Activity Template

Subject Area(s) **Measurement, Physics**

Activity Title **Newtons Law's: measuring "g"**

Header

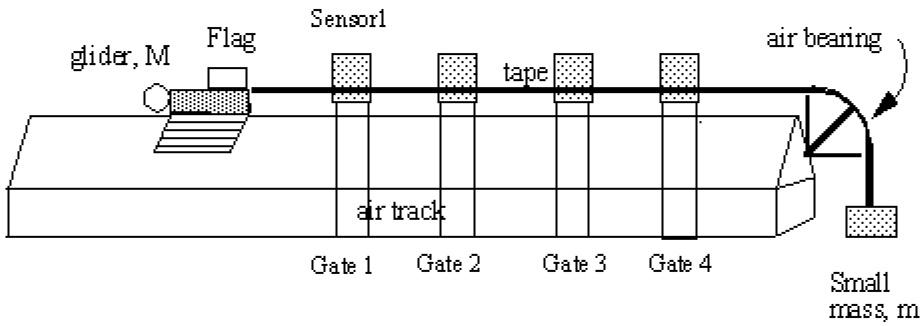

Image 1
ADA Description: Schematic for acceleration due to gravity measurement
Caption: Flow rate apparatus
Image file name: AMPS_Karl_airschematic.jpg

Grade Level 11 (10-12)

Activity Dependency

Time Required **45**

Group Size 6

Expendable Cost per Group US$80

Summary

The purpose of this experiment is to test whether Force = Mass x Acceleration. The technique will be similar to that used to measure g in lab 2. You will use the weight of a small mass, m, to provide the force that accelerates a system consisting of a large mass, M, the air cart + the aluminum "flag," and the small mass, m. **If friction can be neglected**,

$$(M + m)\, a = mg \qquad 1.$$

or

$$a = (mg)/(M + m). \qquad 2.$$

You will measure m, M and a to see if the measured acceleration really is given by the above equation, i.e. does $a_{measured} = a_{theory}$ where the theoretical value is given by the equation above, using the measured masses and $g = 9.80\ m/s^2$.

You will measure the acceleration, a, by recording the time the flag passes the sensors on the air track, the distance between those points and computing the velocity and then the acceleration of the cart. The computer will record the times; **you will measure the distances and compute the velocities and acceleration**.

Engineering Connection
Understanding the acceleration of gravity and Newton's Laws is critical to any and every engineer. From the design of automobiles, to bridges, to buildings a fundamental understanding of Newton's second laws and the structured procedure of creating free body diagrams is of great importance to the aspiring young engineer.

Engineering Category
(#3) Provides engineering analysis or partial design.

Keywords
Newton's 2^{nd} Law, acceleration due to gravity, gravity

Educational Standards
choose from http://www.jesandco.org/asn/viewer/default.aspx
State science:
State math:

Pre-Requisite Knowledge
A basic understand of how to time events. i.e. How to use a stopwatch

Learning Objectives
After this activity, students should be able to:

- Test the effects of pipe diameter on flow rate
- Quantitatively discover the flow rate of a system.

Materials List
Each group needs:

- Vernier Photogate or 4 Lego NXT photogate sensors
- Steel McMaster track
- Pulley set (Vernier or Lego)

Introduction / Motivation
The acceleration of gravity is felt everyday all around us. Objects fall down towards the earth at the acceleration of gravity. Understanding that this acceleration is decoupled from the mass of the object is difficult for many students to understand. Often times, a student will hypothesize that a heavier object will "fall faster" than a lighter object, which in fact, is not true. This experiment helps to debunk the common myth that objects accelerate at a rate dependent on that objects mass. By allowing students to vary the weight of the mass on the frictionless cart, and calculate the same acceleration due to gravity each time, students can see both quantitatively and empirically that acceleration due to gravity is decoupled from the mass of the object.

