Milk Jug Toss

Goal

Use the Calculator Based Ranger (CBR) and LabQuest2 (LQ2) to analyze the motion of a milk jug that is tossed straight up into the air and then caught. More specifically determine the precise time that the jug is airborne and its displacement and distance for that particular interval. Also, you will determine the jug's maximum speed and acceleration rate.

Procedure

1. Connect the CBR to DIG1 on LQ2 – the socket is "hidden" under a rubber flap on the side.
2. You should get to a screen showing a live readout of Position as measured by the CBR. (If not, run the LabQuest App from the home screen and check that the CBR is connected.) The live read out shows the distance to whatever is reflecting sound back to the CBR – move something in front of the CBR an verify that it is measuring the range (position).
3. Change the Rate and Duration of the experiment to 30 samples per second and 3 seconds.
4. Place the CBR on a chair or the floor. Click on the green triangle Collect button. Toss and catch the milk jug directly above the CBR in its "line of sight" (actually its line of *sound* ;). Try to keep your hands to the sides so that sound hits *only the jug* during the toss and catch. Also, the CBR system cannot measure anything closer than about 40 cm (16 in) – so don't get too close to it!
5. If the resulting graphs are not satisfactory then simply repeat the experiment by hitting the Collect button again – old data is automatically erased and replaced with the new experiment. Once you have a good trial you may want to save the data to avoid accidentally erasing.

Data Analysis

1. You may want to view the graphs one at a time. Under the **Graph** menu choose to show only Graph 1. Then you can click on the *y*-axis label and change it to whichever parameter you choose – position, velocity, or acceleration.
2. Using the tools available in the LabQuest app determine the maximum speed and rate of acceleration that occurred during the experiment. Record the results and explain how you determined the values – using what tool(s) and which graph(s) or data.
3. Judging by any and all graphs determine the precise amount of time that the jug was actually in the air. Record the values of time at which the jug left the person's hands when it was thrown and at which it made first contact when it was caught – how can you tell?
4. Use the velocity vs. time graph to determine the acceleration for this interval of time: highlight and select this part of the graph by clicking and dragging. (You may want to zoom in before doing this.) Under the **Analyze** menu select **Curve Fit** and choose an appropriate type of equation. Record the results. According to the curve fit coefficient(s) what was the acceleration? Was this acceleration relatively constant?
5. Use the position vs. time graph to determine the acceleration for the same interval. Use a similar method to the previous step.
6. Now calculate the displacement that occurred while the jug was airborne by using the kinematics formula for displacement, using appropriate values for v_i, a, and Δt.
7. Use an appropriate method to determine the *distance* for the same interval of time.
8. How do the displacement and distance calculated relate to the position vs. time data and graph? Can you confirm your results by comparison? Explain and try it!

Data/Results

Maximum speed of jug during the experiment: v_{max} = ____________________

How was max speed found and what was happening to the jug when this speed occurred? What direction is the velocity at this instant?

Maximum acceleration rate of jug during the experiment: a_{max} = ____________________

How was max acceleration found and what was happening to the jug when this acceleration occurred? What direction is this acceleration?

Milk Jug Airborne Interval

t_1 = ______________ (jug leaves hands) t_2 = ______________ (jug hits hands as it is caught)

$\Delta t = t_2 - t_1$ = ______________ (total time actually in the air)

How were these values determined?

