

Lab: Conservation of Linear Momentum

There is a quantity called *linear momentum* defined as the mass of an object times its velocity, i.e.

$$\vec{p} = m\vec{v}, \quad (1)$$

where \vec{p} is the symbol for linear momentum. Notice that momentum is a *vector* quantity. You must always include the direction when you are reporting an object's momentum.

If there is no net external force present, the *total* momentum of a system of many bodies will be conserved. This property makes momentum an extremely useful quantity when solving problems that involve collisions between objects, since the total momentum before the collision must equal the total momentum after the collision.

For this lab you will collide “cars” on an air track and find their momenta both before and after a collision. You will then compare the total momentum found before a collision to that found after the collision to see if the two values are consistent.

To determine the momentum of one of the cars we must measure both its mass and its velocity. To get a quality measurement for the velocity you will be using photogates that are connected to timers. These work by sending a light beam from one side of the gate to a sensor on the other. When the light beam is broken by a passing object, the timer will run. In the case of a single object passing by only once, the time recorded will tell us how long the object was blocking the beam. We can use this information, along with the length of the object, to figure out how fast the object was moving.

Question:

Sketch a picture, and determine a formula for finding an object's speed, v , in terms of its length, L , and the time that it blocked the beam while passing through the photogate, Δt .

Since velocity is a vector, you must also designate which direction the object was going in as it went through the gate. The photogate and timer have no way to distinguish this, so you will have to define one direction as ‘positive’ and the other direction as ‘negative’, and assign the appropriate signs to all of your velocities yourself. (Be consistent throughout the experiment!)

Another complication arises when a car passes through a gate, collides off of another car and then comes back through the same gate. In this case, your time recorded will be the total time for *both* passes. You would like to find the times for each individual pass so that you can calculate the velocity for each.

Depending on your readout device you will have to do one of two things. Some of the timers have a memory and can store the time for the first interval so that you can retrieve it later. Other models may require you to watch carefully so that you can quickly record the first time *before* the car comes back through on its return trip. This will probably require some teamwork to accomplish. Either way, you will end up with two time values. One represents the time for the first pass, Δt_1 , and the other is the total time for both passes, Δt_{tot} . To find the time for the second pass only you must take the difference,

$$\Delta t_2 = \Delta t_{tot} - \Delta t_1. \quad (2)$$

Then you can use Δt_1 to calculate the initial velocity of the car, and Δt_2 to calculate the final velocity of the car.

Now using the initial and final velocities for the cars, along with their masses, you can calculate the initial and final momentum for each car. These values, in general, will *not* be equal. It is only the *total* momentum that is conserved before and after a collision. Therefore you should calculate the total momentum before the collision by taking the (vector!) sum of all the initial momenta, and the total momentum after the collision by taking the (vector!) sum of all the final momenta. These two values *should* be equal within experimental uncertainties.

You will have to perform this experiment for four different cases, but first we must prepare the experimental setup. Place a car in the center of the air track and see if it starts to move on its own. If it does, the air track is not level. Use the leveling screws and adjust the track to be as level as possible.

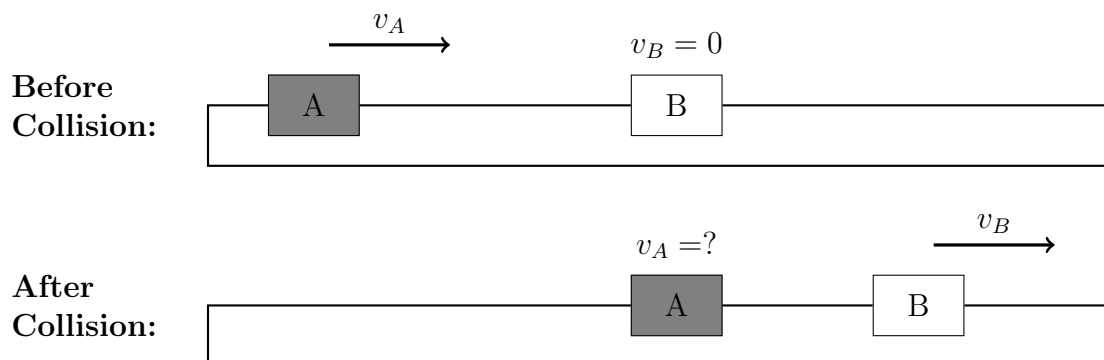
Question:

Why is leveling the air track important?

