SAMPLE LAB WRITE-UP/PHYSICS 2A & 4A-D

Title - Newton's 2^{nd} Law

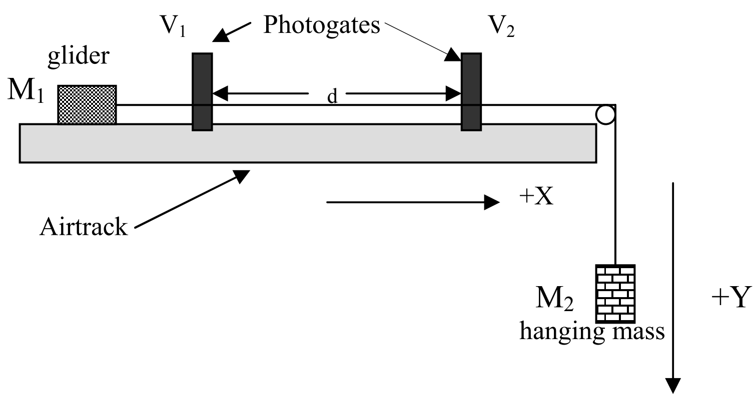
Objective

In this experiment we will attempt to confirm the validity of Newton's 2^{nd} Law by analyzing the motion of two objects (glider and hanging mass) on a horizontal air-track. First, we will calculate the theoretical acceleration by applying Newton's 2^{nd} Law ($\mathbf{F_{net}} = M\mathbf{A}$), neglecting friction, to the glider and hanging mass. Next, we will calculate the experimental acceleration of the glider by applying the kinematic equations of motion as it moves between two markers (photogates) on the track. We will then compare the experimental acceleration to the theoretical acceleration.

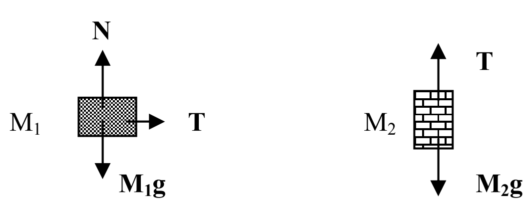
Theory

a) Acceleration using Newton's 2^{nd} Law

Apparatus Setup



Free-Body Diagram



Apply Newton's 2^{nd} Law to mass M_1 and M_2.

Mass 'M_1'

$\Sigma F_x = T = M_1 a$

Mass 'M_2'

$\Sigma F_Y = M_2g - T = M_2a$

Adding both equations gives:

$M_2g = M_1a + M_2a$

$$a_{theo} = M_2g/(M_1 + M_2)$$

b) Acceleration using Kinematic Equations

Using the kinematic equation $V_2^2 = V_1^2 + 2a(x - x_0)$ we will calculate the experimental acceleration of the glider as it moves between the two photogates. We will take the origin of our coordinate system at the first photogate.

d = distance between photogates
$V_1 = (s/t_1)$ velocity of the glider through photogate 1
$V_2 = (s/t_2)$ velocity of the glider through photogate 2
s = diameter of small flag on glider
t_1 = time for small flag to go trough photogate 1
t_2 = time for small flag to go trough photogate 2

$$a_{\exp} = \frac{V_2^2 - V_1^2}{2d}$$

Apparatus

Refer to theory section for apparatus setup
One air track(#21), blower(#2), blower hose and power supply
One digital photogate(#2C) and one accessory photogate(#2A)
One glider(#1B)
One flat accessory box(#22A)
String
Electronic pan balance(#1)
Vernier Calypers (#12c)

Procedure

1. Measure the mass of the glider and hanging mass.
2. Setup the air track and blower as indicated by instructor.
3. Measure the distance between photogates.
4. Measure the diameter of the small flag on glider with vernier calipers.
5. Release glider 10 cm away from photogate 1 and record times trough both photogates.
6. Repeat step (5) four more times.

Data

M_1= 4750 g
M_2=50 g
g = 9.81 m/s^2
d = 60.6 cm
s = 1.01 cm

Run #	t_1	t_2	V_1 (cm/s)	V_2 (cm/s)	d (cm)	a (cm/s^2)
1	0.039	0.023	25.5	43.0	60.6	9.907
2	0.043	0.024	23.0	41.5	60.6	9.862
3	0.044	0.023	22.5	42.5	60.6	10.74
4	0.041	0.023	24.5	42.5	60.6	9.967
5	0.038	0.032	26.0	43.5	60.6	10.05

Calculations

Theoretical Acceleration:

$a_{theo} = M_2g/(M_1 + M_2) = 50\text{ g}*981\text{ cm/s}^2/(4750\text{g} + 50\text{ g})$

$a_{theo} = 10.21\text{ cm/s}^2$

Experimental Acceleration:

$$a_{\exp} = \frac{V_2^2 - V_1^2}{2d} = \frac{(43.5cm/s)^2 - (26.0cm/s)^2}{2(60.6cm)} = 10.05cm/s^2$$ (sample calculation Run #5)

$$a_{exp} = \frac{9.907 + 9.862 + 1074 + 9.967 + 10.05}{5} = 10.10\text{ cm/s}^2$$ (average experimental acceleration)

$$\%\text{ error} = \frac{|\exp - theo|}{theo} \times 100$$

$$\%\text{ error} = \frac{|10.10 - 10.21|}{10.21} \times 100 = 1\%$$

Conclusion

This experiment confirmed Newton's 2nd Law. The percent error between experiment and theory was only 1%. Although the percent error was small there was still some errors involved. These errors include systematic and random errors:

1. In applying Newton's 2nd Law to find the acceleration of the glider we neglected the frictional force. This should have caused the experimental accelerations to be smaller than the expected theoretical value. The data shows this to be true with the exception of one data point. Thus, neglecting friction between the glider and the air track introduced a **systematic error** in the experiment. We could have eliminated this systematic error by compensating for friction during the theory derivation.

2. In measuring the velocity of the gliders through the photogates we used the average velocity instead of the instantaneous velocity. This introduced a **systematic error** that may have resulted in the largest source of error in the experiment. If we had a method of calculating the instantaneous velocity of the glider as it goes through the photogates are results would have been much better.

3. The **random errors** involved were due to the uncertainty of the measured quantities. This includes the uncertainty in the:

    a) the length of the small flag
    b) the length between the photogates
    c) the mass of the glider and hanging mass

    To analyze these random errors in detail we need to use the uncertainties in these measurements and the general error propagation equation to obtain the final acceleration with its uncertainty. Once we obtain such a numerical result we can check to see if the expected acceleration falls within the most probable range (MPR) and comment on the results.