Projectiles - Desmos Style

Overview
In this activity, you will manipulate a graphical model that describes the relationship between the launch angle, launch height, launch speed, and the trajectory of a projectile in order to answer a variety of questions. The graphical model displays the trajectory on an x-y plot. The activity will not involve the algebraic manipulation of equations; rather, you will manipulate variables that are a part of the visual model. The variables that you will manipulate are the launch angle, launch height, and launch speed. This activity will be challenging because you will have to decide exactly how to manipulate the variables and how to interpret the graph in order to answer the questions. Turn on your noodle; it’s thinking time!

You will use the Desmos online graphing calculator to complete this activity:

https://www.desmos.com/calculator/dr8wajbdwo

Using the Model
The graph is a plot of the x- and y-position of a projectile as it travels through the air. The vertical axis is the vertical position (height) axis; the horizontal axis is the horizontal position. There are three variables that you can manipulate. They are:

- A = launch angle of projectile
- v = launch speed of projectile
- h = initial launch height of projectile

The value of these variables can be changed by dragging the corresponding slider found on the left side of the browser window or by typing a value into the accompanying box.

Resizing the Graph
The scale of the graph will change if you scroll when your cursor is inside the graph window. The scale can be reset back to its original settings by clicking on the wrench icon in the top right of the browser window. The original settings are

-10 < x < 240
-5 < y < 80

Use the graphical model to answer the following questions. They begin easy and get progressively more difficult.

1. Set the launch velocity (v) to 30.0 m/s and the launch height (h) to 0.0 m. Alter the angle (A) to determine the angle that leads to the greatest horizontal displacement.

   Angle with the Greatest Displacement = __________ degrees

2. Now raise the launch height (h) to 26.5 meters and keep the launch velocity at 30.0 m/s. What launch angle (A) leads to the greatest horizontal displacement? Is it the same answer as the previous question?
   a. Yes! Changing the launch height does not affect the angle that leads to the greatest displacement.
   b. No! When launched from an elevated location, a smaller angle is needed for the greatest displacement.
   c. No! When launched from an elevated location, a greater angle is needed for the greatest displacement.
3. Return the launch height \( h \) to 0.0 meters and set the launch velocity \( v \) to 20.0 m/s. Starting with 0 degrees, alter the launch angle \( A \) in order to answer the following question:

   Increasing the launch angle will cause the horizontal displacement to ______.
   a. always decrease ... for any range of angles
   b. always increase ... for any range of angles
   c. increase, but only for angles less than 45 degrees
   d. increase, but only for angles greater than 45 degrees

4. a. Set the launch height \( h \) to 0.0 m, the launch angle \( A \) to 60.0°, and the launch velocity \( v \) to 13.0 m/s. Determine the horizontal displacement of the projectile.
   Horizontal Displacement = __________ m

   b. Double the launch velocity to 26.0 m/s and keep all other variables the same. Determine the horizontal displacement of the projectile.
   Horizontal Displacement = __________ m

   Conclusion: Doubling the launch velocity causes the horizontal displacement to _____.
   a. double  b. halve
   c. quarter (become one-fourth the size)  d. quadruple (become four times greater)

5. a. Launch a projectile at 30.0 m/s and an angle of 60.0° from the ground. What is the maximum height to which the projectile rises?
   Maximum height = __________ m

   b. How far has the projectile traveled horizontally when it reaches this highest point?
   Horizontal displacement at Peak = __________ m

6. A place kicker (in football) must kick the football from a distance of 57.0 m from the goal posts. The goal posts are approximately 3.0 meters high. Suppose that he kicks the ball with a speed of 32.0 m/s at an angle of 35.0°. How high above the goal posts will the football be when it has traveled the horizontal distance of 57.0 meters?
   Height above goal posts = __________ m

7. A tennis match is being played indoors in a building with a very low, flat ceiling. A player lobbs a ball from a height of 1.0 m at an angle of 55° and a speed of 24 m/s. The ball travels a horizontal distance of 12.0 m before it hits the ceiling. What is the height of the ceiling?
   Height of Ceiling = __________ m
8. Now increase the initial height to 45 meters. Adjust the launch angle to 0° (as in a horizontally-launched projectile).
   a. If a projectile is launched horizontally from a cliff of this height with an initial speed of 10.5 m/s, how far from its base will it land?
      Horizontal distance from base of cliff = _________ m

   b. If a projectile is launched horizontally with twice the speed - 21.0 m/s - then how far from the base of the cliff will it land?
      Horizontal distance from base of cliff = _________ m

   **Conclusion:** An analysis of Parts (a) and (b) of this question indicate that doubling the launch speed of a horizontally-launched projectile will **double** the horizontal distance that it travels.
      a. not affect      b. double      c. quadruple      d. halve

9. a. Launch a projectile horizontally with a speed of 24.5 m/s from the top of a 32-meter high cliff. How far from the base of the cliff will the projectile land?
      Horizontal distance from base of cliff = _________ m

   b. Launch a projectile horizontally at the same speed from the top of a cliff that is twice as high. How far from the base of the cliff will the projectile land?
      Horizontal distance from base of cliff = _________ m

   **Conclusion:** An analysis of Parts (a) and (b) of this question indicate that doubling the launch height of a horizontally-launched projectile will increase the horizontal distance by a factor of _________.
      (Enter a decimal value.)

10. A cliff diver is running off a 42-meter high cliff. She needs to clear the rocks in the water below that stretch out a distance of 15.0 meters from the base of the cliff. What minimum speed must the diver have in order to safely clear the rocks? (NOTE: The slider changes the launch speed by 0.5. You may need to type values into the field that are not multiples of 0.5 - for instance, 14.7.)
      Minimum speed = _________ m/s (include at least two digits on your answer)