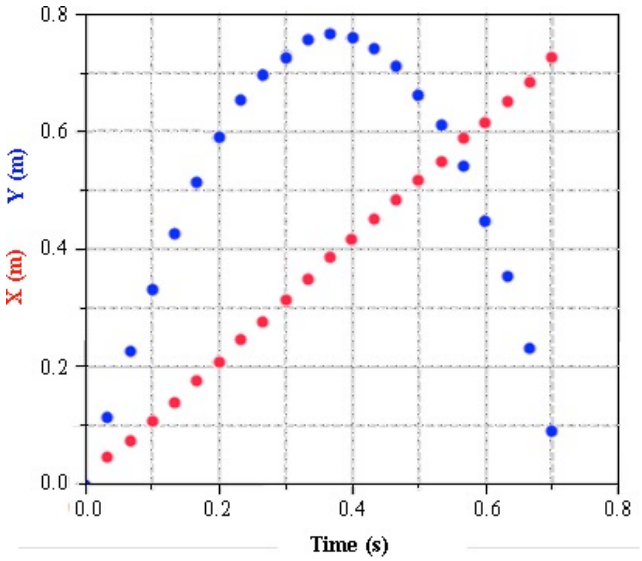
Up and Down

A physics teacher does a demonstration to illustrate principles of projectile motion. A projectile is an object upon which the only force of influence is gravity. The demonstration involves a cart that is equipped with a spring-loaded launcher and a plastic ball that is launched by the launcher. When the cart is at rest, the ball is launched straight upwards and lands back in the cart. Preceding the demonstration, the teacher asks students where they think the ball will land if it is launched from a cart that is moving with a constant speed. Will the ball land in front of the cart, in the cart, or behind the cart?

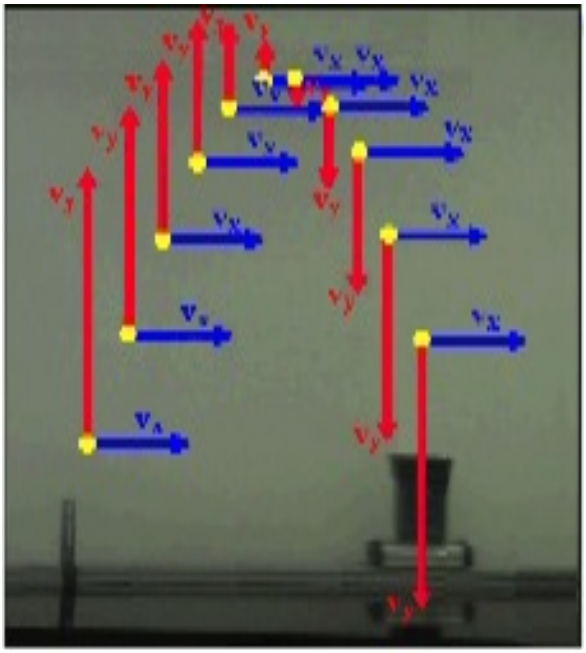
Figure 1



The motion of the cart and the launched ball is captured on video. The motion of the ball is analyzed using video analysis software. Among the information provided by the video analysis is information regarding the position and the velocity of the ball. **Figure 1** shows the horizontal position (**x**) and the vertical position (**y**) of the ball as a function of time. The origin of the graph corresponds to the release location of the ball.

In physics, velocity is a quantity that refers to how fast an object is moving and the direction the object is moving. The direction is often represented by a *vector arrow*. The direction of the arrow indicates the direction the object is moving. And the size of the arrow indicates how fast the object is moving. For objects with both horizontal and vertical motion, it is often useful to represent the velocity in the horizontal direction separate from the velocity in the vertical direction.

Figure 2



The video analysis software produces the graphic shown in **Figure 2.** The position of the ball at regular intervals of time is represented by a dot. The vector arrows represent the horizontal velocity (v_x) and vertical velocity (v_y) of the launched projectile. The constant speed cart is shown positioned just below the ball for the last position shown on the diagram. When the ball finally falls to launcher height, it lands in the launcher.

