Unit 6 *Homework Problems*

Learning Goals:

A.6 For an object undergoing projectile motion, identify the forces acting on the object and qualitatively describe the resulting 2D motion in terms of position, velocity, and acceleration vs. time.

6-1) **What Are Gravitational Forces Like?:** Whenever an object is dropped from a distance very near the surface of the Earth, it speeds up in a downward direction with an acceleration of magnitude 9.8 m/s^2. Two students have come up with different explanations for this phenomenon:

Kasi argues: "An object tends to move with a *velocity that is proportional to the force on it* and when an object falls there must be a gravitational force on it. This gravitational force in the downward direction gets larger and larger as the object falls and gets closer to the Earth. This causes the velocity to get larger and larger as the object falls, so the object undergoes a constant acceleration because the force gets larger at a constant rate as the object falls.

Heather argues: "An object tends to move with *an acceleration that is proportional to the force on it*. Since all falling objects accelerate at a constant rate, there must be a special gravitational force attracting it toward the center of the Earth that is essentially constant near the surface of the Earth.

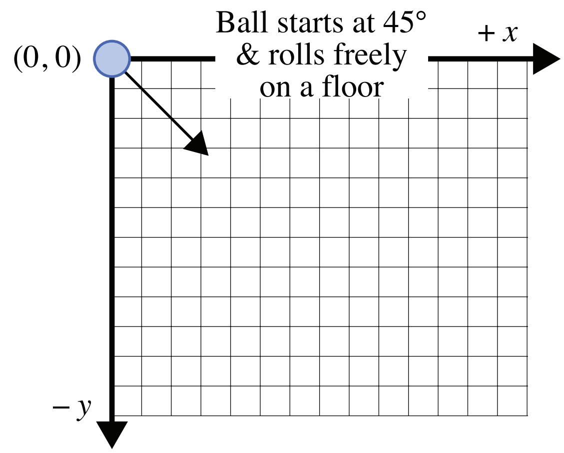
Do you agree with Kasi or with Heather? Which argument is invalid? What observations have you made that would support your opinion? **Hint**: Consider the implications of your observations in Activities 4.3.1, 5.3.2 (d), and 6.3.2.

6-2) **How Does A Ball Rise?:** Your partner argues the following about a ball that is tossed vertically upward after it leaves a person's hand: "At first when the ball is rising it experiences a net upward force left over from the toss that gets smaller and smaller as the ball rises." Do you agree with your partner's statement? What evidence do you have from your own observations and experiments to validate or invalidate the various assertions of your partner? **Hint**: Consider the implications of your observations in Activities 4.3.1, 5.3.2 (d), and 6.3.2..

6-3) **What Happens To The Ball At The Top Of Its Path ?:** Your partner argues the following about a ball that is tossed vertically upward: "At the top of its path the ball stops for a while so its velocity is zero. Also, the net force on it is zero so its acceleration is also zero." Do you agree with your partner's statement? What evidence do you have from your own observations and experiments to validate or invalidate the various assertions of your partner? **Hint**: Consider the implications of your observations in Activities 4.3.1, 5.3.2 (d), and 6.3.2..

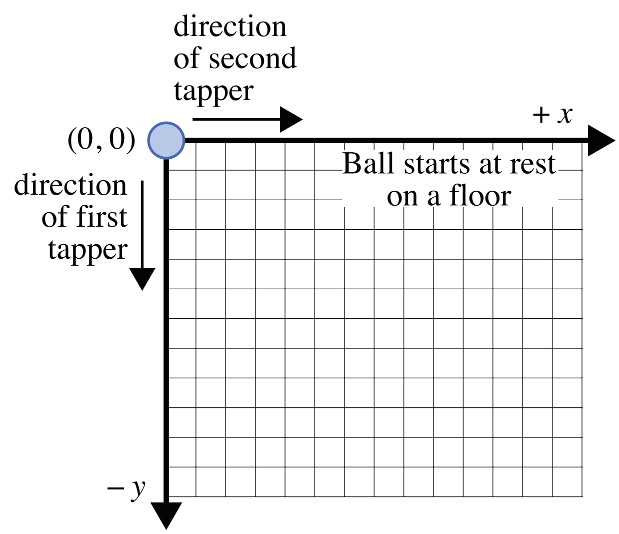
6-4) One of the most powerful attributes of science is the ability that scientists develop to generalize from their observations and then be able to make predictions about observations they have never made. What might happen to the bowling ball you worked with under various new circumstances? What might happen to a rocket launched horizontally from a tower?

(a) Suppose you were to roll the ball briskly in the direction shown and then left it alone. Can you predict what the resulting graph of its two-dimensional motion would look like? Sketch a graph frame like that shown to the right and then sketch the predicted motion in your graph. Explain the basis for your prediction.

