AP PHYSICS
Name: ________________________________
Period: ________ Date: ____________________

DEVIL PHYSICS

BADDEST CLASS ON CAMPUS

EVEN MORE ACCELERATION LAB

(1/2 Point Each, 16 Points Total)

Part I. Elevator Physics (10pts) (with lab partner, lab partner name: ________________________)

Objective – During this portion of the lab you will determine the vertical accelerations in an elevator using a vertical accelerometer. You will also analyze the motion of an elevator.

Discussion – The net force on the mass in the accelerometer is given by the relationships: $F_{net} = F_s - mg$ and $F_{net} = ma_{net}$, where F_s is the force applied by the spring to the mass, and mg is the weight due to gravity of the mass. When the mass is at rest or moving with constant speed in an upward or downward direction, the upward pull of the spring is equal in magnitude to the downward pull of the weight. In these cases, the net force is zero and the net acceleration of the mass is zero. If the accelerometer is calibrated to read "1g" when it is at rest, that recognizes the 1g effect of gravity. To get the net acceleration of zero, you subtract 1g from the reading. If the mass is accelerating downward due to an upward movement of the person holding it, the mass will be in a position below "1g" or, at a reading greater than "1g". Again, the net acceleration can be determined by subtracting 1g from the accelerometer reading. The reading will still be above zero (positive) indicating an upward acceleration of the person. If the mass is accelerating upward (person accelerating downward), it will be above the "1g" position, or a reading of less than 1g. Subtracting 1g will yield a negative net acceleration in agreement with the downward acceleration of the person.

Procedure – You will work in pairs with a lab partner. One person will take readings while the other person records the readings. Take turns performing each function. The person taking readings holds the accelerometer vertical by pressing it to the wall of the elevator. (***Note: do not perform computations until data for all three labs have been taken***)

- Take and record readings directly from the accelerometer for each of the instances in the table below (watch your signs!).
- While standing still, your accelerometer should read 1g (first red line). If your accelerometer is not reading 1g while standing still, this is an error in your tool. Write the amount and either + or - of this error here: _______________
- Attempt to take your readings in movement between the 1st and 3rd floors. Conduct three trials.

	Raw Data		
	Trial 1 (a/g's)	**Trial 2 (a/g's)**	**Trial 3 (a/g's)**
Standing Still			
Beginning Descent			
Middle of Descent			
Slowing Descent			
Standing Still			
Beginning Ascent			
Middle of Ascent			
Slowing Ascent			

Computed Data					
	A. Average (a/g's)	**B. Average Net (a/g's)**	**C. Net Minus Error (a/g's)**	**D. Acceleration in m/s^2 ($a/\ m/s^2$)**	**E. Elevator Force (F_E/N)**
Standing Still					
Beginning Descent					
Middle of Descent					
Slowing Descent					
Standing Still					
Beginning Ascent					
Middle of Ascent					
Slowing Ascent					

A. Once you have recorded all of your raw data, compute an ***Average*** for the three trials.

B. Compute the ***Average Net*** acceleration by subtracting 1g from your average in column A.

C. Compute the ***Net Minus Error*** by subtracting the error in your accelerometer that you noted before you began from your ***Average Net*** in column B.

D. Convert your acceleration from g's to m/s^2 by multiplying the values in column C by 9.81 $\frac{m/s^2}{1g}$.

E. Assume you have a body mass (m) of 70kg and compute the net force the elevator exerts on your feet (F_E) for each instance above and record it in column E using the acceleration (a) from column D,

$\boldsymbol{\Sigma F = ma}$ ***Newton's Second Law of Motion***

$\boldsymbol{F_E - F_g = ma}$ $\boldsymbol{F_g = mg}$ ***, this is the force due to gravity which is your weight***

$\boldsymbol{F_E - mg = ma}$

$\boldsymbol{F_E = ma + mg}$ *(watch your signs for acceleration!)*

Questions:

1. (1pt) When the elevator is standing still or at constant velocity (middle of descent/ascent), the accelerometer should read 1g. If it does not, what type of error does this represent? __________________

   ____

2. (1pt) Explain why the ***magnitudes*** of the accelerations at the ***beginning*** of the ***ascent*** are different from the accelerations in the ***middle*** of the ***ascent***. ____

   ____

3. (1pt) Explain why the ***direction*** of the accelerations at the ***beginning*** of the ***ascent*** are different from the accelerations at the ***beginning*** of the ***descent***. ____

   ____

4. (1pt) What was the difference in magnitude between the ***starting acceleration*** and the ***stopping acceleration*** on the **descent**? Was it more or less than the difference during the ascent? Why do you think this is so? ____

____

____

5. (1pt) Compare how you felt (heavy, light or normal) with the accelerometer readings? ______________

____

____

Part II. Centripetal Acceleration with Stand and Spin (group data collection)

Objective – During this lab you will determine centripetal accelerations using a crash test dummy (student volunteer) on the stand-and-spin using a horizontal accelerometer. You will also compute the tangential velocity of the subject using the equation $a_c = \frac{v^2}{r}$.