Questions:

1. What distance has the ball been traveling horizontally when it is at its highest point?
   a. 0.35 meters
   b. 0.38 meters
   c. 0.56 meters
   d. 0.77 meters

2. At which time is the ball moving upward located a distance of 0.40 meters above its launch position?
   a. 0.13 seconds
   b. 0.38 seconds
   c. 0.42 seconds
   d. 0.62 seconds

3. How high is the ball above the launcher when it has traveled a horizontal distance of 0.50 meters from its original launch position?
   a. 0.12 meters
   b. 0.57 meters
   c. 0.68 meters
   d. 0.72 meters

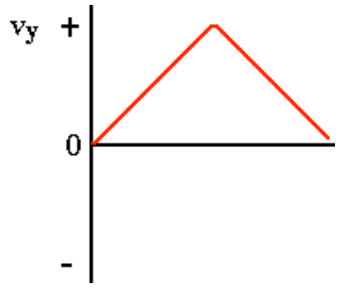
4. How far has the ball traveled horizontally when it is moving downward and located 0.40 meters above the launcher?
   a. 0.42 meters
   b. 0.57 meters
   c. 0.63 meters
   d. 0.76 meters

5. Based on the vector arrows shown in **Figure 2**, which one of the following statements is **NOT** true?
   a. The vertical velocity (v_y) of the ball increases as it rises towards the peak.
   b. The vertical velocity (v_y) always points in the direction that the ball is moving.
   c. The vertical velocity vector (v_y) is directed upward as the ball rises towards its peak.
   d. The direction of the vertical velocity (v_y) changes from upward to downward at the peak.

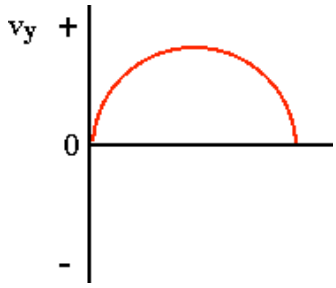
6. Which statement below is most closely associated with the reason for the ball landing in the launcher?
   a. The ball accelerates at a rate of 9.8 m/s/s.
   b. The horizontal speed of both the cart and the ball are constant.
   c. The velocity of the ball decreases as it rises and increases as it falls.
   d. The time it takes the ball to rise to its peak is equal to the time to fall from its peak.

7. The vector arrows in **Figure 2** are a pictorial representation of the velocity of the ball. Using a scale, the size of each vector arrow could be translated into a number. The number could be positive or negative, depending on the direction of the arrow. A positive number would represent an upward or a rightward arrow and a negative number would represent a downward or a leftward arrow. Which of the following graphical representations of the vertical velocity as a function of time would be consistent with the information in **Figure 2**?

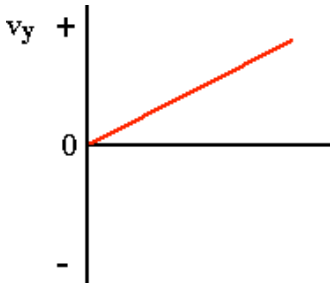
a.



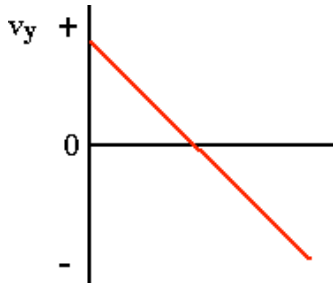
b.



c.

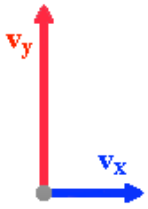


d.

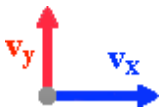


8. Which set of v_x and v_y vector arrows represents the velocity of the ball 0.10 seconds after being launched?

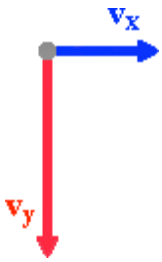
a.



b.



c.



d.