steps 3–4, but this time drop the jumper and let it free fall. Verify the accelerometer arrow is pointed upward. Catch the jumper while the cord is still slack. Determine the average acceleration during the fall. It should be close to –9.8 m/s^2. Record the value in the data table.

6. Now collect data corresponding to the bounces after the free fall portion of the jump.
   a. Let the jumper hang from the bungee cord.
   b. Pull the jumper down 5 cm and release the jumper, creating an up-and-down oscillation similar to a mass suspended from a vibrating spring.
   c. Start data collection.
   d. After data collection has finished, a graph is displayed. Determine the point in the motion where acceleration is both positive in direction and has a maximum magnitude. Does this occur when the jumper is at the bottom, middle, or top of the oscillation? Record your answer in the data table.

Part II A Complete Jump

7. Lift the bungee jumper to the height of the ring stand, as shown in Figure 2. The bungee cord should be hanging to the side and the Accelerometer cable should be clear of the jump path. The accelerometer arrow must be pointed upward. The connection point between the bungee cord and the jumper must also be pointed upward, so that the jumper does not turn over during the jump.
   a. Start data collection.
   b. Wait 1 second and release the bungee jumper so that it falls straight down with a minimum of rotation. Let the jumper bounce a few times. If using the Low-g Accelerometer, verify the cable still has slack when the jumper reaches the lowest point.

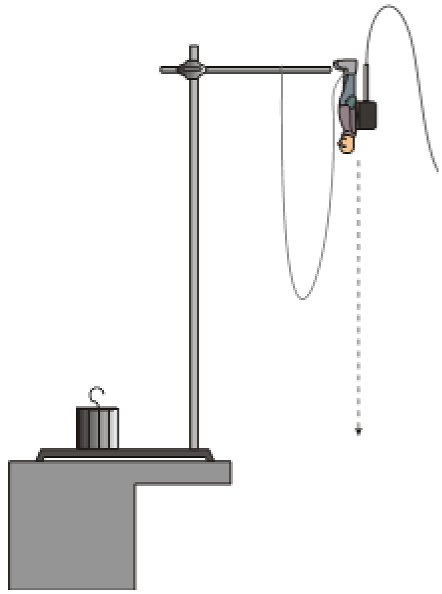

Figure 2

8. Repeat the measurement until you have a satisfactory set of data. A successful run should include a minimum of rotation, a section of free fall before the cord starts to pull on the jumper, and a few bounces, with at least the first bounce high enough to cause the cord to again go slack. The acceleration *vs*. time graph for the laboratory jump should show features similar to the graph of the real bungee jump. Print or sketch your final graph.

DATA TABLE

Acceleration of the jumper prior to jumping	m/s^2
Acceleration during the fall	m/s^2
Jumper's position when maximum upward acceleration occurs (bottom, middle, or top of oscillation)	

Time (s)	Acceleration (m/s^2)	Direction of motion (up, down, or at rest)

ANALYSIS

1. Examine the graph. Determine the acceleration at eight different points on the graph, choosing points during the initial rest, free fall, when the cord is taut, and several bounces. Record the values in your data table. Indicate the direction of the motion using *up, down,* or *at rest.*

2. Perform the same analysis on your bungee jump as was done on the real bungee jump in the Preliminary Questions section.

3. How well does the laboratory jump compare with the real jump? Discuss the similarities and differences.

4. How could you improve the correlation between the lab jump and the real jump?

EXTENSIONS

1. Place a Motion Detector on the floor during a jump. Examine the Motion Detector data (position *vs.* time and velocity *vs.* time graphs) of the jump. How do these data compare to the accelerometer data? Which sensor do you think is a better tool for the analysis of the jump? Explain.

2. If a video camera is available, videotape the laboratory bungee jump or a real bungee jump. View the video and match the accelerometer graph with the video of the jump.

3. Repeat the experiment with a jumper of different mass. What are the similarities and differences between the two sets of data? Discuss some methods that might be used by operators of commercial bungee jumps to assure the safety of jumpers of different weights.

4. Connect the bungee cord to a Force Sensor to examine the cord tension during the jump.

5. Use reference books or the Internet to learn the accelerations experienced by the Shuttle astronauts during takeoff and re-entry. How do the accelerations experienced by the astronauts compare to the maximum acceleration experienced by a bungee jumper?