Discussion:

The Horizontal Accelerometer

With horizontal accelerometers, as opposed to vertical accelerometers, there is not the same confusion between the subjective experience and the accelerometer reading. At rest, the BB's in the horizontal accelerometer settle to the bottom of the curved plastic tube. There is no horizontal force applied and no horizontal acceleration.

When the BB's are above the bottom, as in Figure 2, the inside of the curved plastic tube applies a force to them. The applied force has a vertical component equal to the weight of the BB's and a horizontal component equal to the mass of the BB's times their horizontal acceleration. The applied force acts along the line making the angle q with the vertical, center line of the accelerometer.

Since the components are perpendicular to one another and the horizontal force, *ma*, is opposite the angle θ:

$$\tan\theta = \frac{ma}{mg}$$

and

$$ma = mg\tan\theta.$$

We can divide both sides by the mass of the BB's to obtain:

$$a = g\tan\theta;$$

where *a*, the horizontal acceleration, is always directed forward toward the front of the device.

To measure the horizontal acceleration in the direction you are moving, just hold the accelerometer level with the straw pointed in the direction you are moving.

Multiply *g* by the tangent of the angle to the center of the BB.

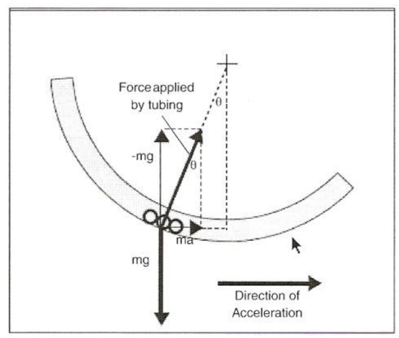


Figure 2: Diagram of the Horizontal Accelerometer

To use the horizontal accelerometer to measure horizontal centripetal accelerations, hold it perpendicular to the direction in which you are headed and as level as possible. For example, on the rotor ride at an amusement park, where you are in a rotating cylinder feeling mashed to the wall, hold the accelerometer with the short side pressed to the wall. It will be level with the floor and, since you are traveling sideways, perpendicular to the direction of travel.

Before the motion begins, the BBs sit in the bottom of the tube. When the ride begins to rotate, a centripetal force is needed to make them go in a circle. The BBs will ride up the side nearest the wall, as if forced outward. In fact, the tube will be exerting a horizontal force on them directed in toward the center of the ride. They will ride up until the angle is large enough to give the necessary horizontal acceleration. In circular motion

$$a = \frac{v^2}{r}$$

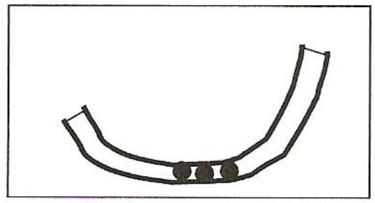
where *v* is the linear speed along the circumference and *r* is the radius of the circle. As the ride picks up speed, the BBs will travel farther up the curve.

A Horizontal G Force Meter is often calibrated in degrees. As illustrated below, when acceleration is experienced, BBs will roll up a tube. The highest angle achieved relates to the G Force in the following way:

G Force = Tangent of the Angle

(i.e. Tan (60 degrees) = 1.7, so 60 degrees corresponds to 1.7 g's.)

The chart below can be used to determine the G Force from the angle on the Horizontal G Force Meter. A G Force to the right will cause the BBs to roll to the left.



Angle	10	15	20	25	30	35	40	45	50	55	60	65
G's	.18	.27	.36	.47	.58	.70	.84	1.00	1.19	1.43	1.73	2.14

Procedure – You will work in a group to obtain readings. One person volunteers to be the crash dummy, one person takes the measurements, everyone else records the data and laughs at the crash dummy getting dizzy. The person taking measurements and the dummy can obtain data from any of the recorders after the experiment once the nausea passes. Take turns performing each function. (6pts)

- With the dummy standing still, measure the radius from the individual's centerline to the zero index in the accelerometer with the dummy holding the accelerometer horizontally in one hand with their arm extended. Use meters for the units.
- Measure the radius from the individual's centerline to the zero index in the accelerometer with the dummy holding the accelerometer with their arm retracted. Use meters for the units.
- With the dummy's arm extended, spin the dummy at a comfortable pace so that he or she can maintain balance.
- Obtain an angle measurement and announce it to the recorders.
- As soon as the measurement is announced, the dummy retracts their arm and tries to maintain balance.
- Obtain an angle measurement with arm retracted and announce it to the recorders.

