Name____

Period_________

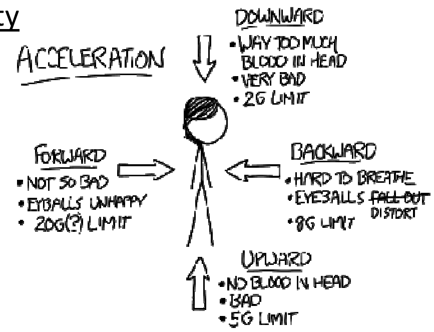
<u>Lesson 3: Changing Motion</u>

3.1 <u>Exercise: Position, Velocity, and Acceleration Graphs of Constant Velocity</u>

Review your graphs of constant velocity from Lesson 2.1.

(a) What feature of a position vs time graph shows constant velocity motion?

(b) What feature of a velocity vs time graph shows constant velocity motion?



(c) Acceleration is defined as the <u>rate of change of velocity with time</u>. On the graph below, **sketch your prediction** of the acceleration you experienced when making the constant velocity graph described above.

PREDICTION: _ _ _ _ _ _ _ _

(d) Use your data from the graph to create an acceleration graph by subtracting pairs of velocities and times as described in class. **Attach graph on a separate page or separate pages.**

Interval #	Average velocity during interval (m/s)	Change of velocity during this interval (m/s)	Duration (time) of this one interval (s)	Average acceleration during interval (m/s/s)	Total Time (s)
1					
2					
3					
4					
5					
6					
7					

Finding Accelerations: To find the acceleration from two velocities, you must first find the vector representing the change in velocity by subtracting the velocities, final minus initial. Then divide this by the time interval over which the velocity change occurs. The average acceleration is given by:

$$\langle a \rangle = \Delta v / \Delta t \text{ or } \langle a \rangle = (v_2 - v_1) / (t_2 - t_1)$$

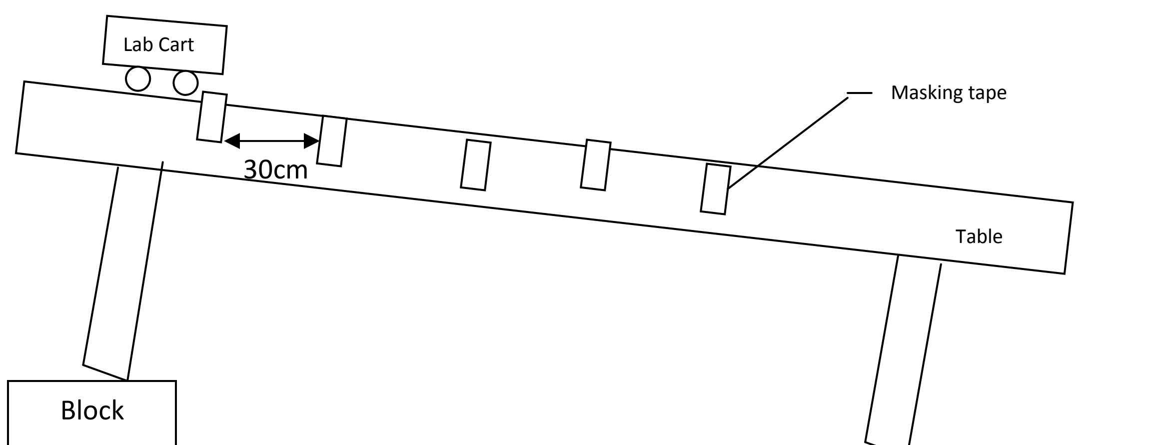
3.2 Exercise: Representing Acceleration

(a) Does the acceleration vs time graph you observed agree with the method of calculating acceleration described above? Explain.

(b) Does it agree with your prediction?

3.3 Experiment: Graphs Depicting Speeding Up

(a) Mark off 0.3m intervals along your tabletop with small pieces of masking tape. Carefully turn your table sideways and screw in the leveling screws all the way on one end (lengthwise) and unscrew the leveling screws on the other side to the same length as far as they can go without coming out. Then lift the taller end of your lab table a small amount and place the spacers under the table's legs to keep them elevated a bit more. This should slightly tilt your table. Now you will be able to observe the motion of a cart when its velocity is changing.



(b) Release your cart from rest at the top of the inclined table and watch carefully. **Be sure to have someone ready at the other end of the table to stop the cart before it falls!** Record the times and positions when the front of the cart passes each piece of tape. This will take some practice, so you may wish to practice a few times before keeping the data. (Not all boxes need be filled in the table below. Just use whatever points you have.)

Interval #	Position (m)	Total Time (s)	Average speed during interval (m/s)	Duration (time) of this one interval (s)	Change of Velocity (m/s)
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

(c) Now create (1) position, (2) velocity, and (3) acceleration graphs by plotting your data on graph paper. Sketch your results below.

(d) How does your <u>position</u> graph differ from the position graphs for <u>steady</u> motion (constant velocity)?

(e) What feature of your <u>velocity</u> graph signifies that the cart was <u>speeding up</u>?

(f) How would a graph of motion with a constant velocity differ from this one where it speeds up?

(g) Is the acceleration on your graph positive or negative?

