# Ball Toss

1. Editable Microsoft Word versions of the student pages and pre-configured TI-Nspire files can be found on the CD that accompanies this book. See *Appendix A* for more information.

2. A volleyball or a basketball works well in this lab. Since these are rather large, a buoyant force and air resistance will affect the acceleration. The students will probably not get 9.8 m/s$^2$, but the shapes of the curves will be correct. Smaller objects that yield better *g* values are difficult to use because they do not reflect the ultrasound well. Do not use a light ball such as a beach ball, since air resistance is too large compared to the gravitational force. The analysis of the motion of a beach ball is suggested as an extension.

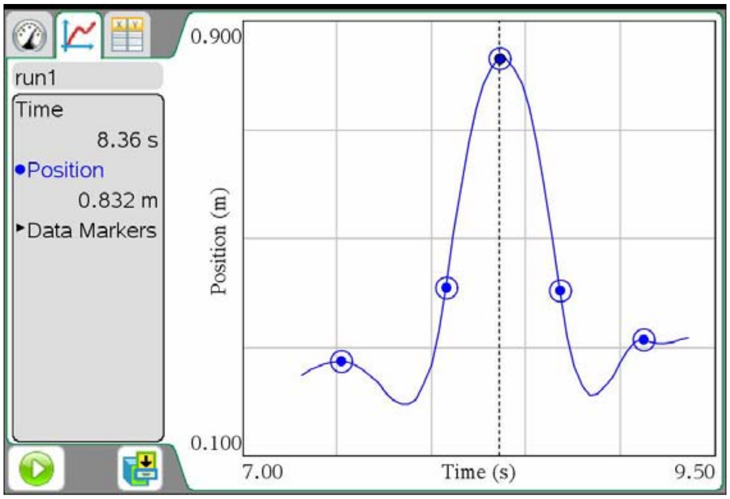
3. Using a beach ball will yield more air resistance and buoyant force effects, while using a baseball or dense rubber ball will do the opposite. Careful analysis may show some small differences between the dense balls and the others. Over a short distance and with the velocities relatively low, air resistance does not become a major factor, except for the beach ball. Nerf® or foam balls do not work well for this experiment.

4. There are several keys to collecting good data. It will help if you demonstrate the toss before the students begin. Here are some tips:
   - Hold the ball with your hands on the sides of it. After you release the ball, get your hands out of the way.
   - Do not toss the ball using one hand underneath the ball. Your hand will interfere with the data collection.
   - It is not necessary to toss the ball high. A height of 0.5 to 1.0 m above the release point works well.
   - The ball must stay directly above the Motion Detector during its motion.

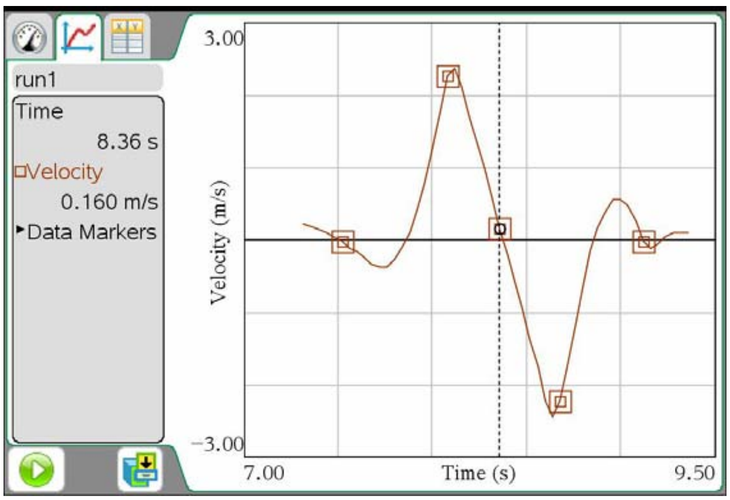
5. Motion detectors without a mode switch do not properly detect objects closer than 0.5 m. As a result, such motion detectors must be farther away from the experiment than described in the student notes. In contrast, Motion detectors *with* a mode switch will detect objects as close as 0.15 m. Ideally, an experiment will be set up so that the target is nearly this close at the point of closest approach, giving the best possible data.

