Name: KEY - DO NOT REPRODUCE Due Date:

Assignment 4.01: Horizontal Projectiles - KEY

1. You throw a rock at 18 m/s directly toward the horizon while standing at the edge of a 25 meter tall cliff.

   (a) How long does it take the rock to hit the ground?

   Using Downward as Positive: $d_y = \cancelto{0}{v_{iy}t} + \frac{1}{2}a_yt^2 \longrightarrow t = \sqrt{\frac{2d_y}{a_y}} = \sqrt{\frac{2\times25m}{9.81m/s^2}} \approx 2.258s$

   (b) How far does the rock land from the bottom of the cliff?

   $d_x = v_{ix}t + \cancelto{0}{\frac{1}{2}a_xt^2} = 18m/s \times 2.258s \approx 40.637m$

   (c) What is the speed that the rock hits the ground at?

   In the X-Direction: $v_{fx} = v_{ix} + \cancelto{0}{a_xt} = 18m/s$

   In the Y-Direction: $v_{fy} = \cancelto{0}{v_{iy}} + a_yt = 9.81m/s^2 \times 2.258s \approx 22.147m/s$

   ${v_f}^2 = {v_{fx}}^2 + {v_{fy}}^2 \longrightarrow v_f = \sqrt{{v_{fx}}^2 + {v_{fy}}^2} = \sqrt{(18m/s)^2 + (22.147m/s)^2} \approx 28.539m/s$

   (d) What is the angle of impact of the rock?

   $tan(\theta) = \frac{opp}{adj} \longrightarrow \theta = tan^{-1}(\frac{opp}{adj}) = tan^{-1}(\frac{v_{fy}}{v_{fx}}) = tan^{-1}(\frac{22.147m/s}{18m/s}) \approx 50.9°$

2. A soldier is practicing at the shooting range. The target is 23 meters away. His rifle has a muzzle-speed of 150 m/s and it is perfectly level with the ground.

   (a) How long does it take the bullet to hit the target?

   $d_x = v_{ix}t + \cancelto{0}{\frac{1}{2}a_xt^2} \longrightarrow t = \frac{d_x}{v_{ix}} = \frac{23m}{150m/s} \approx 0.153s$

   (b) How far does the bullet drop during this time?

   Using Downward as positive: $d_y = \cancelto{0}{v_{iy}t} + \frac{1}{2}a_yt^2 = \frac{1}{2}(9.81m/s^2)(0.153)^2 \approx 0.115m$

3. A pitcher throws a curve-ball at 20 m/s toward home plate, perfectly horizontal. The ball leaves his hand 1.5 meters above the ground.

   (a) How far does the ball go?

   In the Y-Direction: $d_y = \cancelto{0}{v_{iy}t} + \frac{1}{2}a_yt^2 \longrightarrow t = \sqrt{\frac{2d_y}{a_y}} = \sqrt{\frac{(2)(1.5m)}{9.81m/s^2}} \approx 0.553s$

   In the X-Direction: $d_x = v_{ix}t + \cancelto{0}{\frac{1}{2}a_xt^2} = (20m/s)(0.533s) \approx 11.060m$

   (b) With what velocity (magnitude and direction) does the ball hit the ground?

   In the X-Direction: $v_{fx} = v_{ix} + \cancelto{0}{a_xt} = 20m/s$

   In the Y-Direction: $v_{fy} = \cancelto{0}{v_{iy}} + a_yt = 9.81m/s^2 \times 0.553s \approx 5.425m/s$

   ${v_f}^2 = {v_{fx}}^2 + {v_{fy}}^2 \longrightarrow v_f = \sqrt{{v_{fx}}^2 + {v_{fy}}^2} = \sqrt{(20m/s)^2 + (5.425m/s)^2} \approx \underline{20.723m/s}$

   $tan(\theta) = \frac{opp}{adj} \longrightarrow \theta = tan^{-1}(\frac{opp}{adj}) = tan^{-1}(\frac{v_{fy}}{v_{fx}}) = tan^{-1}(\frac{5.425m/s}{20m/s}) \approx \underline{15.176}°$

4. A cannon is placed on a wall, 25 meters above the surrounding area. The cannon shoots cannonballs at a speed of 350 m/s, and is aimed at the horizon.

   (a) What is the distance that the cannonball travels?

   In the Y-Direction: $d_y = \cancelto{0}{v_{iy}t} + \frac{1}{2}a_y t^2 \longrightarrow t = \sqrt{\frac{2d_y}{a_y}} = \sqrt{\frac{(2)(25m)}{9.81m/s^2}} \approx 2.258s$

   In the X-Direction: $d_x = v_{ix}t + \cancelto{0}{\frac{1}{2}a_x t^2} = (350m/s)(2.258s) \approx 790.166m$

   (b) What is the speed that the cannonball hits the ground with?

   In the X-Direction: $v_{fx} = v_{ix} + \cancelto{0}{a_x t} = 350m/s$

   In the Y-Direction: $v_{fy} = \cancelto{0}{v_{iy}} + a_y t = 9.81m/s^2 \times 2.258s \approx 22.147m/s$

   $v_f{}^2 = v_{fx}{}^2 + v_{fy}{}^2 \longrightarrow v_f = \sqrt{v_{fx}{}^2 + v_{fy}{}^2} = \sqrt{(350m/s)^2 + (22.147m/s)^2} \approx 350.700m/s$

   (c) What is the angle of impact for the cannonball?

   $tan(\theta) = \frac{opp}{adj} \longrightarrow \theta = tan^{-1}(\frac{opp}{adj}) = tan^{-1}(\frac{v_{fy}}{v_{fx}}) = tan^{-1}(\frac{22.147m/s}{350m/s}) \approx 3.614°$

5. Billy-Bob rolls a bowling ball off a 35-meter high cliff. The ball lands 15 meters away from the bottom of the cliff.

   (a) What is the amount of time it takes the ball to hit the ground?

   In the Y-Direction: $d_y = \cancelto{0}{v_{iy}t} + \frac{1}{2}a_y t^2 \longrightarrow t = \sqrt{\frac{2d_y}{a_y}} = \sqrt{\frac{(2)(35m)}{9.81m/s^2}} \approx 2.671s$

   (b) What is the initial velocity of the ball?

   In the X-Direction: $d_x = v_{ix}t + \cancelto{0}{\frac{1}{2}a_x t^2} \longrightarrow v_{ix} = \frac{d_x}{t} = \frac{15m}{2.671s} = 5.615m/s$

   (c) What is the final velocity of the ball (speed and direction)?

   In the X-Direction: $v_{fx} = v_{ix} + \cancelto{0}{a_x t} = 5.615m/s$

   In the Y-Direction: $v_{fy} = \cancelto{0}{v_{iy}} + a_y t = 9.81m/s^2 \times 2.671s \approx 26.205m/s$

   $v_f{}^2 = v_{fx}{}^2 + v_{fy}{}^2 \longrightarrow v_f = \sqrt{v_{fx}{}^2 + v_{fy}{}^2} = \sqrt{(5.615m/s)^2 + (26.205m/s)^2} \approx \underline{26.780m/s}$

   $tan(\theta) = \frac{opp}{adj} \longrightarrow \theta = tan^{-1}(\frac{opp}{adj}) = tan^{-1}(\frac{v_{fy}}{v_{fx}}) = tan^{-1}(\frac{26.780m/s}{5.615m/s}) \approx \underline{77.905}°$

6. You are attempting to drive your car over a 2.25-meter wide gap in the road. If both sides of the road are at the same height, are are perfectly level, how fast would you need to go in order to make it across?

   This is impossible to do. A simple proof is shown below:

   In the Y-Direction: $d_y = \cancelto{0}{v_{iy}t} + \frac{1}{2}a_y t^2 \longrightarrow t = \sqrt{\frac{2d_y}{a_y}} = \sqrt{\frac{(2)(0m)}{9.81m/s^2}} = 0s$

   In the X-Direction: $d_x = v_{ix}t + \cancelto{0}{\frac{1}{2}a_x t^2} \longrightarrow v_{ix} = \frac{d_x}{t} = \frac{2.25m}{0s} = undefined$