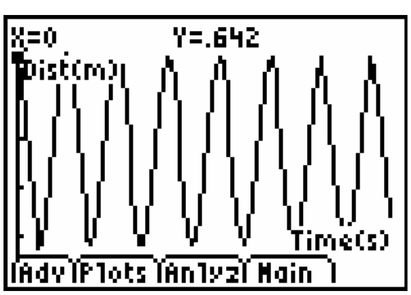
TEACHER INFORMATION

Activity
8

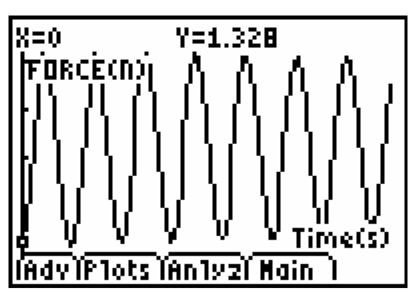
Spring Thing: Newton's Second Law

1. The four different Motion Detectors that can be used for this activity are; Vernier Motion Detector, CBR, CBR 2, or Go! Motion. Whichever Motion Detector is used, it must be connected to a CBL 2 or LabPro and not directly to the calculator. The CBR, CBR 2, and Go! Motion do not include the required cable to connect to a CBL 2 or LabPro. The Motion Detector Cable (order code: MDC-BTD) can be purchased separately from Vernier Software & Technology.
2. Suspend the hanging bob directly above the Motion Detector. Do not allow the bob to come closer than 50 cm to the Motion Detector during data collection.
3. It is best to place a wire basket over the motion detector to protect it from falling weights.
4. Although it is possible to acquire good data with a hand-held Force Sensor, data will be more consistently high quality if the Force Sensor is suspended from a ring stand or other rigid support.
5. It is useful to have high-quality sketches of the four graphs so that students can accurately determine the phase relationship between the four functions. The calculator can't display four graphs simultaneously, so the students are asked to sketch their data. You may choose to have students transfer data to a computer using TI Interactive! or Vernier Logger Pro. The sample data shown below are graphed with Logger Pro.
6. Either a Slinky with a light bob (about 50 g) or a slightly stiffer spring (about 3 N/m stiffness) with a larger bob (200 g) can be used. The key is that the combination of spring and bob yields several cycles during the 5 s data collection. One spring that works well is the Harmonic Motion Spring from VWR International, http://www.vwrsp.com/.
7. If the acceleration data are too noisy, try making the reflection from the bob stronger. An old CD or an index card can be taped to the bottom of the bob, although too large a surface will add damping forces.
8. The values obtained for the slope parameter m are almost always larger than the mass of the bob due to the moving mass of the spring. In the limit of a massless spring, then the bob mass and the slope would be the same. Detailed analysis shows that 1/3 of the mass of a uniform spring should be added to the mass of the bob for comparison to the slope m.

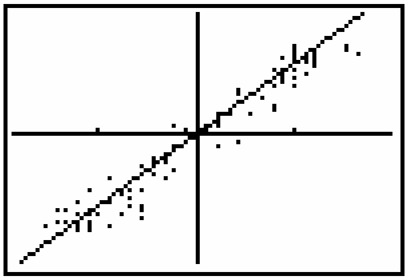
SAMPLE RESULTS



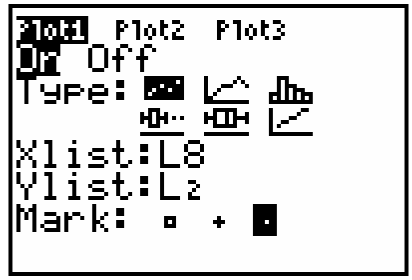
Distance data in EasyData



Force data in EasyData



Force *vs*. acceleration data with model



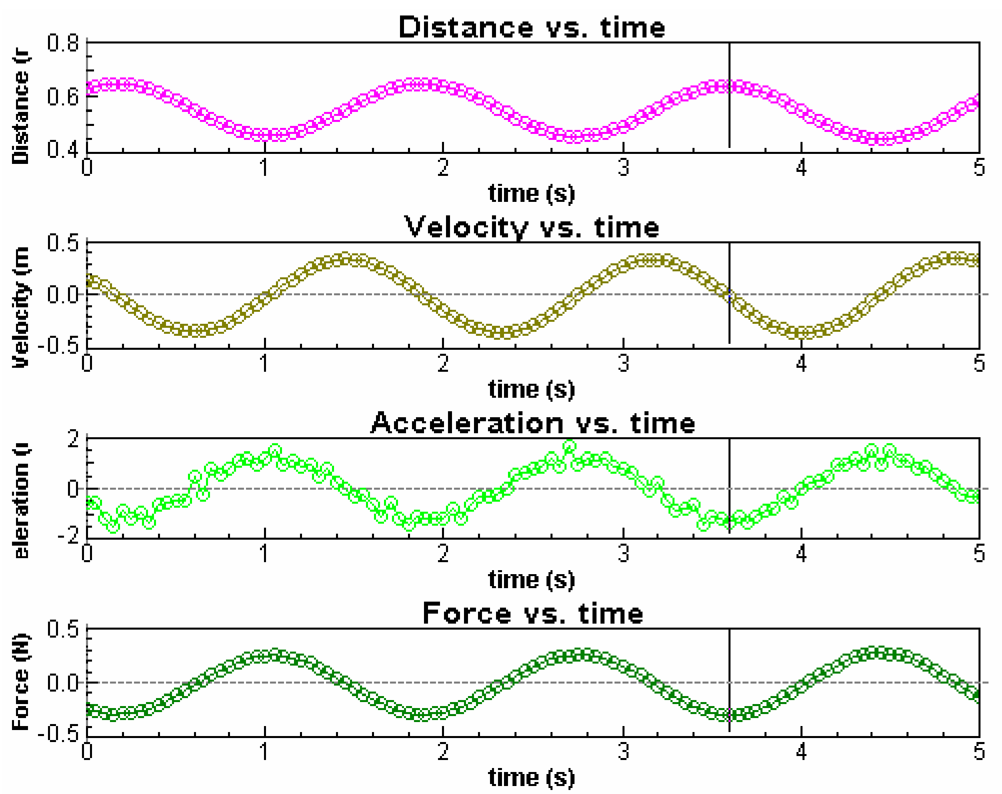
Graph settings for force *vs*. acceleration (TI-83)

DATA TABLE

m	0.22
bob mass (kg)	0.200 kg

ANSWERS TO QUESTIONS

1. Motion and force data graphed in Logger *Pro*. Note that the time cursor is at the same time in each graph, clearly showing the phase relationship between graphs.



2. When the acceleration is at a maximum, the bob is located at a minimum position. The velocity at that time is zero.

3. The velocity can clearly be zero when there is a non-zero acceleration—the time discussed in the previous question is an example. The acceleration is calculated from the rate of change of velocity, not the value of the velocity.

4. The force and acceleration graphs are in the same phase.

5. Since the force and acceleration graphs are in phase, a graph of force *vs*. acceleration would be a straight line going through the origin. When force is at a positive maximum, so is the acceleration, and vice versa.

6. The graph of force *vs*. acceleration shows points generally on a line going through the origin. That is consistent with my prediction in Step 5.

7. Yes, the data are consistent with Newton's second law, $F = ma$. Newton's second law is a simple proportionality, so a graph of force *vs*. acceleration should be a line passing through the origin of slope m.

9. The bob mass is slightly less than the optimum value for the parameter m, but they are still within 10%.

10. The spring has mass, so that perhaps the mass of the spring is combined with the mass of the bob.

