# Projectile Motion Application

Name: ____________

Date: ____________

1. Add these physics facts to your booklet:

- A projectile moves horizontally with constant velocity and vertically with constant acceleration of -g (free fall).
- A projectile's horizontal and vertical motions are independent

2. Circle all the factors that affect the amount of time a ball that is launched horizontally spends in the air. (Assume air resistance is negligible for this entire unit.)

[✓ height of the launch above the ground]
[✓ strength of the gravitational field at that location]
mass of the ball
horizontal launch speed
time of day

3. Two balls roll across a table, then off the table, landing on the floor. Ball 1 has speed $v_o$ on the table, and Ball 2 has speed $2v_o$ on the table.

a. Compare the amount of time Ball 1 and Ball 2 spend in the air. Justify your answer.

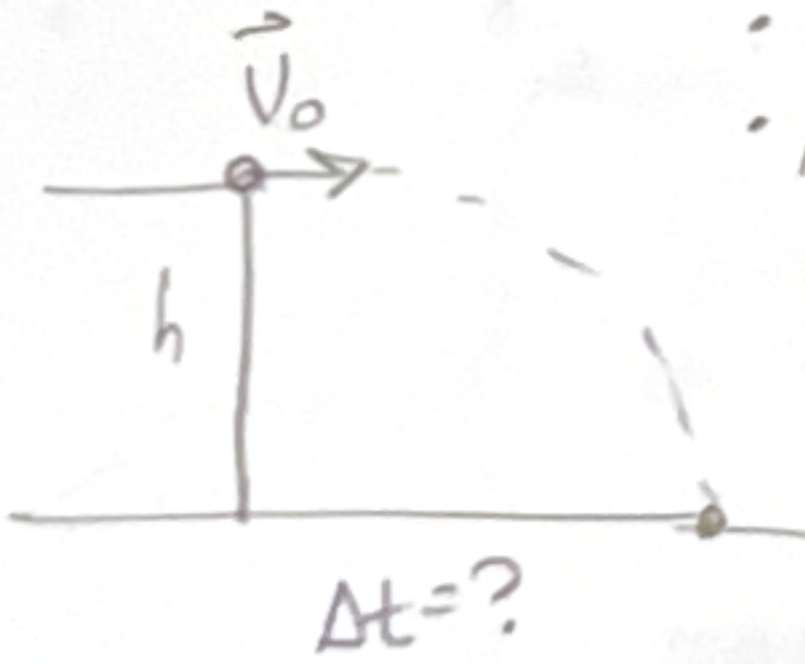
The time in the air depends on the vertical motion, and since they both have the same initial vertical velocity and $\Delta y$, they will spend the same amount of time in the air.

b. Compare the landing distances of Ball 1 and Ball 2 from the table. Justify your answer.

The landing distance depends on the horizontal velocity and the time in the air. They both spend the same time in the air, but Ball 2 is moving faster horizontally, so Ball 2 lands further from the table.

c. Derive an expression for the time spent in the air in terms of the height of the table *h*, and fundamental constants as appropriate. (Be sure to make a sketch and list variables!)

- Find $\Delta t$
- Analyze from Launch to Landing



| H | V |
|---|---|
| $\Delta x =$ | $\Delta y = -h$ |
| $V_x =$ | $V_{iy} = 0$ |
| $\Delta t =$ | $V_{fy} =$ |
| | $a_y = -g$ |
| | $\Delta t = ?$ |

$$\Delta y = V_{iy}\Delta t + \frac{1}{2}a_y \Delta t^2$$

$$-h = 0(\Delta t) + \frac{1}{2}(-g)\Delta t^2$$

$$-h = -\frac{g}{2}\Delta t^2$$

$$\boxed{\sqrt{\frac{2h}{g}} = \Delta t}$$

d. If the height of the table is doubled, by what factor does the time in the air change?

$$\Delta t_1 = \sqrt{\frac{2h}{g}}$$

$$\Delta t_2 = \sqrt{\frac{2(2h)}{g}} = \sqrt{2}\sqrt{\frac{2h}{g}} = \sqrt{2}\,\Delta t_1$$

$\boxed{\text{It changes by } \sqrt{2}}$

e. Derive an expression for the landing distance $d_1$ of Ball 1 in terms of the height of the table $h$, the launch velocity $v_o$, and fundamental constants as appropriate.

- Find $d_1$
- Analyze from launch to landing

| H | V |
|---|---|
| $\Delta x = d$ | $\Delta y = -h$ |
| $V_x = V_o$ | $V_{iy} = 0$ |
| $\Delta t =$ | $V_{fy} =$ |
| | $a_y = -g$ |
| | $\Delta t =$ |

I know from (c) the time is $\Delta t = \sqrt{\frac{2h}{g}}$.

Looking at the horizontal direction,

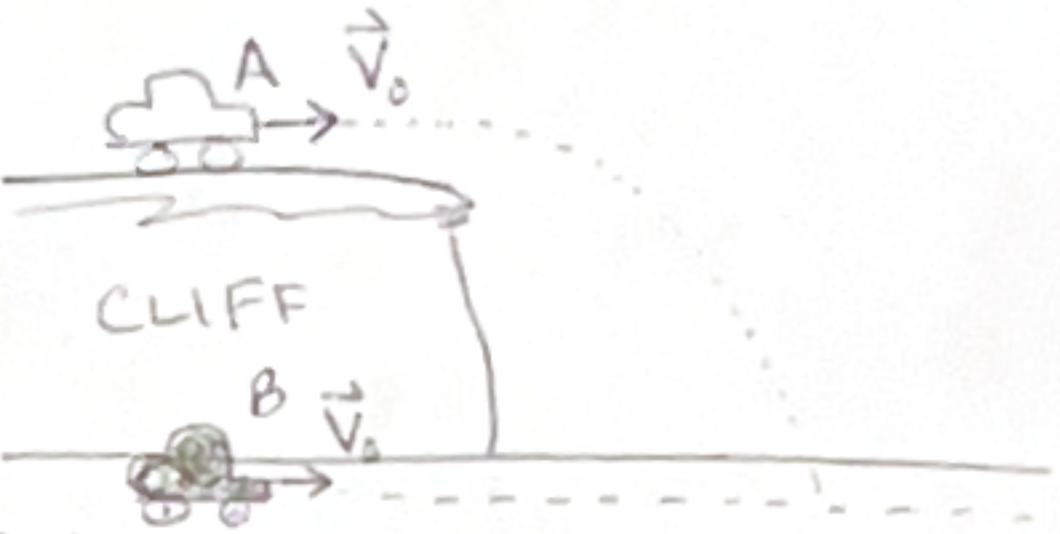
$$\Delta x = V_x \cdot \Delta t \quad (\text{or: } x_f = x_i + V_x \Delta t)$$

$$\boxed{d = V_o\left(\sqrt{\frac{2h}{g}}\right)}$$

f. If the launch velocity is doubled, by what factor does the landing distance change?

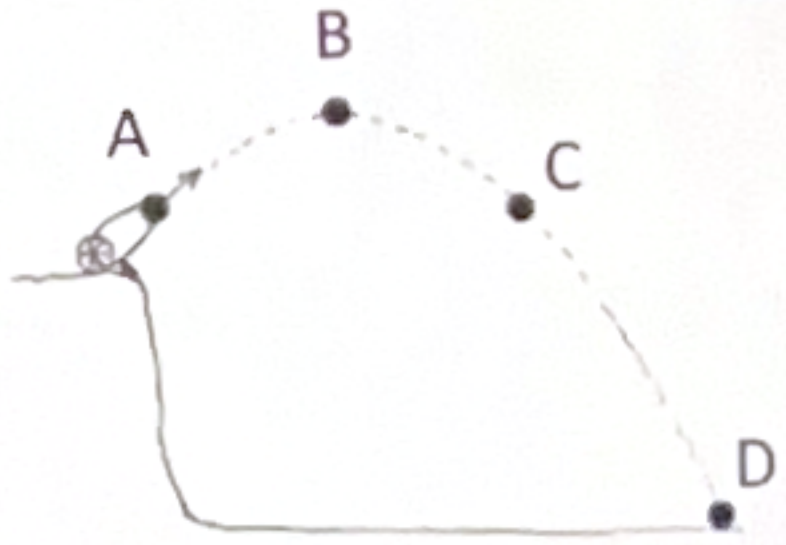
The distance is directly proportional to $V_o$, so if $V_o$ doubles, the distance doubles.

