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Experiment 1.06: Momentum

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I. EXPERIMENT 1.06: MOMENTUM

A. Abstract

A body moving at constant speed collides with another stationary body. The two bodies stick and move off after the collision. Conservation of momentum is explored.

B. Formulas

$$p_x^{(initial)} = p_x^{(final)} \tag{1}$$

$$m_1 u_{1x} + m_2 u_{2x} = m_1 v_{1x} + m_2 v_{2x} \tag{2}$$

The equation reflects the conservation of momentum as it applies to a one-dimensional collision between two bodies. In this experiment, the moving body ($u_{1x} \equiv u$) collides with a stationary body ($u_{2x} = 0$).in a totally inelastic manner by sticking together ($v_{1x} = v_{2x} \equiv v$).

C. Description and Background

On a level surface, free of frictional forces, when a body moving at constant speed collides with one that is stationary, the two stick together and continue moving after the collision. This is an inelastic collision, and momentum is conserved, but kinetic energy is not.

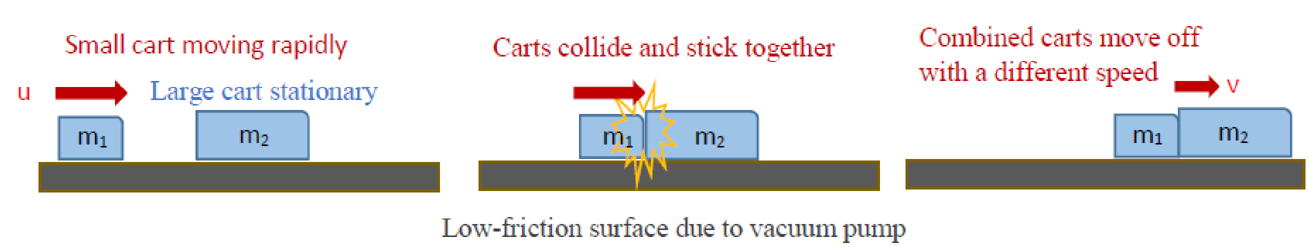


FIG. 1. Inelastic, 2-particle, 1-dimensional collision.

In this experiment, an inelastic collision is created using the same air track apparatus used in previous experiments. This time, the air track is not inclined, but is instead level with the table. A second glider is placed in the middle of the track and in between two photogates.

The first glider is launched from one end of the track, so that it passes through one gate (A) before bonding with the second, stationary glider. The two adjoined gliders then pass through the second gate (B). The first glider has a "flag," or "fence," attachment that blocks the gate light beam for a measurable time ($t_{A,B}$), thereby allowing the determination of the speeds before and after collision

$$u = \frac{\ell_F}{t_A} \tag{3}$$

$$v = \frac{\ell_F}{t_B} \tag{4}$$

where ℓ_F is the length of the opaque strip in the fence.

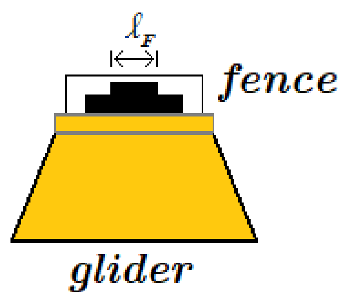
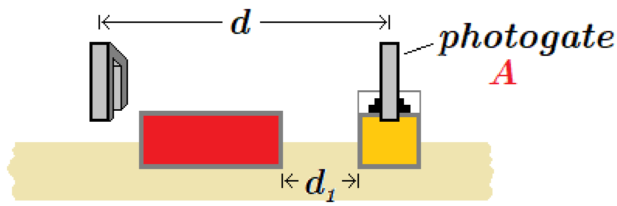


FIG. 2. Glider with flag/fence.

