Unit 6 *Homework Problems*

- Carefully read the section 4 excerpt on unit vectors from chapter 1 of *Matter and Interactions*, a .pdf file included on the homework web page with this assignment.

To get credit for the homework problems, you must include all of the following:

1. All equations must be solved in symbol form before substituting in any numbers.
2. All numbers substituted into the equations must have the correct units and number of significant figures, and the correct vector notation (where appropriate).
3. All final numerical answers must have the correct units, correct number of significant figures, and correct vector notation (where appropriate),
4. All problems should include a reference to the Activity Guide activity or activities that are related to the problem, a discussion of ***how*** the activity is related, and a discussion of the ***concepts*** that were learned in the activity.

UNIT 6 HOMEWORK AFTER SESSION ONE

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 4.4.1, 5.2.4 (d), 6.3.3, and 6.3.4.

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 4.4.1, 5.2.4 (d), 6.3.3, and 6.3.4.

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 4.4.1, 5.2.4 (d), 6.3.3, and 6.3.4.

6-4) The Demon Drop is a popular ride at the Cedar Point Amusement Park in Ohio. It allows 4 people to get into a little cage and fall freely for a while. Physics professor Bob Speers of Firelands College in Huron, Ohio took a videotape of the drop. A digital movie with the file name DSON001 has been made of one of the Demon Drop falls. Use Logger Pro and Excel to analyze and develop a ***mathematical model*** (rather than a fit using "Add Trendline …") that describes the fall. You should use a conventional coordinate system to express all your vector quantities and vector components in which the positive *y*-axis points up. The coordinate system origin has been placed so that the bottom of the cage has a position in the first frame as close as possible to $y_1 = +28$ m.

(a) Include a printout of your spreadsheet data, graph, and model along with the answers to questions (b) through (e).

(b) According to your model, what is the equation that you think describes the *y*-component (denoted *y*) of the vertical position of the bottom of the cage as a function of time?

(c) According to your equation what are the values of the initial position and velocity of the cage in conventional vector notation? Express your vectors in terms of the $\hat{x},\hat{y},\hat{z}\left(\text{or } \hat{i},\hat{j},\hat{k}\right)$ unit vectors (also known as dimensionless pointers).

(d) According to your model, what is the acceleration of the cage in conventional vector notation? Describe the direction of this acceleration in words.

(e) Is it possible that the fall is truly free fall or do you see evidence that the cage is experiencing other forces as it drops?

6-5) Suppose a group of 4 people with an average mass of 55 kg each are put in the Demon Drop cage of mass 2.0×10^{3} lb. Assume the cage is dropped from rest from a height of 28 meters. **Note**: To get full credit on this problem use the techniques you have been practicing for constant acceleration problems: diagram, *v* vs. *t* graph sketch, listing values and unknowns in a table, equation(s), algebra and solutions, etc. Use the kinematic equations and the accepted value of the acceleration for objects in free fall to answer the following questions:

(a) Where will the cage be at one second?

(b) How fast will it be moving at that time?

(c) What is the force on the whole falling system consisting of the cage and the people? Be sure to indicate the direction of the force.

(d) How does the position you calculated for $t = 1$ s using the kinematic equation compare with the position you measured using Logger Pro in problem 6-4. If they are different discuss why this might be the case.

UNIT 6 HOMEWORK AFTER SESSION TWO

6-6) A pea leaves a peashooter at a speed of 5.4 m/s. As it heads up and toward the right out of the peashooter it makes an angle of +30˚ with respect to the horizontal.

(a) Calculate the *x*-component of the pea's initial velocity.

(b) Calculate the *y*-component of the pea's initial velocity.

(c) Write an expression for the pea's velocity, $\vec{v}$, using unit vectors for the *x*-direction and the *y*-direction.

Caution: You can use a scientific calculator to find these components from the given angle using degrees (assuming your calculator is in degrees mode), but if you use a spreadsheet you'll have to express the angle in radians to find the components. (It turns out that $30^{o} = 0.52$ radians.)

