Impulse and Breaking Boards

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Introduction

Impulse , $\vec{J}$, is the product of the average force, $\bar{F}$, and the time during which the force acts, Δt :

1) $\vec{J}=\bar{F}\Delta t$

Impulse is simply a reformulation of Newton's 2nd law:

2) $\sum F=ma=m\frac{\Delta v}{\Delta t}=\frac{\Delta p}{\Delta t}$

This leads to the Impulse-Momentum theorem equating the change in momentum with the impulse:

3) $\vec{J}=\bar{F}\Delta t=m\Delta v=\Delta p$

Impulse is a quantity which makes it easy to calculate quantities associated with collisions. If one knows that mass of *one* object in a collision, can determine its change in velocity, and can determine the impact time, it is possible to calculate the force of impact using equation 2).

In this lab, we will be breaking a rebreakable board by dropping a mass on it from a height h. Using conservation of energy, we can then calculate the velocity, v_o, of the mass at the moment of impact with the board.

4) $v_o=\sqrt{2gh}$

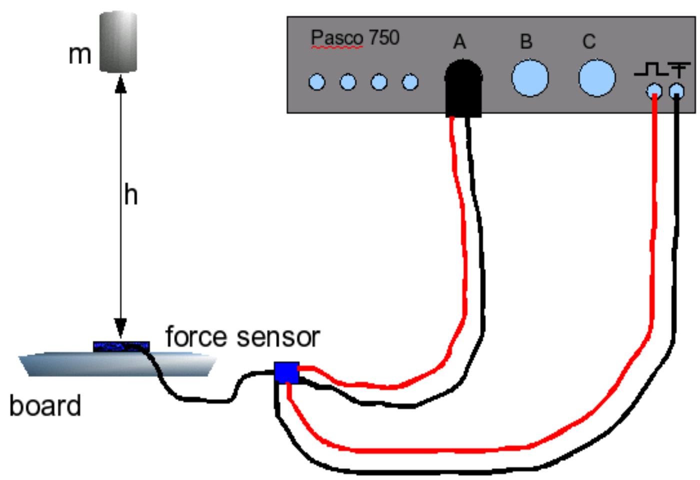

Illustration 1: Setup of experiment

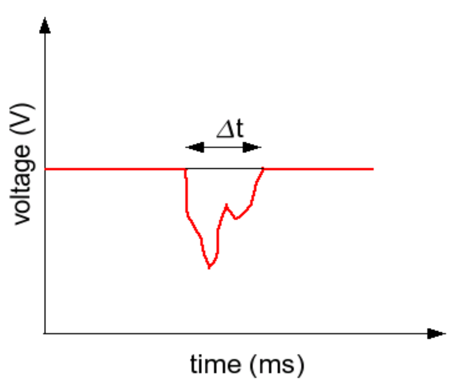

Illustration 2: Determining time of impact

The final velocity after the board breaks will be $v_f=0$ m/s. This is an approximation because the mass may still be moving downwards after the board breaks if given room.

A force sensor which is made of conducting foam (a substance which decreases in electrical resistance upon compression) will be used to determine the time of impact. This change in resistance of the foam leads to a change in the voltage across the sensor which can be measured by a voltage probe. Although this sensor can be calibrated to force, we will not need to do this because the impact time is the quantity of interest, and this will not change with Voltage to Force calibration. Incidentally, when the Voltage is calibrated to Force, the area contained between the deflection and the baseline *is* the impulse.

Procedure:

Our goal is to estimate the minimum force that can be used to break the board. Set up the experiment as indicated in **Illustration 1** but without the sensor. Place the board on the supports so that only 1 cm overlaps the supports on each side. Starting set up Data Studio with a voltage probe and a power amplifier. Click on the power amplifier and delete it, and the signal generator will automatically plug in on the right hand side of the screen. Set the signal generator for +5 V auto. Double click on the voltage probe and set the sampling rate to 4000 frames per second. Use the graph to display your data.

Starting at about 0.5 m drop the 1 kg mass on the board and drop it. Increase the height by 5 cm each time until the board actually breaks. Then bracket your measurement by 1 cm increments until you have found the minimum height from which you can drop the mass and still break the board. Record this height and its uncertainty.

Reassemble the board, and tape the foam force sensor to the board directly in the center of the board. Drop the mass onto the board 10 times, this time collecting data using Data Studio. Record Δt as indicated in **illustration 2**. Calculate the force needed to break the board each time. *For extra credit (up to 10 pts out of 100) try to calibrate the sensor. Then collect one trial in which you determine the impulse from the area under the curve and compare it to the change in momentum of the dropped mass. Are they equal within experimental uncertainty? Why or why not?*

dropped mass: ___________________

height at which board breaks, h: _________________

velocity before impact, v_o: _________________

Trial	t_1	t_2	$\Delta t = t_2 - t_1$	***F***
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
			Average Force:	
			STDEV Force:	

Analysis:

How accurately can one estimate the force it takes to break a board using this method? How precise is this method? Back up your answers by referencing your data and uncertainties. What are the sources of uncertainty, and specifically how do they change the calculated force? What quantities would you wish to measure more precisely to get better answers (and why?). Presuming that at height $h_2 = h - 0.01$ m, the board doesn't break **AND** that the rebound velocity: $v_f = -v_0$, **AND** that your average time of impact would be the same, how much more force would the mass experience because of rebounding instead of penetrating the board?