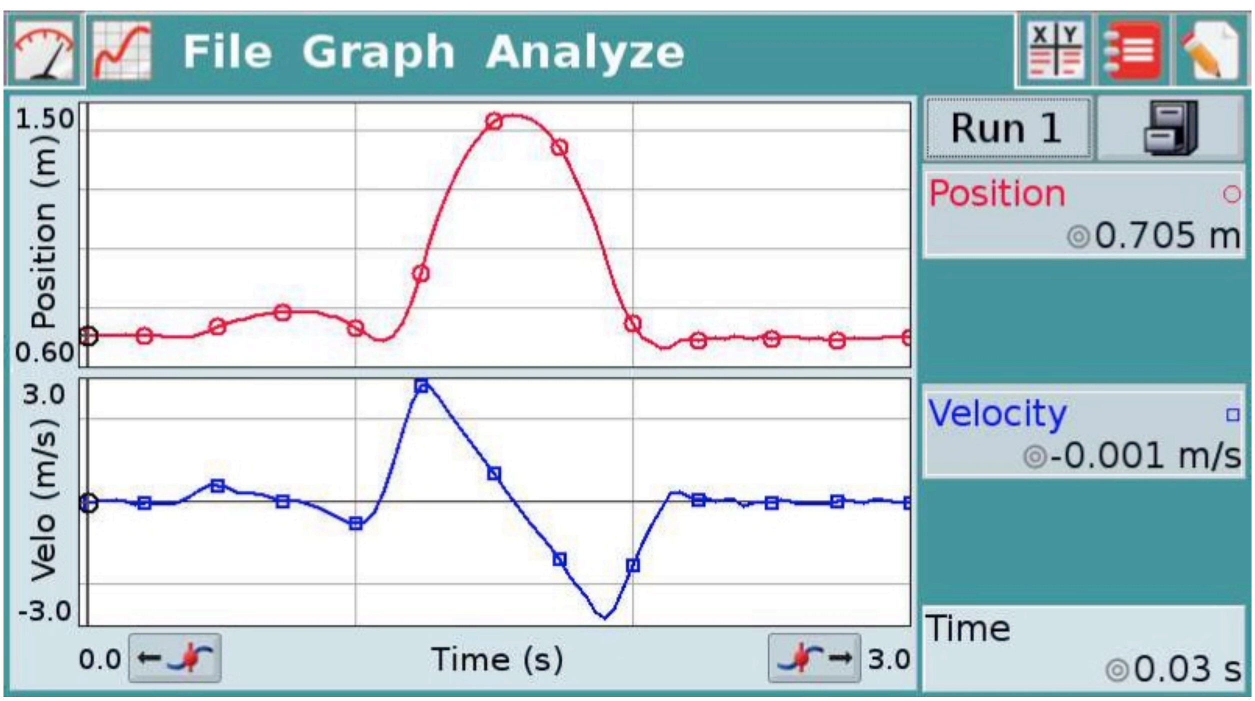
Velocity vs. time – curve fit equation for airborne motion, acceleration determined from regression coefficients, evidence that acceleration is relatively constant?