6. This activity makes use of the Strip Chart feature in DataQuest. Based on the setup, only the last five seconds of data will be retained after stopping data collection. It is strongly recommend that students work in pairs when collecting data where one person throws the ball and the other person starts and stops data collection.

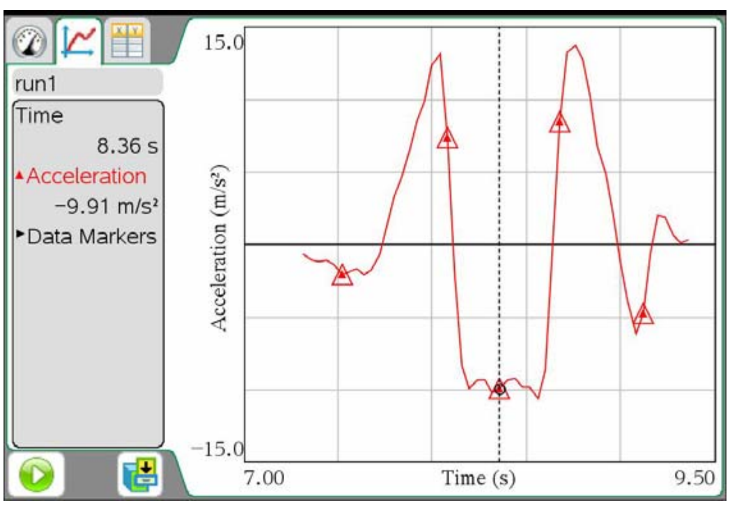
## SAMPLE RESULTS




*Typical position* vs. *time graph.*




*Typical velocity* vs. *time graph.*




*Typical acceleration* vs. *time graph.*

| | Analysis Parameters | | |
|---|---|---|---|
| | A *or* M *or* Average | B | C |
| Distance ($Ax^2 + Bx + C$) | – 4.79 | 80.38 | – 335.9 |
| Velocity ($Mx + B$) | – 9.67 | 81.02 | |
| Average acceleration | – 9.58 | | |

## ANSWERS TO QUESTIONS

1. The velocity when the ball is at the top should be close to 0 m/s. The acceleration when the ball is at the top should be close to – 9.80 m/s$^2$.
2. In this example, the coefficient of the $x^2$ term is – 4.79. For free fall without air resistance, 1/2 $g$ should be – 4.90.
3. When a straight line is fit to the velocity graph, the slope of the line is – 9.67 m/s$^2$, compared to the acceleration due to gravity of – 9.80 m/s$^2$.
4. The mean acceleration from the acceleration graph is – 9.58 m/s$^2$, compared to the acceleration due to gravity of – 9.80 m/s$^2$.
5. The acceleration of the ball was consistently smaller than the accepted acceleration due to gravity. This is largely due to air resistance and the buoyancy of the surrounding air.

## EXTENSIONS

1. Since the balls used in this lab are rather large, a buoyant force and air resistance will affect the acceleration. The students will probably not get 9.8 m/s$^2$, but the shapes of the curves will be correct. Smaller objects that yield better $g$ values are difficult to use because they do not reflect the ultrasound well. Variations in your measurements will indicate that there is error in determining the distance that will affect your results.
2. For the half-trip up, the net force on the ball is affected by the upward-directed buoyant force and the downward-directed air resistance. For the half-trip down, the net force on the ball is affected by the upward-directed buoyant force and air resistance.
3. Using a beach ball will yield more air resistance and buoyant force effects. You should expect a lower value for g in this case.
4. Using a baseball or dense rubber ball will yield less air resistance and buoyant force effects. Careful analysis may show some small differences between the dense balls and the others.