Question:

Why do we use an air track rather than just slide our objects on a regular surface?

Case I. Use two cars of approximately equal mass. Set the first car near the middle of the track so that it stays stationary. Start the other car from one end of the track and push it (not too fast) so that it collides with the first car. Determine the total momentum before and after the collision and compare the two values.



Gate Times	A	B
Δt_1		_____
Δt_{tot}		_____
Δt_2		

	Car A	Car B
mass		
length		
initial velocity		
final velocity		
initial momentum		
final momentum		

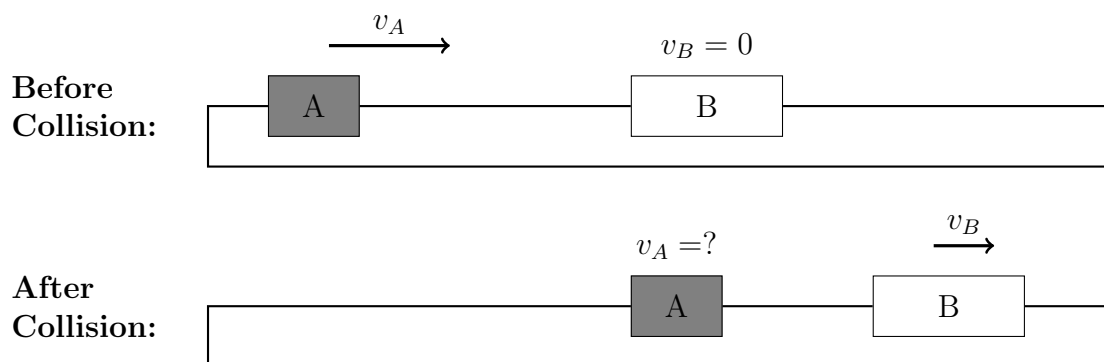
Total Momentum

initial: _____ final: _____

% difference: _____

Comment on any sources of error you may have noticed while doing this experiment:

Case II. Repeat the experiment from Case I, but this time replace the stationary car with one of heavier mass.



Gate Times	A	B
Δt_1		_____
Δt_{tot}		_____
Δt_2		

	Car A	Car B
mass		
length		
initial velocity		
final velocity		
initial momentum		
final momentum		

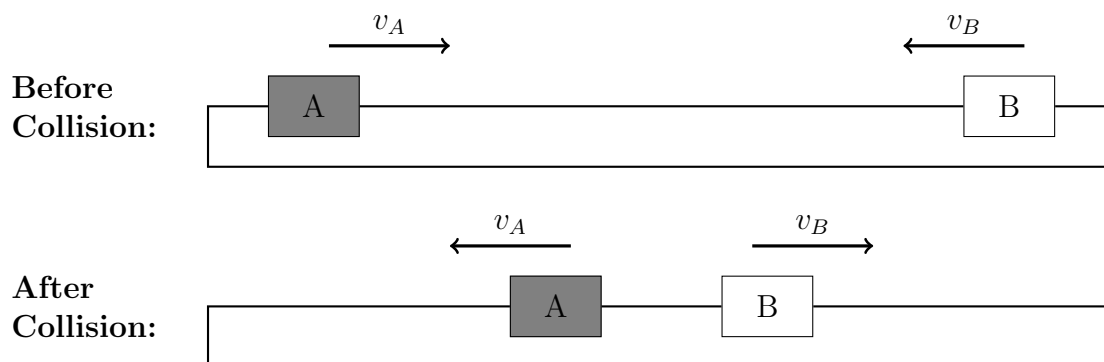
Total Momentum

initial: _____ final: _____

% difference: _____

Comment on any sources of error you may have noticed while doing this experiment:

Case III. Go back to using two cars of approximately the same mass, but this time start *both* cars off with a push so that they are initially moving towards each other.



Gate Times	A	B
Δt_1		
Δt_{tot}		
Δt_2		

	Car A	Car B
mass		
length		
initial velocity		
final velocity		
initial momentum		
final momentum		

Total Momentum

initial: _____ final: _____

% difference: _____

Comment on any sources of error you may have noticed while doing this experiment:
