NAME PERIOD DATE

SOCCER PHYSICS: WORLD CUP 2022

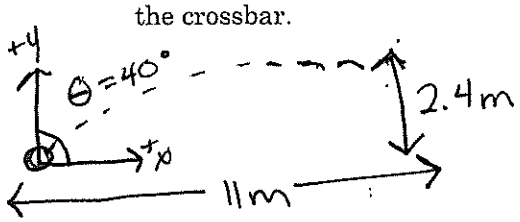
1. While warming up for a match at the World Cup, Neymar challenges Aleksandar Mitrović to a crossbar challenge. Both players must take their shot 11 meters away from the goal, but the angle and speed of their kicks can vary. The crossbar is 2.4 meters above the ground. Assuming air resistance is negligible, answer the following questions:

a. If Neymar kicks the ball at a 40° angle, and it takes .87 seconds to hit the crossbar, what must the initial speed of the ball be?

b. Mitrović launches the ball at a 41° angle with a velocity of 18.4 m/s. It flies through the air, passing 1 meter above the crossbar. How long is the ball in the air?

c. Challenge Question: The next round, Mitrović kicks the ball with an initial velocity of 21.0 m/s. Determine the minimum and maximum kicking angles required for the ball to make contact with the crossbar.

A)



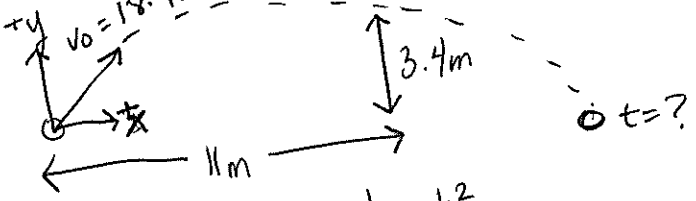
$t = 0.87s$

$x = x_0 + v_0 \cos\theta\, t$

$11 = 0 + v_0 \cos 40°(0.87s)$

$\boxed{v_0 = 16.5\ m/s}$

B)



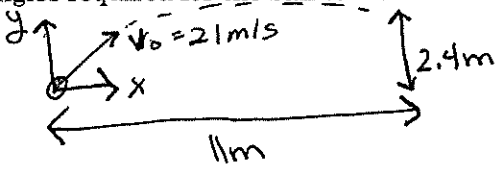
$y = y_0 + v_{oy}t + \frac{1}{2}at^2$

$0 = 0 + 18.4\sin 41°\, t + \frac{1}{2}(-9.8)t^2$

$4.9t^2 - 12.1t = 0$

$t = \frac{12.1}{4.9} = \boxed{2.47s}$

C)



$y = y_0 + v_{oy}t + \frac{1}{2}at^2$

$2.4 = 0 + 21\sin\theta\, t + \frac{1}{2}(-9.8)t^2$

X motion:

$x = x_0 + v_{ox}t$

$11 = 0 + 21\cos\theta\, t$

$t = \frac{11}{21\cos\theta}$

$2.4 = 11\frac{\sin\theta}{\cos\theta} - \frac{1.344}{\cos^2\theta}$

$2.4 = 11\tan\theta - 1.344(1 + \tan^2\theta)$

$2.4 = 11\tan\theta - 1.344 - 1.344\tan^2\theta$

$1.344\tan^2\theta - 11\tan\theta + 3.744 = 0$

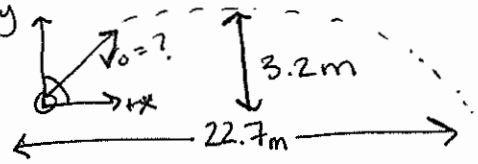
$\tan\theta = \frac{11 \pm \sqrt{(11)^2 - 4(1.344)(3.744)}}{2(1.344)}$

$\tan\theta = 7.828, 0.356$

$\theta = 82.72°$

$19.60°$

2. During a World Cup match, Lionel Messi kicks the ball at a 45° angle from ground level. It reaches a maximum height of 3.2 meters and lands 22.7 meters down the pitch. Assuming air resistance is negligible, answer the following questions:



a. What is the initial vertical velocity of the ball?

b. How long does it take for the soccer ball to reach the ground?

c. What is the initial horizontal velocity of the ball?

A) $y = y_0 + V_{0y}t + \frac{1}{2}at^2$

$0 = 3.2 + 0t + \frac{1}{2}(-9.8)t^2$

$t = 0.81s$

$V_y = V_{0y} + at$

$0 = V_{0y} - 9.8(0.81s)$

$\boxed{V_{0y} = 7.94 m/s}$

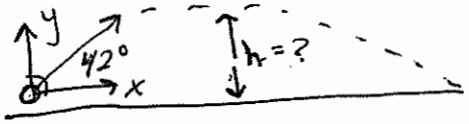
B $t_{total} = 2(0.81)$

$\boxed{t_{tot} = 1.62s}$

C) At 45° $V_{0x} = V_{0y}$

$\boxed{V_{0x} = 7.94 m/s}$

3. When the soccer ball leaves the field during a match, a corner kick is performed to restart the game. To perform a successful corner kick, the player must kick the ball at just the right angle, so that it bypasses opponents and lands near teammates. During a practice session for the World Cup, Cristiano Ronaldo makes a corner kick at a 42° angle, launching the soccer ball with an initial velocity of 26 m/s. Assuming the ball travels with projectile motion and air resistance is negligible, answer the following questions:



$V_0 = 26 m/s$

a. At what time does the soccer ball reach its peak height?

b. What is the maximum height reached by the soccer ball?

A) $V_y = V_{0y} + at$

$0 = 26\sin 42° - 9.8t$

$\boxed{t = 1.78s}$

B) $y = y_0 + V_{0y}t + \frac{1}{2}at^2$

$y = 0 + 26\sin 42°(1.78) + \frac{1}{2}(-9.8)(1.78)^2$

$\boxed{y = 15.44m}$

4. While practicing for the World Cup, Kylian Mbappé kicks the ball from the ground at a 41° angle. As the ball launches with an initial speed of 28.5 m/s, an opponent 54 meters away at the opposite side of the soccer field begins running to get the ball. What is the average speed he must maintain in order to make contact with the ball just before it hits the ground?

y $\begin{cases} y = y_0 + V_{0y}t + \frac{1}{2}at^2 \\ 0 = 0 + (28.4\sin 41)t + \frac{1}{2}(-9.8)t^2 \end{cases}$

$t = 3.81s$

x $\begin{cases} X = X_0 + V_{0x}t \rightarrow X = 0 + 28.5\cos 41(3.81s) \\ X = 81.95m \end{cases}$

$X = V_0 t$

$(81.95 - 54m) = V_0(3.81)$

$\boxed{V_0 = 7.3 m/s}$