(h) How does speeding up while moving away from the origin result in this sign of acceleration? (Hint: Remember that acceleration is the <u>rate of change</u> of velocity. Look at how the velocity is changing.)

(i) How does the velocity vary in time as the cart speeds up? Does it increase at a steady rate or in some other way?

(j) How does the acceleration vary in time as the cart speeds up?

(k) Is this what you expect based on the velocity graph? Explain.

3.4 Exercise: Calculating Accelerations

(a) Find the average value of the acceleration from the acceleration graph by adding your accelerations together and dividing by the number of accelerations you have. Show your calculation:

$$a_{avg} = \frac{\sum a}{n} =$$

Average (mean) value of the acceleration: _________ m/s/s

Average acceleration can also be calculated as the change in velocity divided by the change in time, <a> = Δv/Δt (by definition, the slope) which is a quantitative measure of the steepness of the graph.

$$a_{avg} = < a > = \frac{\Delta v}{\Delta t} = \frac{(v_2 - v_1)}{(t_2 - t_1)}$$

(b) Use the method described just above to **calculate your average acceleration from the slope of the velocity vs time graph**. Use two points as far apart on your best-fit line as possible. **Show your calculation below**:

Point 1: v_1 = ________ m/s ; t_1 = _________ s   Point 2: v_2 = _________ m/s ; t_2 = _________ s

$$< a > = \frac{\Delta v}{\Delta t} = \frac{(v_2 - v_1)}{(t_2 - t_1)} =$$

$< a > =$ _________________ m/s/s

(c) Is the average acceleration positive or negative? Is this what you expected?

(d) Does the average acceleration you just calculated from the velocity graph agree with the average acceleration you estimated from the acceleration graph in part (a)? (Are the acceleration values about the same or not?)

(e) Do you expect them to agree? **How would you account for any differences**?

3.5 Experiment: Moving Away Slowing Down, Turning Around, then Moving Toward Speeding Up

(a) This time, give your cart a gentle push – just enough to get it to slow down and roll back near the last position mark on the other side of the table. Remember that the front of the cart will pass the top tape mark *twice*. **Station a team member at the other end of the table to stop the cart from coming off the table. Take care not to push it all the way off the table!**

(b) Once you've gotten used to your push procedure, watch the motion carefully, **recording the times and positions** the front of the cart passes each tape mark. (Hint: The "front" will look like the "back" of the cart when it moves backward. The important thing to remember is to use the same part of the cart for the whole trip, whatever you call the front.)

Interval #	Position (m)	Total Time (s)	Average speed during interval (m/s)	Duration (time) of this one interval (s)	Change of Velocity (m/s)
1	0				
2	0.3				
3	0.6				
4	0.9				
5	1.2				
6	1.2				
7	0.9				
8	0.6				
9	0.3				
10	0				

(c) Create position, velocity, and acceleration graphs from the recorded data and sketch them below:

(d) How does your velocity graph show that the cart was moving toward the origin when it was moving that way?

(e) Write the word “top” at the point on the velocity graph where the cart reaches the top of its motion.

(f) What is the approximate velocity of the cart at this position?

$V_{top} \approx$ ___________________ m/s

(g) Write the word “top” on the acceleration graph at the same time the word “top” appears on your velocity graph. What is the approximate acceleration at this point?

$a_{top} \approx$ ___________________ m/s/s

(h) Did either the value or the sign of the acceleration change at the top of the track where the cart stopped for an instant?

(i) How is the sign of the acceleration represented on a velocity graph? (What on a velocity graph tells you when it's +a or –a?)

(j) How did the value or sign of the acceleration change as it moved through this motion?

3.6 Exercise:

Based on your observations in this lesson, use the prompt below to formulate a general rule to predict the sign of the acceleration if you know the sign of the velocity (i.e. the direction of motion) and whether the object is speeding up or slowing down. **Circle each correct choice**:

Rule: If the velocity is positive (moving away) and the object is speeding up, then the acceleration is **(1)positive / (2)negative** and points **(1) away from the origin / (2) toward the origin**.

If the velocity is positive (moving away) and the object is slowing down, then the acceleration is **(1)positive / (2)negative** and points **(1) away from the origin / (2) toward the origin**.

If the velocity is negative (moving toward the origin) and the object is speeding up, then the acceleration is **(1)positive / (2)negative** and points **(1) away from the origin / (2) toward the origin**.

If the velocity is negative (moving toward the origin) and the object is slowing down, then the acceleration is **(1)positive / (2)negative** and points **(1) away from the origin / (2) toward the origin**.

3.7 Exercise: The Rise and Fall of a Ball

Suppose you throw a ball up into the air. It moves upward, reaches its highest point and then moves back down toward your hand. What can you say about the directions of its velocity and acceleration at various points?

(a) Consider the ball toss carefully. Assume that upward is the positive direction. **Indicate in the table that follows whether the velocity is positive, zero, or negative during each of the three parts of the motion**. Also indicate whether the acceleration is positive, zero, or negative. **Hint**: Remember that to find the acceleration, you must look at the change in velocity.

In each box, choose: + or – ? or zero?

	Moving Up	At Highest Point	Moving Down
Velocity			
Acceleration			

(b) In what ways is the motion of the ball similar to the motion of the cart studied in this lesson?