Connor Lind · Dr. Philhour · AP Physics · 1st Period · 11.09.09

Precision Measurements of Force and Impulse

The motion of objects in our universe can be described in many different ways. I hypothesize that the change in momentum of an object is the integral of the applied force over time. Hoping to verify this hypothesis, I used:

- one force plate
- Vernier Lab Pro
- a meter stick
- one textbook
- two known weights (of significantly different mass)

Momentum is determined by an object's mass and velocity ($m \cdot v$). I plan on dropping the book on the force plate from a known height, calculating the objects initial velocity using energy conservation, and then verifying that the impulse delivered by the force plate was equal and opposite to the books momentum before impact, do to the assumption that the final momentum of the book is zero. The exact procedure was as follows:

1. Connect the force plate to Lab Pro
2. Calibrate the force probe by placing a known mass on the scale and entering that weight in Newtons in the Lab Pro program. *I used 9.789 as the gravitational acceleration at the location of our lab in San Francisco. Go to www.wolframalpha.com to check the gravitational acceleration at your location.*
3. Hold the meter stick lightly on top of the force plate.
4. Raise the book, level at a specific height. Record this height to calculate potential energy in your calculations.
5. Drop the book on the force plate
6. Take the integral after the point of impact to the point at which the book is no longer bouncing slightly
7. Subtract the integral of equal time interval of the straight line at the end of your data (which is the normal force of the book alone) of equal time interval

The following equations were derived prior to to the experiment:

$$U_{initial} = K_{before\ impact}$$
$$mgh = (1/2)mv^2$$
$$(2gh)^{(1/2)} = v_{before\ impact}$$

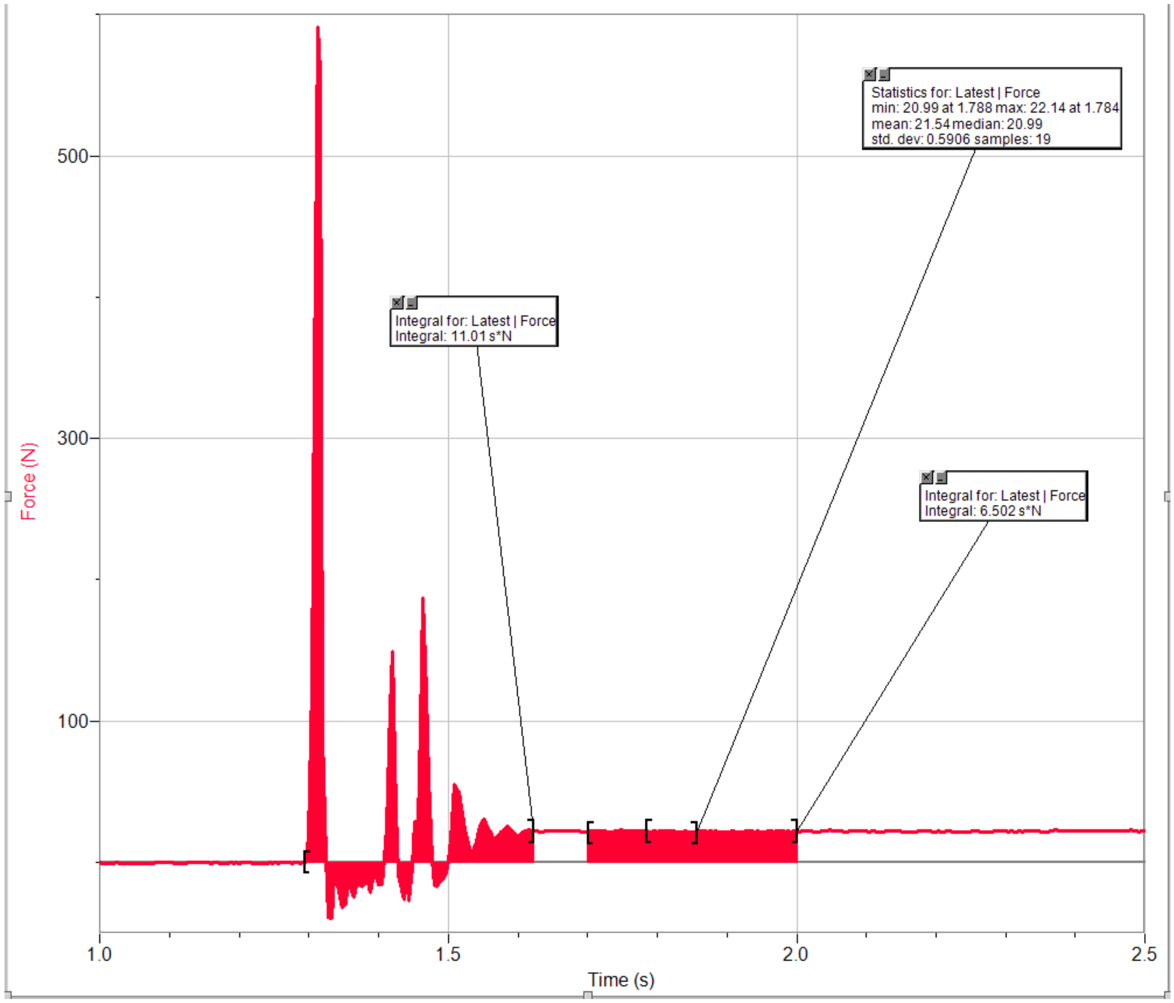
$$p = m \cdot v$$
$$p_f = 0$$
$$J = \Delta p = p_f - p_i$$

Hypothesis

$$-mv_{before\ impact} = J$$
$$-m(2gh)^{(1/2)} = J = -\int F \cdot dt$$

As a result of these equations, it is clear that height and mass are the independent variables that verify that the dependent variable, theoretical impulse, is equal to the measured impulse.

The following data was recorded at a height of **0.20 m**:



The first integral describes the impact of the textbook. The second integral represents the normal force on the book, resting on the force plate. In order to accurately describe the impulse, we must subtract the integral of that normal force of an equal time interval from the impulse integral. *In this trial, both integrals were taken at equal time intervals.*

$U_{initial} = K_{before\ collision}$

$(2gh)^{(1/2)} = v_{before\ collision}$

$(2*9.789m/s^2*0.2m)^{(1/2)} = 1.9788\ m/s$

$-mv_{before\ collision} = J$

$-m(2gh)^{(1/2)} = J = -\int F \cdot dt$

$-2.2004*1.9789 = -\mathbf{4.3544\ kg*m/s}$

$J = -\int F \cdot dt = -11.01 + 6.502 = -\mathbf{4.508\ kg*m/s}$

Percent Discrepancy: **3.466%**

One obvious inherent error in the experiment is in the measurement of mass:

Max: 22.14 N

Min: 20.99 N

Percent Error: **5.333%**

Error could also exist in our measurement of height. Although the initial height was measured at 0.2m, it could have fluctuated slightly in the amount of time before the book was dropped. Regardless, our percent discrepancy is smaller than the percent error.

Our hypothesis that impulse is describe as $\int F \cdot dt$ is confirmed, and is an accurate statement of the laws of physics. The benefit of having an accurate force plate made the affirmation of this law much easier. The only possible improvement to this experiment would be to devise a latch that dropped the book from a consistent height. One could also verify $J = \int F \cdot dt$ without having the final momentum zero, possibly with the use of a bouncy ball.