5. Two cars are moving horizontally with the same speed. Car A is driving at ground level, and Car B is directly above on a cliff. After Car A drives off the cliff, where does it land relative to Car B? Justify your answer.



The projectile car A keeps moving horizontally at the same speed while it is falling, so it is always vertically aligned with car B. It will land beside car B.

6. This picture shows the initial launch of a cannonball from the edge of a cliff at an angle on the earth.



a. For each possible change to the situation below, circle the answer that indicates how that change, by itself, would affect the amount of time the cannonball spends in the air, as compared to the initial launch.

- Aim the cannon at a higher angle: *[✓ Increase], decrease, no change*
- Aim the cannon horizontally: *Increase, [✓ decrease], no change*
- Aim the cannon at a downward angle: *Increase, [✓ decrease], no change*
- Launch the cannon from a higher cliff: *[✓ Increase], decrease, no change*
- Launch the cannon on the moon: *[✓ Increase], decrease, no change*
- Use more gunpowder: *[✓ Increase], decrease, no change*
- Use a heavier cannonball: *Increase, decrease, [✓ no change]*

b. At what point on the trajectory does the cannonball's velocity have the greatest magnitude? D The least magnitude? B

c. Does the force on the cannonball increase, decrease, or stay the same during its flight? same

d. Is the acceleration of the cannonball at A greater than, equal to, or less than the acceleration of the cannonball at D, the instant before it impacts the ground? equal

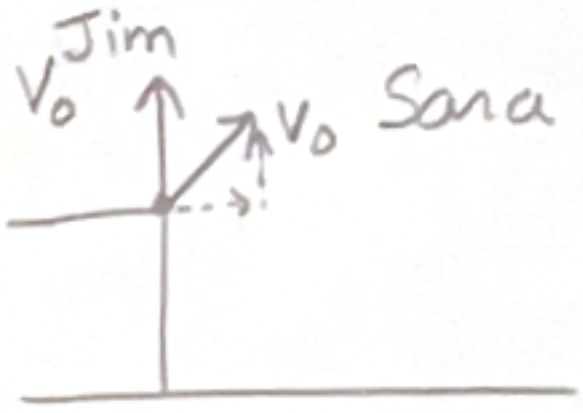
e. What is the acceleration of the cannonball at point B? $-10\ m/s^2$

f. At what point(s) on the trajectory are $\vec{v}$ and $\vec{a}$ parallel to each other? never

g. At what point(s) on the trajectory are $\vec{v}$ and $\vec{a}$ are perpendicular to each other? B

h. Which of the following quantities are constant and non-zero during the flight: x, y, $v_x$, $v_y$, v, $a_x$, $a_y$? $V_x$, $a_y$ Which are equal to zero during the entire flight? $a_x$

7. ~~14~~. Jim and Sara stand at the edge of a cliff on the moon. Jim extends his arm over the cliff edge and throws a ball straight up with an initial speed of $v_o$. Sara throws an identical ball with the same initial speed, but she throws the ball at an angle of θ above the horizontal.



For each question, choose your answer ~~and explain briefly~~.

a. Which ball takes more time to reach the ground?
Sara's [✓ Jim's] Both are the same

b. Which ball reaches a greater maximum height above the ground?
Sara's [✓ Jim's] Both are the same

c. Consider each ball at the highest point in its flight. At this point:

i. Which ball has the greater vertical velocity?
Sara's Jim's [✓ Both are the same]

ii. Which ball has the greater horizontal velocity?
[✓ Sara's] Jim's Both are the same

iii. Which ball's velocity vector has greater magnitude?
[✓ Sara's] Jim's Both are the same

d. Now consider each ball just before it hits the ground. At this point, which ball has the greater vertical velocity?
Sara's [✓ Jim's] Both are the same

e. Which ball reaches the peak of its flight more quickly after being thrown?
[✓ Sara's] Jim's Both are the same

References:
#6 is adaped from Knight, Physics for Scientists + Engineers, and #14 is adapted from a post by Greg Jacobs on AP Central.