PHYSICS SAMPLE LAB WRITE-UP
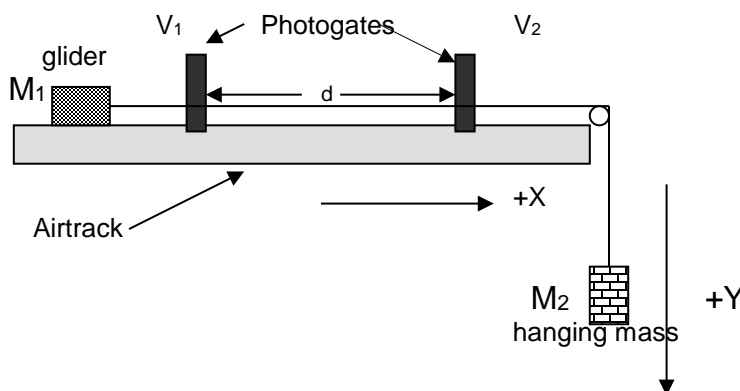

Title - Newton's 2nd Law

Objective

In this experiment we will attempt to confirm the validity of Newton's 2nd 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 2nd Law (F_{net} = MA), 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 2nd Law

Apparatus Setup

Free-Body Diagram

Apply Newton's 2nd Law to mass M₁ and M₂.

Mass 'M₁'
$\Sigma F_x = T = M_1 a$

Mass 'M₂'

1

$$\Sigma F_Y = M_2g - T = M_2a$$

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$_2$=50.00 g
g = 9.80 m/s^2
d = 60.65 cm
s = 1.01 cm

Run #	t$_1$	t$_2$	V$_1$ (cm/s)	V$_2$ (cm/s)	d (cm)	a$_{exp}$ (cm/s^2)
1	0.039	0.023	25.5	43.0	60.65	9.91
2	0.043	0.024	23.0	41.5	60.65	9.86
3	0.044	0.023	22.5	42.5	60.65	10.7
4	0.041	0.023	24.5	42.5	60.65	9.97
5	0.038	0.032	26.0	43.5	60.65	10.1

Calculations

Theoretical Acceleration:

a$_{theo}$ = M$_2$g/(M$_1$ + M$_2$) = 50.00 g*980 cm/s^2/(4750g + 50.00 g)

a$_{theo}$ = 10.2 cm/s^2

Experimental Acceleration:

$$a_{exp} = \frac{V_2^2 - V_1^2}{2d}$$ = (43.5 cm/s)^2 - (26.0 cm/s)^2 /(2*60.65 cm) (sample calculation Run #5)

a$_{exp}$ = (9.91 +9.86+10.7+9.97+10.1)/5 = 10.1 cm/s^2 (average experimental acceleration)

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

% error = $\left| \dfrac{10.1 - 10.2}{10.2} \right|$ X 100 = 0.98 %

Conclusion

1. The theoretical acceleration using Newton's 2nd Law was 10.21 cm/s^2 and the average experiment acceleration using the kinematic equations was 10.10 cm/s^2. The percent error between experiment and theory was only 1%. Although the percent error was small, there were still systematic and random errors present.

2. Based on the relative small % error of 0.98% we can conclude that the objective of confirming Newton's 2nd Law was accomplished.

3. In measuring the velocity of the gliders through the photogates we used the average velocity instead of the instantaneous velocity. This resulted in the average velocity *always being smaller* than the instantaneous velocity. This will then cause $a_{exp} = \dfrac{V_2^{\,2} - V_1^{\,2}}{2d}$ to be consistently smaller than a_{theo} which resulted in a **systematic error**. A second **systematic error** was that in applying Newton's 2nd Law to derive a_{theo} of the glider we neglected the frictional force. The resulting equation should have been $a_{theo} = (M_2g - fk)/(M_1 + M_2)$. Neglecting friction on the a_{theo} equation should result in a_{theo} being consistently larger than a_{exp}. The data shows this to be true with the exception of one data point.

4. In addition to the **random errors** involved due to the uncertainty of the measuring devices, other **random errors** involved in the experiment include:

   a) Not releasing the glider from same initial point every run.
   b) Trying to balance the air track.
   c) Having the hanging mass M_2 swinging when releasing M_1 from rest.

   All these random errors contributed to the uncertainty in the final results for the accelerations. These random errors also contributed to the 0.98% error in the final results.