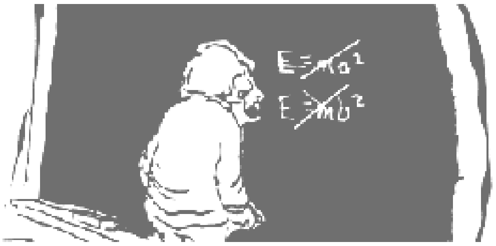
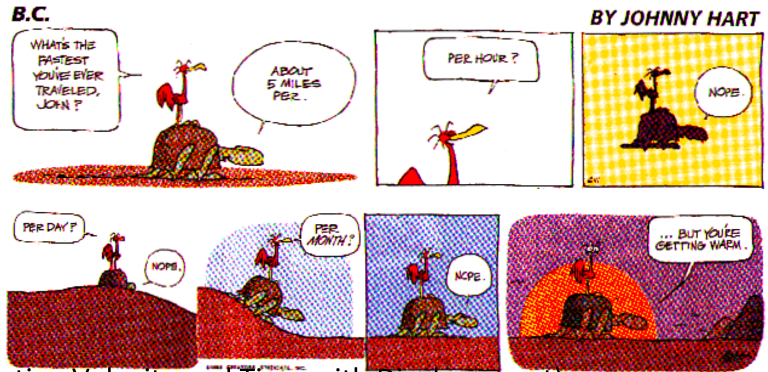
Name_______________________________________

Period_________

<u>Lesson 4: Describing Motion With Equations</u>





4.1 <u>Exercise: Motion at Constant Velocity (Relating Velocity and Time with Displacement)</u>

(a) If you are moving at 2 m/s, how far do you travel:

in 1 second? _____; in 2 seconds? _____; in 3 seconds? ____ **; in a time *t*? ________**

(b) If you are moving at 4 m/s, how far do you travel:

in 1 second? _____; in 2 seconds? _____; in 3 seconds? ____ **; in a time *t*? ________**

(c) SO: What is the general equation that relates your distance traveled Δx to your average speed v_{avg} and the time t that you have been moving? (Note that if we let v stand for velocity rather than speed, we can have negative values for v and for Δx also.)

4.2 <u>Exercise: Motion with Constant Acceleration (Relating Acceleration and Time with Change of Velocity)</u>

(a) If you are moving at +3 m/s^2, by how much does your velocity change:

in 1 second? _____; in 2 seconds? _____; in 3 seconds? ____ **; in a time *t*? ________**

(b) If your acceleration is –2 m/s^2, by how much does your velocity change:

in 1 second? _____; in 2 seconds? _____; in 3 seconds? ____ **; in a time *t*? ________**

(c) SO: What is the general equation that relates your change in velocity Δv to your average acceleration a_{avg} and the time t that you have been accelerating?

(Note that "Δ" always means *final value – initial value*, so $\Delta v = v_f - v_i$.)

4.3 <u>Exercise: Example Problem:</u>

You are driving at 10 m/s when you see the light ahead turn green. You accelerate at a rate of 3 m/s^2. How long will it be until you are going 22 m/s?

(a) <u>*First*</u>: Identify the variable you are interested in solving for. In this case you are looking for the time, *t*.

(b) *<u>*Second*</u>: Write down an equation that will get you x_f from the information you have.
We have $\Delta v = at$, so $t = \Delta v/a = (v_f - v_i)/a$.

(c) <u>*Finally*</u>: Plug in numbers, with units. $t = (v_f - v_i)/a = (22\text{ m/s} - 10\text{ m/s})/(3\text{ m/s}^2) =$ **4 s**.

4.4 <u>Using the Kinematic Equations for Constant Acceleration to Solve Problems</u>

(a) When examining motion of an object that is constantly accelerating, there are five different things we can find information about. These five things show up as variables in the equations. <u>What are all those five variables and what does each one stand for</u>?

(b) Each equation has only four of the five variables in it. One variable is missing from each equation. (1) <u>Write out all five</u> equations here. Then (2)<u>write</u>, next to each one, <u>which variable is missing</u> (the fifth one).

*When solving problems involving constant acceleration, you <u>need three</u> of the five variables to begin with before you can solve for any of the others. It is a good idea to write out all five variables first, writing in the values of the three you know. That leaves two variables, so you can put in a question mark for the one you're trying to solve for. After that, the fifth one is all that's left. Since it's left out of the problem, you can use that to choose which of the kinematic equations to use. Just pick the one that's missing that variable.

(c) Example: Suppose that you want to solve for the distance an accelerating bicycle travels over 3 seconds, knowing that it accelerated from rest at a rate of 2 m/s/s during that time. <u>Write in the three variables</u> we know and their values.

(d) What are we trying to find out about in step (c)? (Note: This is the fourth variable.)

(e) What is the fifth variable left out of this analysis? (That is, which one haven't we used?)

(f) Which equation would we use to calculate the distance of the accelerating bicycle?

(g) Perform the calculations using the equation you chose in step (f) to find the distance traveled.

First: Identify the variable you are interested in solving for.
Second: Write down an equation that will get you that variable from the information you have.
Finally: Plug in numbers, with units.