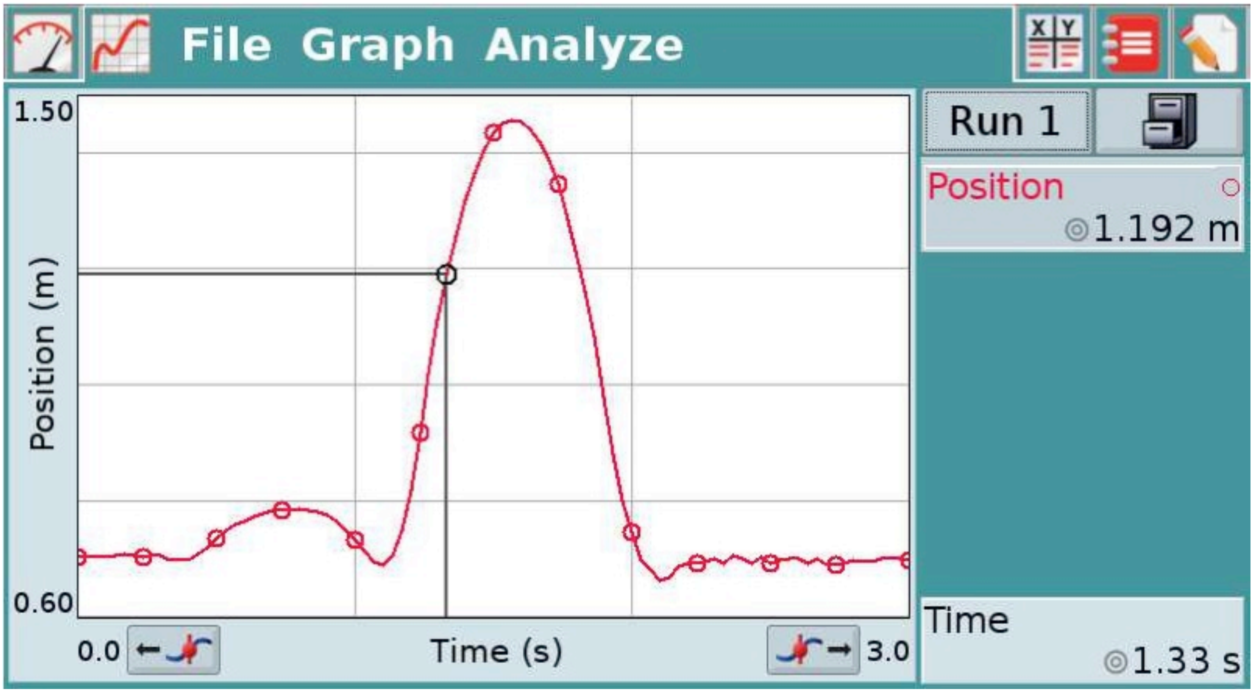
Position vs. time – curve fit equation for airborne motion, acceleration determined from regression coefficients, evidence that acceleration is relatively constant?

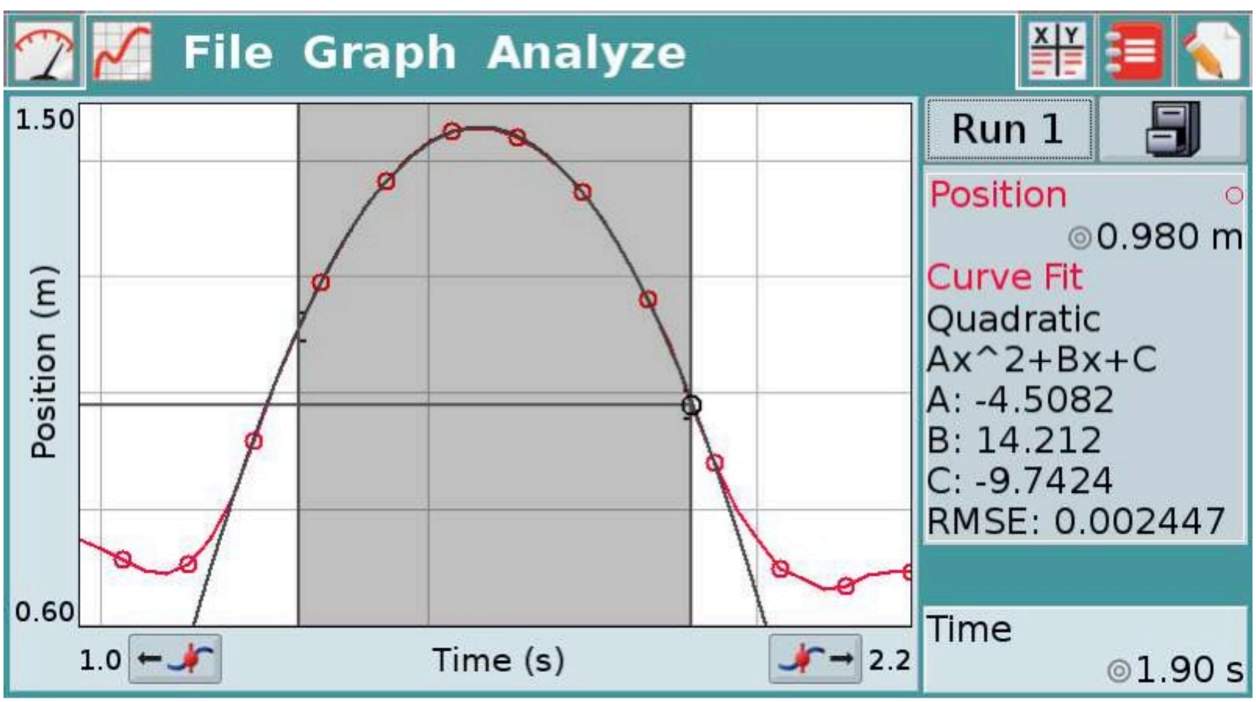
Displacement calculated by $d = v_i t + ½at^2$:

