Three-point Shot

Introduction

There are many cases of parabolic trajectories in sports. Anything involving jumping, throwing objects, etc. A very interesting example is a basketball three point shot. All the important distances on a basketball court are well known, which makes the analysis simpler. In this experiment we will see how well the parabolic motion formulae describes a real three point shot.

Method

Cones will be setup on a basketball court in the Sports Complex with the spacing given in the Procedure. Each student will shoot twice from the Three-Point line, while being filmed on a digital camera. From this movie, it is possible to get the time it takes the ball to travel a distance Δx, and the distance at which the ball reaches its maximum height. From these, one can apply the parabolic motion formulae to compare with the actual motion of the basketball.

Equipment List

1 Laptop, 1 Media Card, 1 Media Card reader, 1 ruler.

Procedure

1. The TA will tell the students the number of the Memory Card that will be used to record the data. Each student must write down that number.

2. Everyone goes to the Sports Complex Basketball courts with a few people carrying the cones and measuring stick and the TA carrying the digital camera and media cards.

3. The TA will show the court that will be used for the activity. The cones will be set up in a straight line. The first cone will be placed at the center of the three-point line. The second cone will be 6 ft away from the first cone (at the free-throw line). The third cone will be placed 1.5ft away from the previous cone (should match the first mark). The next three cones will be placed every three feet (should match the remaining three marks). The last cone will be placed 3.25ft away from the sixth cone (should match the center of the rim). There should be a total of seven cones on the ground. The distance from the first cone to the seventh cone should be 19.75ft (19ft, 9in).

4. A student will step at the center of the three point line. Another student, standing by the 5th cone, will hold the 2-meter stick upright, with the bottom touching the ground. When the TA says “GO!” the student will take a shot. This will be done twice by each student.

5. After each student has been recorded twice shooting a three-pointer, everything will be picked up and taken back to the lab room.

6. The students will get the corresponding Memory Card from the TA and put it in the Memory Card reader. If a window opens asking what to do with the files contained in the

Memory Card, click on "Take no action", or "Cancel". Double click on the Quick Time Player icon on the desktop. Click on "File" on the menu bar, then on "Open" from the menu list. Go to "Memory Card (X:)" and then to the directory containing the Video Clips. Open your first Video Clip. Resize the video clip window if necessary.

7. Use your ruler to measure the 2-meter stick on the monitor. Write down this relation (i.e. 2 m: X cm). You will need this scale relation when measuring the maximum height of the ball.

8. Use the left and right arrows on the keyboard to move *frame-by-frame* throughout the Video Clip. Go to the frame where the basketball is above the center of the first cone. This is where $t=0$.

9. Make a table writing down the distance per interval (distance between cones) and the number of frames it takes the ball to get above the center of the next cone (center of the rim for the last interval). After you have got the frame where the ball is parallel to the center of the rim, leave the video clip on that frame for the time being. Calculate and write down in the table the time that took the ball to go through each interval. Use the frame-per-second rate of the Camera: 20 fps. Now you can obtain the average velocity of each interval by dividing the interval distance over the Δt you just calculated. Add the "interval velocity" to your table. Also calculate the overall average velocity (v_x):

$$v_x = \frac{\Delta x_{tot}}{\Delta t_{tot}}$$

10. With the Video Clip on the frame where the ball is parallel to the center of the rim, go back to the frame where the ball is at its maximum height, and count the number of frames it takes you to get there. Subtract this number from the number of frames it took the ball to get to the rim (from the $t=0$ frame) and find the time elapsed up to this point using the fps rate of the camera. Also, use the ruler to measure the maximum height of the ball as it is on the monitor. Using the scale relation from (7), convert this to the actual maximum height.

11. Use the average horizontal speed from (10) to calculate the horizontal distance traveled up to this point. Now, do the same for the frame in which the ball is again at the same height as the rim, but closer to the shooter (time elapsed and horizontal distance). You will use these two points in the parabolic motion formulae.

12. Make a table of the time elapsed and horizontal distance traveled by the ball at the following events: a) ball is for the first time at the rim height; b) ball reaches its maximum height; c) ball is in (or parallel to) the center of the rim (the rim is 10ft above the ground).

13. Repeat steps 7-12 for the video clip of your second shot. DO NOT skip (7) when analyzing your second shot.

14. Use the following formula to calculate the tangent of the initial angle:

$$\tan\alpha = \frac{d_1 g}{v_x}$$

Where d_l is the distance traveled when the ball reaches its maximum height, and v_x is the average horizontal velocity calculated in (9). Now you can calculate the initial vertical velocity (v_{y0}):

$$v_{y0} = v_x \tan\alpha$$

15. Using the data from the table from part 11, calculate for each shot the height of the basketball at: 1) maximum height; 2) ball parallel to the center of the rim. Assume a perfect parabolic trajectory:

$$y = y_0 + v_{y0} t \quad \frac{1}{2} g t^2$$

Compare this with the actual values as measured on the basketball court.

Questions

According to the data, is the ball moving with constant horizontal velocity? If not, how can you explain this?

Do your calculations predict that the ball will follow the actual trajectory? (I.e. fall into the basket or not)

What sources of error, both in measuring and analyzing, could account for any discrepancies found?