Show your calculations and answer here.

Distance traveled: _______________m

4.5 Motion of a Falling Ball

(a) Toss a ball straight up a couple of times and observe its motion as it falls downward. Describe in words how you think it might be moving. Some possibilities include falling at a constant velocity, falling with an increasing acceleration, falling with a decreasing acceleration, or falling with a constant acceleration. What do you think? Explain how you based your prediction on your observations of the ball's motion.

(b) Suppose that you drop the ball from a height of about 1.5m above the floor, releasing it from rest. **Sketch your prediction** for a graph of elevation vs. time, velocity vs. time, and acceleration vs. time **for the ball's motion as it falls to the floor**. Assume that the positive y-direction is upward.

PREDICTION: – – – – – – – –

(c) Now use the motion detector to drop a ball beneath the motion detector and sketch the graphs.

ACTUAL: ————————

(d) What does the nature of the motion look like – constant velocity, constant acceleration, increasing acceleration, or decreasing acceleration?

(e) How do your observations compare with the predictions you made?

(f) What motion observed in a previous lab resulted in similar graphs to the ones for the falling ball? Describe what was moving and precisely how it was moving.

(g) Is the acceleration of the ball positive or negative as it falls?

(h) Does this sign agree with the way that the velocity appears to be changing on the velocity vs. time graph? Explain.

(i) What is the value of the average acceleration from the acceleration graph?
Average Acceleration: __________ m/s/s

(j) Accurate measurements of the gravitational acceleration yield a value of 9.8 m/s/s. How big is the difference between this value and the values you obtained in this exercise?

What could account for the difference?

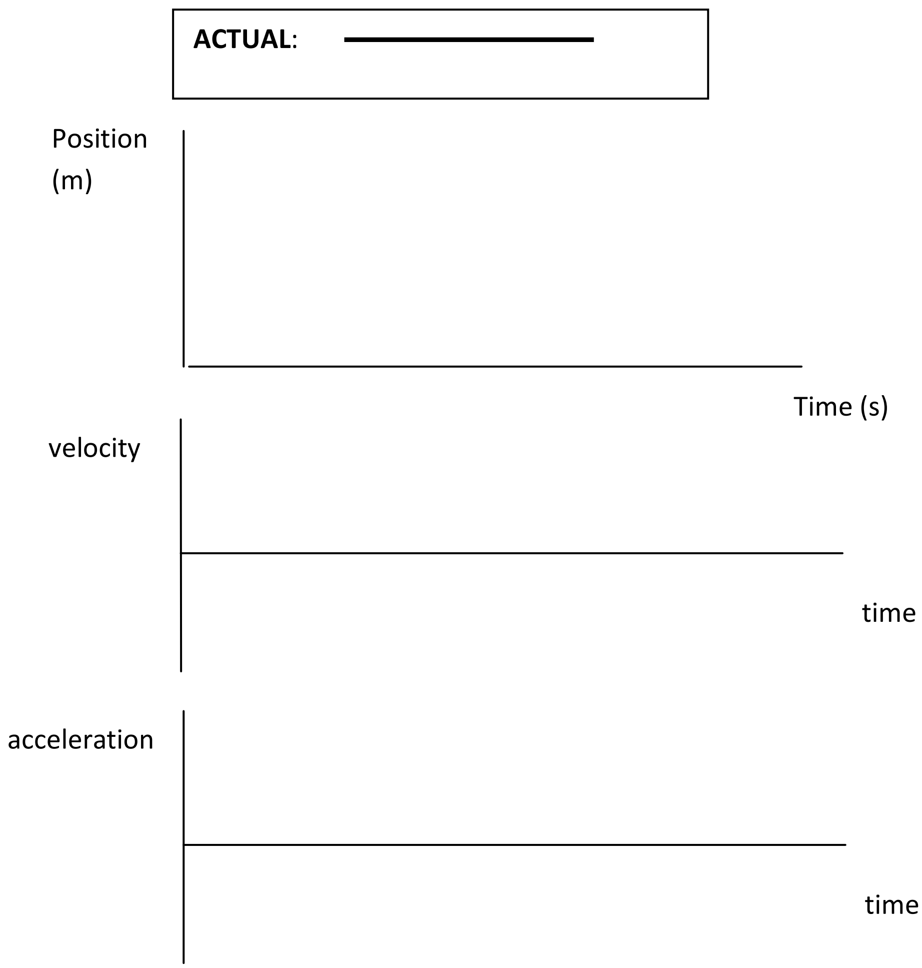
4.6 <u>Exercise: Motion Up and Down</u>

(a) Suppose that you toss a ball upward and analyze the motion as it moves up, reaches its highest point, and falls back down. Is the acceleration of the ball the same or different during the three parts of the motion – when moving upward, while momentarily at the highest point, and when moving downward? Explain.

(b) Sketch your predictions of the velocity vs. time and acceleration vs. time graphs for the entire motion of the ball from the moment it leaves your hand until it returns to your hand. Assume that the positive direction is upward.