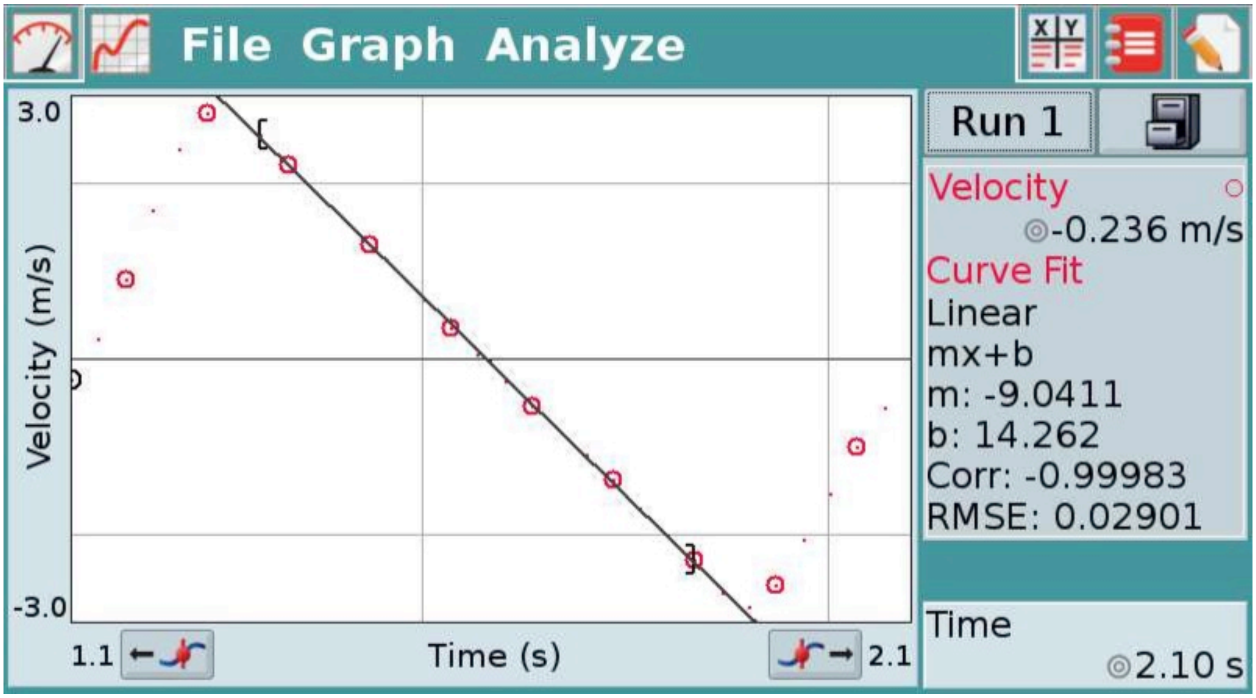
Distance calculation (show work):


File Sensors
DIG 1: Position
2.105 m
Mode:
Time Based
Rate:
30 samples/s
Duration:
3.0 s

