TEACHER INFORMATION

Experiment **28**

Newton's Second Law

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. This experiment is not intended for use with Easy or Go! Products since data from two sensors must be collected at the same time. While you can use two different handhelds, each with their own sensor or multiple Go! Products on the same computer, to collect the data, a single, multi-channel interface is preferred.

3. Traditional experiments for Newton's second law often use motion detectors or spark timers to measure distance data and calculate acceleration. This experiment uses an Accelerometer to actually measure the acceleration. This device, along with the Force Sensor, makes it easy to quickly collect accurate force and acceleration data.

4. In this experiment, the students will analyze the force *vs.* acceleration graph. During this analysis they will perform a linear fit on the data. The slope of this fit should be close to the mass of the cart and added objects. To get the best possible results, you may want to calibrate both the Force Sensor and Accelerometer.

5. Since the Accelerometer is sensitive to inclination, the students are instructed to make sure the surface is level and to zero the sensors prior to data collection.

6. The mass used in this experiment is the *inertial mass*, as opposed to the *gravitational mass*. You may wish to make this distinction with your students.

7. If the accelerometer data seem noisy, make sure that the sensor is securely fastened to the cart. If it isn't fastened firmly, it could rattle and introduce more noise to the data set.

8. It is critical that the only external horizontal force applied to the cart come through the force sensor. If the cables drag, then there will be other forces not measured by the force sensor. Be sure to have the students move the cables with the cart.

9. Explore all magnitudes of force by moving the cart back and forth in a random way. Do NOT just pull the cart at a uniform speed or at uniform acceleration, since you'll concentrate points in a small region of the force *vs*. acceleration plot that way.

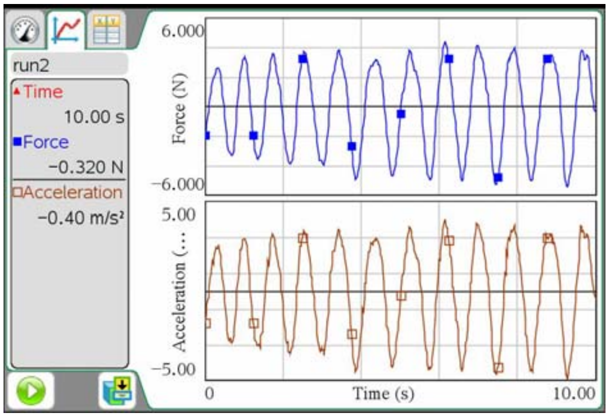
ANSWERS TO PRE-LAB QUESTIONS

1. The larger the force, the more the motion changes. This is a direct relationship.

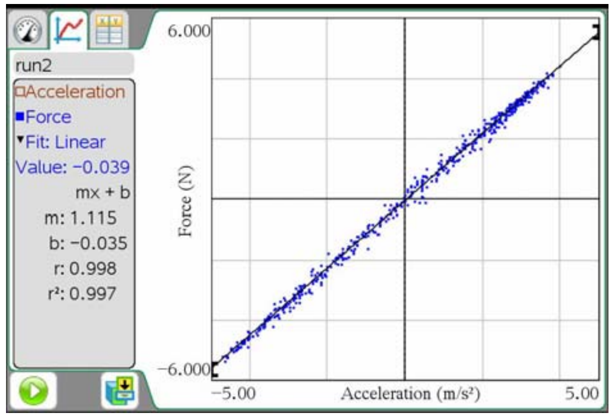
2. The baseball will change its motion more than the bowling ball.

3. The new acceleration would be half as large. This is an inverse relationship between mass and acceleration.

SAMPLE RESULTS



Typical force vs. time and acceleration vs. time graphs.



Typical force vs. acceleration graph shown with a linear fit

Trial I

Mass of cart with sensors (kg)	0.66 kg

Regression line for force *vs*. acceleration data			
y = 0.62 x + -0.013			
Acceleration at 1.0 N Force	0.607 m/s^2	Acceleration at -1.0 N Force	-0.633 m/s^2

Trial 2

Mass of cart with sensors (kg)	1.16 kg

Regression line for force *vs*. acceleration data			
y = 1.115 x + -0.035			
Acceleration at 1.0 N Force	1.080 m/s^2	Acceleration at -1.0 N Force	-1.150 m/s^2

ANSWERS TO QUESTIONS

1. The graphs look very similar, showing that force and acceleration are closely related. The peaks on one graph occur at the same time on each graph.

2. Force and acceleration are directly proportional. This relationship can be seen when the graphs of force *vs.* time and acceleration *vs.* time are compared. Also, the graph of force *vs.* acceleration shows a linear relationship.

3. $\dfrac{N}{\left(\dfrac{m}{s^2}\right)} = \dfrac{\left(kg \cdot \dfrac{m}{s^2}\right)}{\left(\dfrac{m}{s^2}\right)} = kg$

4. In Trial 1, the mass was 0.66 kg while the slope of the linear regression line was 0.62 $N/(m/s^2)$. In Trial 2, the mass was 1.16 kg while the slope of the linear regression line was 1.115 $N/(m/s^2)$. In both cases the mass was within the uncertainty of the fitted slope. The slope corresponds to the combined mass of the cart, sensors, and any added mass.

5. $F = m \cdot a$