		Dummy #1 Name ____________	**Dummy #2 Name** ____________	**Dummy #3 Name** ____________
RAW DATA	Extended Arm Radius (m)			
	Retracted Arm Radius (m)			
	Max Accelerometer Angle – Arm Extended (deg)			
	Max Accelerometer Angle – Arm Retracted (deg)			
COMPUTED DATA	Arm Extended g's			
	Arm Extended a_c (m/s^2)			
	Arm Extended v (m/s)			
	Arm Retracted g's			
	Arm Retracted a_c (m/s)			
	Arm Retracted v			

Individual Computations: (***Note: do not perform computations until data for all three labs have been taken***)

- Complete the following computations for data obtained for arm extended, and then for arm retracted.
- Use the chart above to convert deflection angles into g-forces (use interpolation).
- Convert g-forces into acceleration by multiplying by 9.81 m/s^2.
- Solve for tangential velocity using the equations, $a_c = \frac{v^2}{r}$, $v = \sqrt{a_c r}$.

Questions:

1. (1pts) If velocity were held constant, what would be the quantitative difference in ***g-forces*** when the arm was extended versus when the arm was retracted? Does your data reflect this? Why or why not? ______

____

____

2. (1pts) In general, what was the quantitative difference in ***velocities*** when the arm was extended versus when the arm was retracted in your data? Explain why. ______________________________

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Part III. Using Horizontal Accelerometer as a Sextant

Objective – During this lab you will determine the height of the ceiling using the horizontal accelerometer as a sextant.

Using the Horizontal Accelerometer as a Sextant

The horizontal accelerometer can be used to measure the heights of objects that are too high to measure directly, such as measuring the height from the ground to the top of King Kong's head, in Figure 3. You can measure these distances with reasonable accuracy using just the accelerometer, a piece of string that is marked out in meters, and a little trigonometry. The procedure is as follows:

1. Measure the distance S with a piece of string marked out in meters.

   S is the horizontal distance between your point of observation and a point directly below the object of interest.

2. Sight through the straw to the top of King Kong's head, and measure the angle θ on the accelerometer.

   θ is the angle that the center BB aligns with on the horizontal accelerometer. It is also the angle between your horizontal line of sight and your line of sight to the top of King Kong's head.

3. Measure h_0, the vertical distance between the base of your height measurement and your observation point.

   As long as the ground is level between you and the building on which King Kong is standing, h_0 is just the distance from the ground to your eyes.

4. Then:

$$H = h_0 + h_1 = h_0 + S \tan \theta.$$

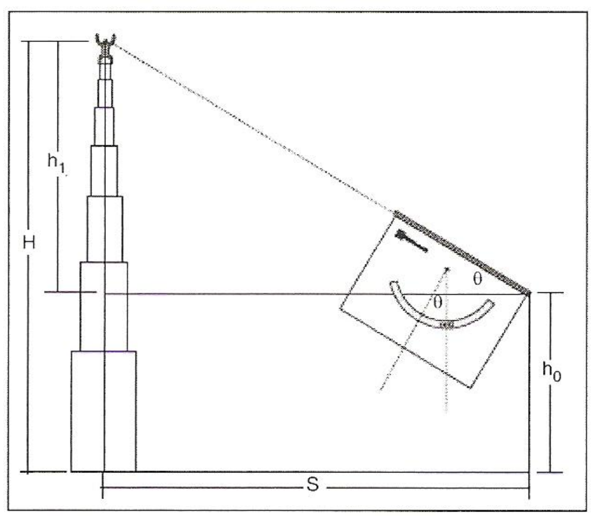

Figure 3: Measuring Heights with the Horizontal Accelerometer

Procedure – This lab is to be done individually. (6pts)

From any position in the room, use the horizontal accelerometer to measure the angle between your line-of-sight and the top of one of the walls. Be sure to measure along a line perpendicular to the wall.	θ =
Have your partner use a ruler to measure the height of your line-of-sight from the ground.	h_0 =
Use the floor tiles to measure your distance to the wall. Each tile is 12" x 12".	S =
Compute the height of the wall above line-of-sight, $h_1 = S \tan\theta$	h_1 =
Find the height of the wall, $H = h_0 + h_1$	H =
Measure the actual height of the wall	actual height =
Compute a percent difference between computed value and the actual value $\left(\frac{computed - actual}{actual}\right) x100\%$	% difference =

Questions:

1. (1pt) What do you think generated the error between your computed value and the actual value? ______

   ____

   ____

2. (1pt) What type of error is this? ____

The answers on this lab are a product of my own work and effort. Though I may have received some help in collecting data and understanding the concepts and/or requirements, I did the computational work myself and came up with the answers to all questions on my own.

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Student Signature (for electronic submission, type student number in lieu of signature)

ROOM FOR IMPROVEMENT

This lab can be improved by:

When complete, E-mail to Mr. Smith @ smithky@pcsb.org

Ensure your filename is "FirstInitialLastNamePerXLabName"