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MAT 266
Professor Brewer
MWF 10:45AM – 11:35AM
Honors Contract
Double Projectiles in Basketball

Introduction

Calculus based physics is important to mathematics. It is especially important to projectiles. Projectiles are objects that are propelled through the air. Calculus based physics determine velocities and angles it takes for the projectile to travel through the air.

Steve Nash is the Phoenix Suns sharp shooting point guard. He is arguably the best shooter in the league because his shooting form is perfect. Calculus based physics can determine the speed and angle until the ball goes through the hoop.

A double projectile is when the propelled object is interfered with by an external force. Although it is highly unlikely for a deflected basketball to obtain enough speed to still go through the hoop, calculus based physics can determine the speeds and angles if it is deflected.

Data Analysis

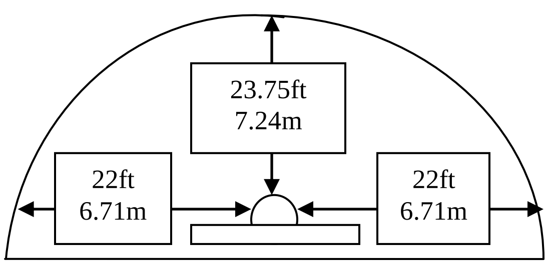
Given:
Height of Steve Nash = 6.083ft = 1.85m
Theoretical height of Steve Nash when he releases the ball = 9.12ft = 2.78m
Height of basketball hoop = 10ft = 3.05m
Time ball is in the air = 2.5 seconds
Time ball is in the air before another player deflects the shot = 0.3 seconds
Time ball is in the air after another player deflects the shot = 2.2 seconds

The following two equations will be used to relate the initial velocity and angle to the time the ball is in the air:

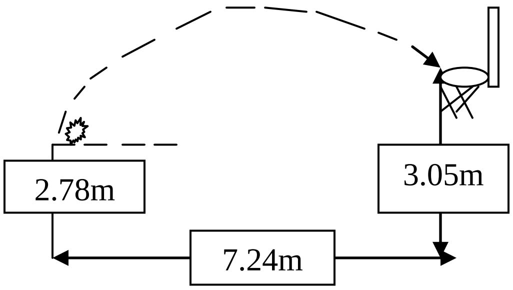
$y(t) = v_0 \cdot \sin\alpha \cdot t - (1/2) \cdot g \cdot t^2 + y_0$
This equation will be used to solve the angle Nash makes when he releases the ball.

$x(t) = v_0 \cdot \cos\alpha \cdot t$
This equation accounts for the range—how far the ball is from the hoop when it is released.

Bird's eye view of basketball court:



Part 1: Projectile



Side view of Nash shooting a three pointer at the top of the three point line.

= α = The angle of the arc Nash makes when he shoots the ball.

