<u>Systematic Study of Bouncing Projectiles</u>

Hans Choe
High Speed Imaging
Dr. Winters
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Goals of this project: This projects focuses on a collision system where a tennis ball and basketball, on one another respectively, are released at the same time from a certain height in such a way that the tennis ball will bounce off the basketball with a much greater velocity. The goal of this project is to observe if the energy in this system is conserved by graphing the positions of a tennis ball and basketball and then fitting a line through it to obtain its velocity. Aside from the physics, an artistic goal is to try to obtain a quality picture of the tennis ball and basketball during the collision so that deformation in each of the balls is present.

Theory: Energy of the system before the collision is $½(m_t+m_b)v^2$. Energy of the system after the collision is $½m_t v_t^2 + ½m_b v_b^2$. m_t the mass of the tennis ball. m_b is the mass of the basketball. v_i is the initial velocity of the tennis ball or basketball and v_f is the final velocity. If energy is conserved then these two values are equal. At initial glance it does not look like the energy is conserved because the tennis ball shoots out at a tremendous amount of speed.

Equipment: I had collected various amounts of equipment to carry out this project. I obtained a basketball and tennis ball. Alternative lighting was used so that I could increase the shutter speed on my camera. A black backdrop was used so that the light hit only the two balls. The camera that was used to take pictures was a Cannon Optura motion picture camera that was standing on a tripod. I also used Microtools, Adobe Premiere, Video Point, and Graphical Analysis to obtain and analyze my pictures.

Procedures: I found a spot to conduct my experiment. I found a black backdrop and strung it on the wall hooks of the lab. I took several pictures of a colliding basketball and tennis ball with the Optura. The camera was 5.1 meters away from the subject. All the pictures were taken with an exposure of -8 and a shutter speed of 1/30 second. I had 3-4 collisions that seemed like the tennis ball shot straight up instead of at an angle. The tennis ball was 6.5cm in diameter and the basketball was 23.5 cm in diameter. (see setup diagram 1.1 & 1.2) I took several pictures of a colliding basketball and tennis ball with the Optura. I uploaded the video and found that I made an unfortunate mistake. I knew that the shutter speed of 1/30 second would not be quick enough to capture a high-speed collision like this but yet I overlooked that fact.

So I took a guess and increased the shutter speed to 1/500 second and also added one alternate lighting source. The clips came out pretty nice but there was a shadow effect to the left because I placed the lighting source on the right side. Despite the shady pictures, the position of the balls was discrete. I was able to plot the positions of the balls using Video Point. Then I later plotted a graph of the y-values, height, versus time using Graphical Analysis and fit a quadratic line to it. I found out that there were not enough data points.

I took more shots of my bouncing balls. This time I laid the camera on its side so that I would so I would have a longer vertical view rather than a horizontal view. This would enable me to get more frames of the tennis ball. I also added another light source to increase the exposure and reduce the shadowing effect. (see diagram 1.1 and 1.2) I uploaded the clips and cut out the clips that were usable. This time, just as I predicted, I got more frames of the tennis ball after the collision. The only inconvenience is that I had to turn my head side ways in order to view the dropping effect.

I used Video Point and Graphical Analysis to analyze these clips also. I analyzed the numbers and decided to depend on this clip to give me the answer to my goal question.

Data:

Basketball before the collision:
Video Trial: 2, 3
Original Clip: Bounce2.2.avi, Bounce 3.2.avi
Video Point: 2.2.VPT, 3.2.VPT
Graphical Analysis: bb2.2, 3.2b

Tennis ball before the collision:
Video Trial: 2, 3
Original Clip: Bounce2.2.avi, Bounce 3.2.avi
Video Point: 2.2.VPT, 3.2.VPT
Graphical Analysis: bt2.2, 3.2t

Basketball after the collision:
Video Trial: 3, 3
Original Clip: Bounce3.4.avi, Bounce 3.2.avi
Video Point: 3.4.VPT, 3.2.VPT
Graphical Analysis: ab3.4, 3.2b

Tennis ball after the collision:
Video Trial: 3, 3
Original Clip: Bounce3.4.avi, Bounce 3.2.avi
Video Point: 3.4.VPT, 3.2.VPT
Graphical Analysis: at3.4, 3.2t

Analysis:

$$\frac{1}{2}(m_{t+}m_b)v^2 = \frac{1}{2}m_t v_t^{2} + \frac{1}{2}m_b v_b^{2}$$

Linear Regresion: distance = A + Bt + Ct^2

First derivative: velocity = B + 2Ct

Time was the point right before and after the collision.

Calculation Trial 1

$v_{bi\,=}$ -3.9006m/s + 2 (-3.9216m/s^2)(.135s) = -4.959432m/s

$v_{ti\,=}$ -3.6323m/s + 2 (-4.926m/s^2)(.135s) = -4.962482m/s

$v_{bf\,=}$ 6.7297m/s + 2 (-5.3556m/s^2)(.335s)= 3.141448m/s

$v_{tf\,=}$ 10.691m/s + 2 (-3.8818m/s^2)(.335s)= 8.090194m/s

½[(.0622kg) + (.5939kg)](24.61m/s)^2 = ½(.0622kg)(65.45m/s)^2 + ½(.5939kg)(9.87m/s)^2

16.146 J = 9.932 J

(9.932 – 16.146) / (9.932 + 16.146) * 100 = -23.82 % difference

Analysis: The initial velocities of the two balls are equal to the nearest hundredth. Also there is significant difference in the velocity of the tennis ball.

Calculation Trial 2

$v_{bi\,=}$ -2.5814m/s + 2 (-4.6557m/s^2)(.2683s) = -5.07m/s

$v_{ti\,=}$ -2.57515m/s + 2 (-4.6384m/s^2)(.2683s) = -5.06m/s

$v_{bf\,=}$ 8.9655m/s + 2 (-8.5093m/s^2)(.335s)= 3.2642m/s

$v_{tf\,=}$ 13.706m/s + 2 (-7.5525m/s^2)(.335s)= 8.645825m/s

½[(.0622kg) + (.5939kg)](25.654m/s)^2 = ½(.0622kg)(74.75m/s)^2 + ½(.5939kg)(10.65m/s)^2

16.825J = 10.974J

(10.974 – 16.825)/ (10.974 + 16.825) * 100 = -21.04 % difference

Analysis: The results are very similar to those in trial one. The initial velocities of both balls are almost the same as in trial one. The energy also comes out very similar to the values in trial one.

Discussion: The results reveal many interesting points. The initial energy and final energy does not match up. This means that we must have lost energy somewhere during the collision. Thermal energy and sound energy must have been present during the time of the collision. Although the measurements, when compared, came out really close, there was a lot of room for error. Some possible sources of error are the inaccuracy of human measurement, the imperfect alignment of the balls as they dropped, and overall the collision did not take place in an ideal situation. It seems that my results are consistent with theory in a sense that some of the energy after the collision became thermal and sound energy.

Conclusion: My results show that in this collision about 22% of the energy is lost to thermal and sound energy. I thought that energy was not conserved at the beginning because of the tennis ball shooting out faster than its initial velocity. Now I see that actually energy is lost after the collision to thermal and sound energy. The goals of this project were appropriately met.