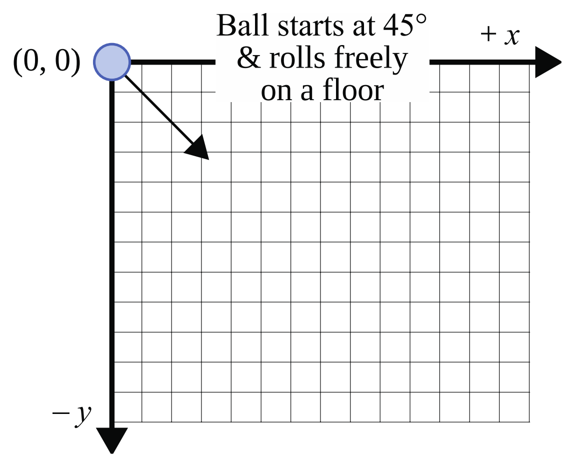
6-7) In each case sketch the vector and find the magnitude and angle of the motion with respect to the *x*-axis of the following bowling balls moving with respect to a certain coordinate system:

(a) $\vec{v} = \left(+7.53\dfrac{\text{m}}{\text{s}}\right)\hat{x} + \left(+4.96\dfrac{\text{m}}{\text{s}}\right)\hat{y}$

(b) $\vec{v} = \left(+5.45\dfrac{\text{m}}{\text{s}}\right)\hat{x} + \left(-8.52\dfrac{\text{m}}{\text{s}}\right)\hat{y}$

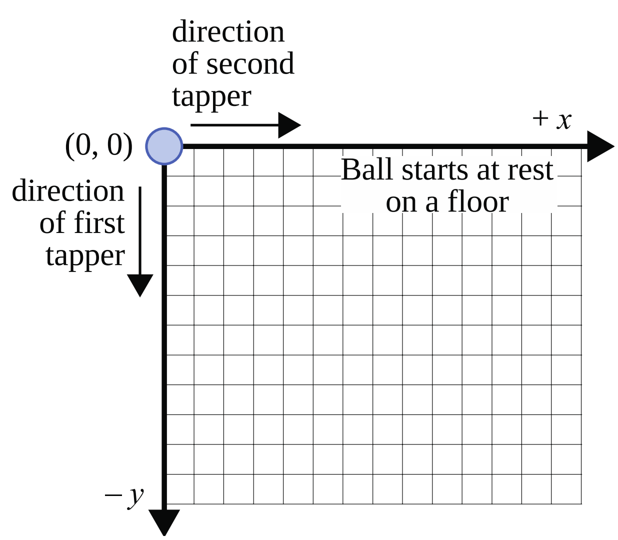
6-8) One of the most powerful attributes of science is the ability that scientists develop to generalize from their observations and then be able to make predictions about observations they have never made. What might happen to the bowling ball you worked with under various new circumstances? What might 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.

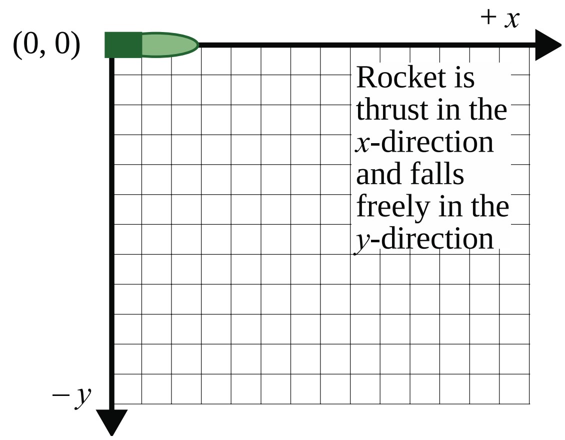


(b) If the initial speed of the ball is 3.5 m/s, what is the *x*-component of velocity, v_{1x}? Is the direction positive or negative? What is v_{1y}? Is the direction positive or negative?

(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.



UNIT 6 HOMEWORK AFTER SESSION THREE

In exercises 6-9 and 6-10 you will be asked to use the Logger Pro software and the Excel spreadsheet *modelingWorksheet.xlsx* 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.

6-9) Digital Projectile One

Use the Logger Pro software to collect data to explore the nature of the horizontal and vertical motions of the projectile. For this problem, **6-9**, don't do any curve fitting or modeling – you will do that in problem **6-10**. 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?

6-10) Digital Projectile Two

Use the Logger Pro software and the Excel spreadsheet **ModelingWorksheet.xlsx** to find the equation that describes the horizontal motion *x* vs. *t*. Also, find the equation that describes the vertical motion *y* vs. *t*. **Note:** You must do this problem using mathematical modeling techniques because mastering it will allow you to fit more complicated motions in the future that the "Add trendline …" fitting can't handle.

(a) Hand in a printout of your two models. Place your name, date and section # on it, and answer questions (b) through (e) at the bottom of the page.

(b) 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}?

(c) 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, a_y? What is its initial vertical velocity, v_{1y}?

(d) 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?

(e) Compare your answer to part (d) to your approximation from part (a) of the previous problem. Finding the percent difference will be helpful in making your comparison.