$y(t) = v_0 * \sin\alpha * t - (1/2) * g * t^2 + y_0$

$3.05 = 7.24 / (\cos\alpha * t) * \sin\alpha * t - (1/2) * 9.8 * t^2 + 2.78$

$0.27 = 7.24 * \tan\alpha - 4.9 * t^2$

$x(t) = v_0 * \cos\alpha * t$

$7.24 = v_0 * \cos\alpha * t$

$7.24 / (\cos\alpha * t) = v_0$

If t = 2.5 seconds the ball is in the air then…

$0.27 = 7.24 * \tan\alpha - 4.9 * 2.5^2$

$30.90 = 7.24 * \tan\alpha$

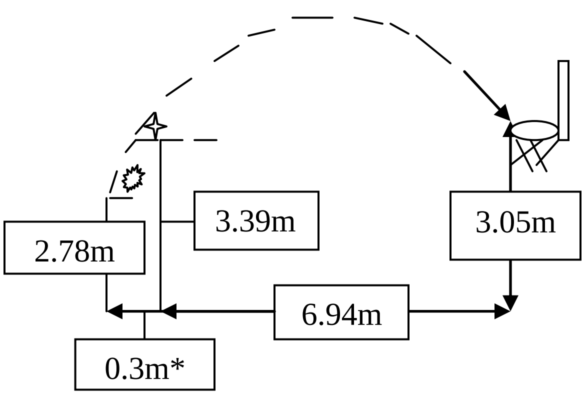
$\tan^{-1} (30.90 / 7.24) = \alpha$

$76.8° = \alpha$

$7.24 / (\cos((76.8) * 2.5) = v_0$

$12.7 \text{ m/s} = v_0$

Part 2: Double Projectile



Side view of another player deflecting Nash's shot upwards at the top of the three point line.

*The distance between Nash and the player who deflects the ball.

= α_1 = The angle of the arc the ball makes when Nash shoots the ball.

= α_2 = The angle of the arc the ball makes when a player jumps up and deflects it up.

$y(t) = v_0 * \sin\alpha_1 * t - (1/2) * g * t^2 + y_0$
$3.05 = v_0 * \sin\alpha_1 * t - (1/2) * g * t^2 + y_0$
$3.05 = 0.3 / (\cos\alpha_1 * t) * \sin\alpha_1 * t - (1/2) * 9.8 * 0.3^2 + 2.78$

$x(t) = v_0 * \cos\alpha_1 * t$
$0.3 = v_0 * \cos\alpha_1 * t$
$0.3 / (\cos\alpha_1 * t) = v_0$

If t = 0.3 seconds before the ball is deflected then…
$0.27 = 0.3 * \tan\alpha_1 - 4.9 * 0.3^2$
$0.711 = 0.3 * \tan\alpha_1$
$\tan^{-1}(0.711 / 0.3) = \alpha_1$
$67.1° = \alpha_1$

$0.3 / (\cos((67.1°) * 0.3) = v_0$
$2.57 m/s = v_0$

After the ball is deflected upwards, it spends 2.2 seconds in the air…
$y(t) = v_1 * \sin\alpha_2 * t - (1/2) * g * t^2 + y_0$
$3.05 = 6.94 / (\cos\alpha_2 * t) * \sin\alpha_2 * t - (1/2) * 9.8 * 2.2^2 + 3.39$
$-0.34 = 6.94 * \tan\alpha_2 - 4.9 * 2.2^2$
$23.4 = 6.94 * \tan\alpha_2$
$\tan^{-1}(23.4 / 6.94) = \alpha_2$
$73.5° = \alpha_2$

$x(t) = v_1 * \cos\alpha_2 * t$
$6.94 = v_1 * \cos\alpha_2 * t$
$6.94 / (\cos\alpha_2 * t) = v_1$

$6.94 / (\cos(73.5°) * 2.2) = v_0$
$11.1 m/s = v_0$

Conclusion

In Part 1: Projectile, Nash makes a 76.8° angle with respect to the floor when he shoots a three pointer at the top of the three point line. The value of y_0 is 2.78m, which is the height at which Nash releases the ball. If the ball is in the air for 2.5 seconds after Nash shoots the ball, then its speed is 12.7 m/s before it goes through the hoop.

In Part 2: Double Projectile, Nash's three point shot is deflected after being in the air for 0.3 seconds. The angle, α, from Part 1 is different from the angle, α_1, in Part 2 because there is another player who deflects the shot. After the player deflects the shot, the value of y_0 must change to the height it is deflected at, which is 3.39m. Now the angle, α_2, the ball makes is 73.5°. The ball must now travel 11.1 m/s to still go through the hoop.

It is very unlikely for a ball to carry enough speed after a deflection and continue on a straight path to the hoop. The diagrams and calculations above are tested under perfect conditions—air resistance is negligible, and the ball is deflected straight up, instead of being swatted in another direction. Double projectiles are common in the world of sports, and calculus based physics can help determine different variables of them.