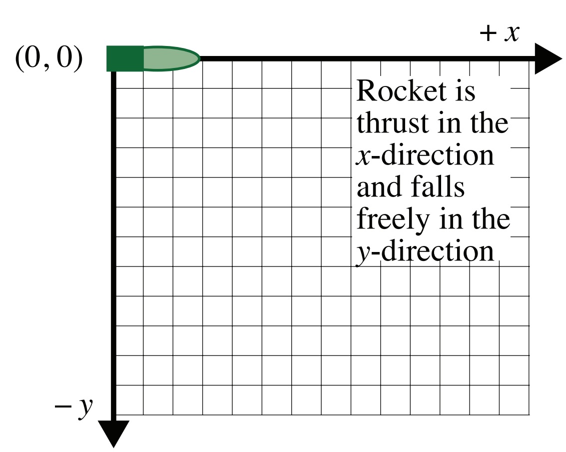


(b) If the initial speed of the ball is 3.5 m/s, what is the x-component of velocity, v_{1x}? Is the direction positive or negative? What is v_{1y}? Is the direction positive or negative?

(c) Suppose you and your partner were to each tap the ball rapidly with each set of taps being at right angles to the other. Can you predict what the resulting graph of its two-dimensional motion would look like? Sketch a graph frame like that shown to the right and then sketch the predicted motion in your graph. Explain the basis for your prediction.



(d) Suppose a rocket ship is thrust from a tower, resulting in a constant acceleration that has a magnitude of about 9.8 m/s^2 in the x-direction, and also allowed to fall freely toward the ground in the y-direction. Can you predict what the resulting graph of its two-dimensional motion would look like? Sketch a graph frame like that shown below and then sketch the predicted motion in your graph. Explain the basis for your prediction.



In exercises 6-5 and 6-6 you will use the Logger Pro software to explore and analyze the nature of a projectile launch depicted in a digital video movie with the filename PASCO106. In this movie a small ball of mass 9.5 g is launched at an angle θ with respect to the horizontal (positive x-axis).

6-5) Digital Projectile One

Use the Logger Pro software to scale the movie and collect data to explore the nature of the horizontal and vertical motions of the projectile. For this problem, **6-5**, don't do any curve fitting or modeling – you will do that in problem **6-6**. For simplicity, the origin in the video analysis has been set at the location of the ball at time $t_1 = 0$ seconds.

(a) What is the approximate angle, θ, with respect to the horizontal that the ball is launched at? ***Hint***: Use the two data points for x vs. t and y vs. t in the first two frames to find the approximate values for the x-component and y-component of velocity. Given that information, an "inverse tangent" calculation should give you the angle.

(b) Explain in which direction, x or y, the ball has a constant velocity and cite the real evidence (not just theoretical) for this constant velocity.

(c) Explain in which direction, x or y, the ball has a constant nonzero acceleration. Cite real evidence (not just theoretical) for this constant acceleration.

(d) Theoretically, what is the net vertical force on the 9.5 g ball when it is rising? Falling? Turning around? What is the observational basis for this theoretical assumption?

(e) Theoretically, what is the net horizontal force on the 9.5 g ball when it is rising? Falling? Turning around? What is the observational basis for this theoretical assumption?

(f) What do you predict will happen to the shapes of the x vs. t and y vs. t graphs if you rotate your coordinate system by 90° so that the x-axis points upward in the vertical direction and the y-axis points left in the horizontal direction?

(g) Rotate your coordinate system by +90° so that the x-axis points upward in the vertical direction and the y-axis points left in the horizontal direction. (To rotate the coordinate system, select the "Set Origin" icon (3rd icon down in the column of icons on the right) and then click and drag the yellow dot/circle on the x-axis of the coordinate system.) What happens to the shapes of the graphs? Is this what you predicted?

6-6) Digital Projectile Two

Use the Logger Pro software to find the equation that describes the horizontal motion x vs. t. Also, find the equation that describes the vertical motion y vs. t.

Please turn in your graphs with your assignment (*e.g.*, take screenshots of the graphs and include them in your submitted PDF file).

(a) According to your horizontal model, what is the equation that describes the horizontal position of the ball, x, as a function of time. What is the ball's horizontal acceleration component, a_x? What is its initial horizontal velocity component, v_{1x}?

(b) According to your vertical model, what is the equation that describes the vertical position, y, of the ball as a function of time. What is its vertical acceleration component, a_y? What is its initial vertical velocity component, v_{1y}?

(c) Use the initial velocity components v_{1x} and v_{1y} to compute the initial speed of the ball. What is the launch angle with respect to the horizontal?

(d) Compare your answer for the launch angle with the approximation you made in part (a) of problem **6-5**. Find the percent difference for comparison.

6-7) Problem 6.8.1 from the Activity Guide.