VII. Discussion Questions

1. At what launch angle θ is the maximum horizontal displacement, or range of the projectile, achieve its greatest numeric value?

   45 degrees. See the lab.

2. What is the vertical velocity when a projectile is at its maximum height? Explain.

   0.00 m/s; the ball's vertical velocity changes from a positive to a negative value.

3. How does doubling the velocity from v_0 to $2v_0$ affect the maximum height y_{max}? By what specific numerical factor is it increased? Hint: see Table 1 above.

   If the initial velocity is doubled, then the maximum height quadruples; by a factor of 4.

4. How does doubling the velocity from v_0 to $2v_0$ affect the time t_{ymax} to reach its maximum height y_{max}? By what specific numerical factor is it increased?

   If the initial velocity is doubled, then the time to reach maximum height is doubled; by a factor of 2.

5. How does doubling the velocity from v_0 to $2v_0$ affect the range R, the maximum horizontal displacement? By what specific numerical factor is it increased?

   If the initial velocity is doubled, then the range quadruples; by a factor of 4.

6. How do you calculate the total travel time t_{total} of the projectile if you know the time t_{ymax} to reach its maximum height y_{max}?

   Double the time to reach the maximum height to get the total flight time.

7. How would tripling the velocity from v_0 to $3v_0$ affect the maximum height y_{max}? By what specific numerical factor would it be increased? Hint: see the note below Table 1.

   If the initial velocity is tripled, then the maximum height is multiplied by a factor of 9.

8. How would tripling the velocity from v_0 to $3v_0$ affect the time t_{ymax} to reach its maximum height y_{max}? By what specific numerical factor would it be increased?

   If the initial velocity is tripled, then the time to reach maximum height is multiplied by a factor of 3.

9. How would tripling the velocity from v_0 to $3v_0$ affect the range x, the horizontal distance? By what specific numerical factor would it be increased?

   If the initial velocity is tripled, then the range is multiplied by a factor of 9.

Part 2: Projectiles

10. Which one of the two balls do you and your team members think will land first? Explain your reasoning.

    Answers vary.

11. What actually happened when you fired the balls? Did they land as you expected? Explain why or why not.

    The balls land at the same time.

12. Explain why the numeric value of the **vertical acceleration** for each of the two balls is the same. What is the numeric value of a_y? Why is it negative?

    The acceleration of gravity is the same on both balls. a_y = -9.81 m/s^2. The balls are falling downward.

13. What is the numeric value of the **initial vertical velocity** v_{0y} of the balls? Hint: read the instructions.

    v_{0y} = 0.00 m/s

14. Write the equation to calculate the **vertical displacement** y at time t. Hint: start with the kinematics equation $y = y_0 + v_{0y}t + \frac{1}{2}a_y t^2$ to calculate y and **simplify as much as possible**.

    $$y = y_0 + v_{0y}t - \frac{1}{2}gt^2 \rightarrow y = y_0 + v_{0y}t - \frac{1}{2}gt^2 \rightarrow y = -\frac{1}{2}gt^2$$

15. Solve the equation in the step directly above for time t, to reach fall displacement y. Neatly show your work.

    $$y = -\frac{1}{2}gt^2 \rightarrow 2y = -gt^2 \rightarrow t^2 = \frac{2y}{-g} \rightarrow t = \sqrt{\frac{2y}{-g}}$$

16. Describe the shape of the path of the ball with the **non-zero horizontal velocity**. “Curved” is not the correct answer. You must be more specific.

    The shape of the path is a parabola

17. Are the balls accelerating in the **horizontal** direction? Explain. Hint: read the instructions.

    No. We are assuming that the horizontal velocities are constant.

18. What is the numeric value of the horizontal velocity for the ball falling straight down?

v_{xdown} = <u>0.00 m/s</u>

19. Is the numeric value of the horizontal velocity v_x for the ball with the **non-zero horizontal** velocity negative or positive? Explain.

Positive, per the lab.

20. Write the equation to calculate the horizontal displacement x at time t for the ball with a non-zero horizontal velocity v_x. Hint: start with the kinematics equation $x = x_0 + v_{0x}t + \frac{1}{2}a_x t^2$ and simplify as much as possible.

$x = v_{0x}t$

21. Solve the equation in the step directly above for time t.

$t = \frac{x}{v_{0x}}$

22. Solve the equation in the step directly above for the initial horizontal velocity v_{0x}.

$v_{0x} = \frac{x}{t}$

23. In two previous steps, you derived two different equations for t, one involving x and the other involving y. Set them equal to each other and solve for y then replace v_{0x} with v_x. Neatly show your work.

$$t = \sqrt{\frac{2y}{-g}} \text{ and } t = \frac{x}{v_{0x}} \rightarrow \sqrt{\frac{2y}{-g}} = \frac{x}{v_{0x}} \rightarrow \frac{2y}{-g} = \left(\frac{x}{v_{0x}}\right)^2 \rightarrow y = \frac{-g}{2}\left(\frac{x}{v_{0x}}\right)^2 \rightarrow$$

$$y = \frac{-g}{2}\left(\frac{x}{v_x}\right)^2 \rightarrow y = \frac{-gx^2}{2v_x^2}$$

24. Demonstrate that $\frac{-g}{2v_x^2}$ is in units of $\frac{1}{meters}$. Include the units for each variable and neatly show your work.

$$\frac{m/s^2}{(m/s)^2} = \frac{m/s}{m^2/s^2} = \left(\frac{m}{s}\right)\left(\frac{s^2}{m^2}\right) = \frac{1}{m}$$

25. Demonstrate that $\frac{-gx^2}{2v_x^2}$ is in units of meters. Include the units for each variable and neatly show your work.

$$\frac{(m/s^2)(m)^2}{(m/s)^2} = \frac{(m/s)(m^2)}{m^2/s^2} = \left(\frac{m}{s^2}\right)(m^2)\left(\frac{s^2}{m^2}\right) = \frac{m^3}{m^2} = m$$

26. Calculate the numeric value of $\frac{-g}{2v_x^2}$. Neatly show your work.

See Excel answers.

27. Compare the numbers in Table 5, column B and Table 5, column D. They should be the same. Explain why. If they are not the same, you will need to redo your calculations.

Both are calculated using the same data.

28. Explain why θ is negative. Your answer must include a physical justification.

θ is negative because the projectile's path is downward as measured from the x-axis.