Vocabulary / Definitions

Word	Definition
Newton's Laws	Consist of three physical laws that form the basis for classical mechanics. They describe the relationship between the forces acting on a body and its motion due to those forces
Newton's 2^{nd} Law	A body of mass *m* subject to a force **F** undergoes an acceleration **a** that has the same direction as the force and a magnitude that is directly proportional to the force and inversely proportional to the mass, i.e., $\mathbf{F} = m\mathbf{a}$.
Acceleration due to gravity	The acceleration on an object caused by gravity. Neglecting friction such as air resistance, all small bodies accelerate in a gravitational field at the same rate relative to the center of mass

Procedure

How do you measure a? You will measure a by measuring the position of the cart at different times and then calculating the average velocity as a function of time, just like in lab 2.. You will then use these average velocities to calculate $a_{measured}$. There are four gates or sensors that tell when the flag on the cart passes them. The computer will record the times when the flag enters and leaves the position of the sensor. You need to make the measurements below, which will be your "RAW DATA".

1. **MEASURE THE POSITIONS OF THE CART (e.g. THE FRONT EDGE OF THE CART) WHEN THE FLAG ENTERS AND WHEN IT LEAVES THE SENSOR POSITION**. (Measure **both** the entering and leaving position for each sensor!) If you have four sensors, you will measure **eight positions**. Keep track of which positions go with each sensor or gate.
2. Measure the **mass of the cart** (including the aluminum flag) and the **small weights**. Also measure the mass of the **tape**.
3. **As a check, record a run without the small mass, i.e. no tape attached to the cart. Start the data taking and gently shove the cart down the track.** If the track is level and frictionless, the velocity or speed should be constant (until it reaches the end). If it isn't, get the problem fixed before proceeding.

When you have recorded these you will attach a small weight (10g) to one end of the tape, and the other end of the tape to the cart. The tape will hang over the air bearing with the small weight hanging down. Hold the cart about 10 cm before the first gate (**record this value**), start the "Newton's Laws" program and then release the cart. The computer will record and display the times the cart entered and left each gate or sensor. You will need to supply a file name for each run. Choose short descriptive names like Wt10g, Wt20g, Wt30g and Wt0g.

4. Save the **times for each gate**. (The computer program will do this for you.) These times are accurate to about the nearest 1ms or 0.001s.
5. Repeat for **two more small weights (20g & 30g)**.

These represent your raw data. Now you need to analyze them to find the measured accelerations for each small weight and compare it to the expected acceleration for that weight.

Before the Activity

- 1. Explain the concept of time keeping
- 2. Assign tasks to each student. i.e. time keeper, button presser, water releaser/pourer, etc.
- 3. Explain the use of the photogate to tell time.

Safety Issues

- None

Assessment

Make a plot of velocity vs. time (Use the times from columns C and G and the velocities from columns D and H) and then calculate the "measured" acceleration by doing a linear regression of velocity vs. time.

The X variable coefficient is the slope or acceleration and the standard error of the coefficient is the "uncertainty" or standard deviation for the slope. ***Compare this measured acceleration to the expected acceleration calculated from equation 2.*** (When you do this calculation of the expected acceleration, you should consider the effect of the tape's mass. Where will it go***?*** ***Indicate whether you included it and if so, where!***) A sample sheet is shown below. You may want to put each run on a separate worksheet.

In your discussion, consider how close the measured acceleration is to the expected acceleration and what factors might affect your results, e.g. your position measurements and friction. Indicate HOW these factors would influence your results and try to be quantitative. You should indicate the results of your "no small weight" run. Was the acceleration zero for that run? If not, how would that influence your results?

I've show a sample spreadsheet below. Again, I've altered the data slightly.

	A	B	C	D	E	F	G	H
1	time	state gate 2	gate 1 time (s)	velocity gate 1 (m/s)		state gate 2	gate 2 time (s)	velocity gate 2 (m/s)
2	2.035416	1						
3	2.105384	0	0.0699688	1.043322166				
4	2.266708					1		
5	2.309784					0	0.0430756	1.694694908
6								
7								
8	time	velocity	acceleration		friction force (N)	m1 (kg)	m2 (kg)	
9	2.105384	1.043322166			1.27161	0.286	0.201	
10	2.309784	1.694694908	3.186761334					
11								
12	g (m/s^2)						KEY	
13	9.872597						computed	
14							measured (LoggerPro)	
15							measured (Scale)	
16							given	
17								

Post-Activity Assessment

1. What effect does the friction of the track have on the measurements?
2. How does the photogate work?
3. Is acceleration dependent on the mass of the system?