PREDICTION: _ _ _ _ _ _ _ _

(c) Drop the ball as before then graph and observe the up-and-down motion of the ball consisting of the motion of the ball after it first hits the floor and then bounces up and returns to the floor. Sketch the portion of the graph corresponding to the ball's up and down motion on a new set of axes for elevation vs. time, velocity vs. time, and acceleration vs. time.



(d) Compare your graphs to your predictions. In what ways do they differ and in what ways are they the same?

(e) Qualitatively **compare the acceleration during the three parts** of the motion – on the way up, at the highest point, and on the way down.

Acceleration on the way up:

Acceleration at the top:

Acceleration on the way back down:

(f) Explain your observations based on the sign of the change in velocity, as you did in Lesson 2.

4.7 <u>Exercise: The Acceleration Of a Bouncing Ball</u>

(a) Is the ball's acceleration as it rises the same as or different than its acceleration as it falls?

How does this compare to your prediction?

What do you conclude about the acceleration of a bouncing ball?

(b) Many people are interested in what happens when the ball "turns around" at the top of its trajectory. Some students argue that its acceleration at the top is zero; others think not. **What do you think happens** to the acceleration at this point?

(c) Explain your answer to Step (b) on the basis of your data, graph, and analysis.

4.8 Experiment: Gravitational Acceleration When Different Masses Fall

(a) If you were to drop a golf ball and not-very-massive ping pong ball at the same time, would they fall with the same acceleration?

Explain the reasons for your prediction.

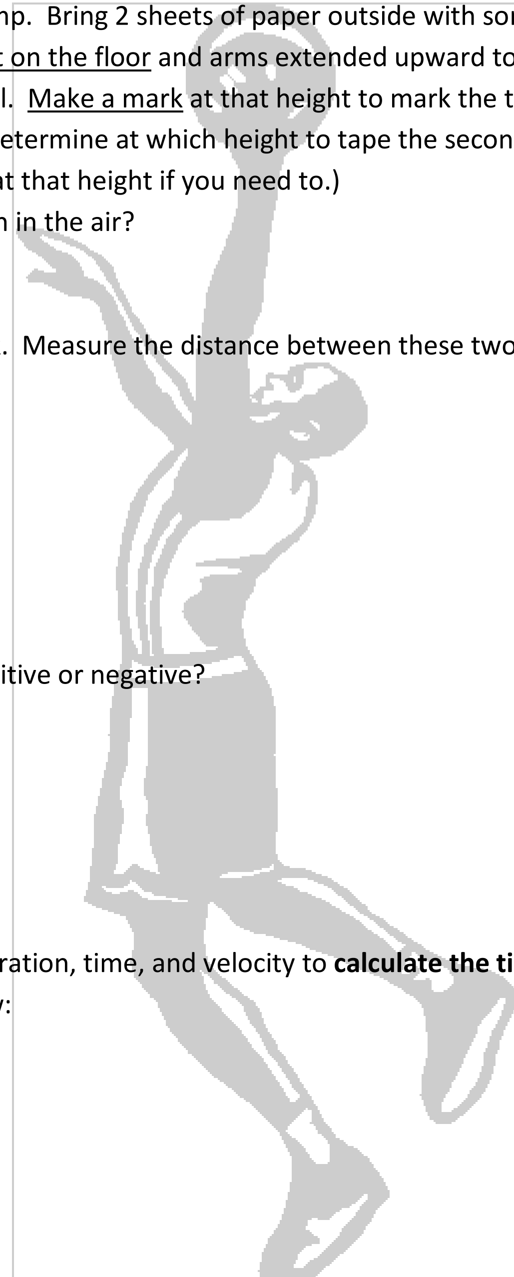
(b) Drop the two objects from the same height at the same time. Observe when they hit the floor. Repeat several times.
Did one object take significantly longer than the other to reach the floor, or did they both hit at about the same time?

(c) What do you conclude about the accelerations of the two objects – is one significantly larger, or are they both about the same in magnitude?

(d) Based on your observations, in the absence of air resistance, would a massive elephant or a not-so-massive peanut experience a larger acceleration when in freefall?

Explain.

4.9 Experiment: Physics of Sports: Finding Your Personal Hang Time



(a) Jumping ability is best measured by a standing vertical jump. Bring 2 sheets of paper outside with some tape and a meter stick. Stand facing the wall, and with feet flat on the floor and arms extended upward to determine where to tape one sheet of paper onto the wall. Make a mark at that height to mark the top of your reach with a line. Then jump and touch the wall to determine at which height to tape the second sheet of paper. (You can climb onto a chair to safely tape it on at that height if you need to.)
PREDICT: How many seconds do you think you will remain in the air?

(b) Now make your jump and at the peak make another mark. Measure the distance between these two marks to determine your vertical leap:

Vertical Leap Height: _______________ m

(c) What is the value of your velocity at the top of your leap?

(d) What is your acceleration while you're in the air? Is it positive or negative?

Why?

(e) Use the kinematic equation that has displacement, acceleration, time, and velocity to **calculate the time it took you to rise to the top**. Show your calculations below:

(f) Is this your entire hang time, up *and* down?

What must you do to find the whole time?

(g) Make your final calculations to find your hang time. Show your calculations.
My Personal Hang Time: ______________ s