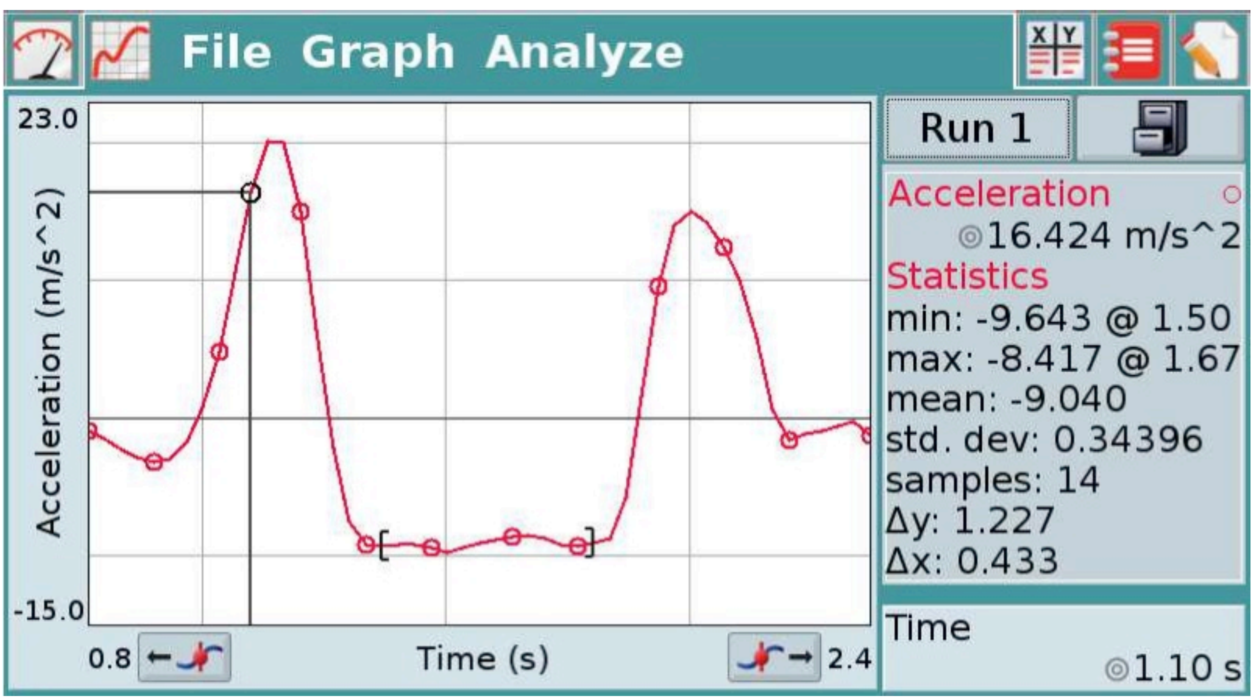

File Graph Analyze
Run 1
Position
0.705 m
Velocity
-0.001 m/s
Time
0.03 s
1.50
Position (m)
0.60
3.0
Velo (m/s)
-3.0
0.0
Time (s)
3.0


File Graph Analyze
1.50
0.60
Position (m)
0.0
Time (s)
3.0
Run 1
Position
1.192 m
Time
1.33 s


File Graph Analyze
1.50
0.60
Position (m)
1.0
Time (s)
2.2
Run 1
Position
0.980 m
Curve Fit
Quadratic
Ax^2+Bx+C
A: -4.5082
B: 14.212
C: -9.7424
RMSE: 0.002447
Time
1.90 s



File Graph Analyze
3.0
-3.0
Velocity (m/s)
1.1
Time (s)
2.1
Run 1
Velocity
-0.236 m/s
Curve Fit
Linear
mx+b
m: -9.0411
b: 14.262
Corr: -0.99983
RMSE: 0.02901
Time
2.10 s



File Graph Analyze
23.0
-15.0
Acceleration (m/s^2)
0.8
Time (s)
2.4
Run 1
Acceleration
16.424 m/s^2
Statistics
min: -9.643 @ 1.50
max: -8.417 @ 1.67
mean: -9.040
std. dev: 0.34396
samples: 14
Δy: 1.227
Δx: 0.433
Time
1.10 s