D. Procedure

1. Measure the masses of the two gliders.
2. Position the two photogates at two locations, A and B, along the air track.
3. Make sure the photogates are positioned properly so the fence on the glider blocks the gates' light beams.
4. Measure the distance between the two photogates, d.
5. Position the larger glider (m_2) on the air track so that it remains stationary between the photogates (and close to the second one). This may require adjustments in the heights of the air track supports/legs. Use the air track's ruler to note this *starting* location in case the experiment needs to be executed more than once and, indeed, for the next step.



6. Place the smaller glider so that its fence (*i.e.,* the 2.50 cm opaque strip) is halfway through the gate's beam. Measure the distance, d_1, from the leading edge of this glider to the trailing edge of the stationary one in its *starting* location. Also measure the distance, d_2, from the leading edge of first glider to the trailing edge of the second one when they are bonded. Record the difference, $d_3 = d_1 - d_2$.
7. Propel the smaller glider (m_1) from one end of the air track (before photogate A) towards the stationary one. This glider has the attached fence. The glider will pass through the gates, and it will bounce off the end of the track, so make sure it does not run through the second gate again.
8. You will only be collecting the data for one successful run of the experiment (*i.e.*, collision with bonding of the gliders and usable time readings). Repeat until the run is successful.

9. Record the two time intervals (A and B) from the CPO timer for the successful run.

Nota Bene: The transparent parts of the fence attachement must be free of smudges or marks that could obstruct the photogate beams after the opaque strip has. An indication that this may have occurred is an anomalously short time reading for either t_A and/or t_B.

E. Measurements

mass of moving glider, m_1 [$gram$]	
mass of stationary glider, m_2 [$gram$]	
fence length, ℓ_F [cm]	
d [cm]	
d_3 [cm]	

Time Intervals	
t_A [sec]	t_B [sec]

F. Instructions

1. Calculate the velocity of the single glider (u), before the collison, and of the two adjoined gliders (v), after the collision.

2. Calculate the momentum before and after the collision

$$p^{(ini)} = m_1 u \tag{5}$$

$$p^{(fin)} = (m_1 + m_2)\, v \tag{6}$$

3. Calculate the kinetic energies.

4. Take the initial momentum to be the accepted value, and determine the percent error in the final momentum.

5. For the initial state, calculate the uncertainty in the momentum, $\delta p_{ini,}$ using the following (propagated error) formula

$$\delta p^2 = p^2 \left[\left(\frac{\delta m}{m}\right)^2 + \left(\frac{\delta \ell_F}{\ell_F}\right)^2 + \left(\frac{\delta t}{t}\right)^2 \right] \tag{7}$$

   taking $\delta m = 0.1\ g,\ \delta \ell_F = 0.02\ cm$, and $\delta t = 0.0001\ sec.$

6. For the final state, calculate the uncertainty in the momentum, $\delta p_{fin,}$ using (7).

7. Do the two intervals, $(p_{ini} - \delta p_{ini},\ p_{ini} + \delta p_{ini})$ and $(p_{fin} - \delta p_{fin},\ p_{fin} + \delta p_{fin})$ overlap?

8. If these intervals overlap that would confirm momentum conservation to the limits of our uncertainty. If they do not overlap, and especially if $p_{fin} < p_{ini}$, it is likely due to the presence of a (non-zero) net external force acting along the track, *i.e.*, kinetic friction. If this is the case for you, calculate the effective coefficient of kinetic friction on the air track

$$\mu = \frac{1}{2g} \frac{p_{ini}^2 - p_{fin}^2}{\left[m_1^2 d_3 + (m_1 + m_2)^2 (d - d_3)\right]} \tag{8}$$

G. Calculations

state	speed: $v = \ell_F \;/\; t$ [m/s]	momentum: p [$N \cdot s$]	energy: KE [$Joules$]
before collision			
after collision			

%-Err (p_{fin})	
δp_{ini} [$N \cdot s$]	
δp_{fin} [$N \cdot s$]	
$(p_{ini} - \delta p_{ini},\ p_{ini} + \delta p_{ini}) \cap (p_{fin} - \delta p_{fin},\ p_{fin} + \delta p_{fin})$	
μ_k	