

# Momentum

As you work through the steps in the lab procedure, record your experimental values and the results on this worksheet. Use the exact values you record for your data to make later calculations.

## Conservation of Momentum Lab – Simulation and Tools

Open the Virtual Momentum Track simulation to do this lab. You will need to use the VPL Grapher to complete this lab.

### I. Conservation of Momentum in a Collision

8. What is the sign of the red cart's initial momentum,  $m_R \mathbf{v}_{R0}$ , its momentum just before the collision?

9. What is the sign of the red cart's final momentum,  $m_R \mathbf{v}_{Rf}$ ?

10. What is the sign of the change in the red cart's momentum,  $\Delta(m_R \mathbf{v}_R) = m_R(\Delta \mathbf{v}_R)$ ?

11. The blue cart's initial momentum,  $m_B \mathbf{v}_{B0}$ , doesn't have a sign. What is its momentum before the collision?

12. What is the sign of the blue cart's final momentum,  $m_B \mathbf{v}_{Bf}$ ?

13. What is the sign of the change in the blue cart's momentum,  $\Delta(m_B \mathbf{v}_B) = m_B(\Delta \mathbf{v}_B)$ ?

14. Complete Tables 1a and 1b. Record the carts' velocities before ( $\mathbf{V}_o$ ) and after ( $\mathbf{V}_f$ ) the collision. Using the known masses you can now calculate the momentum of each cart before and after the collision. You can then calculate the initial ( $\mathbf{P}_{(sys)o}$ ) and final ( $\mathbf{P}_{(sys)f}$ ) system momenta by adding the individual momentum values in the rows above. Finally, you can calculate the change in momentum of the system ( $\Delta \mathbf{P}_{sys}$ ) from  $\mathbf{P}_{(sys)f} - \mathbf{P}_{(sys)o}$ .

**Table 1a: Momentum Before and After a Collision** (Note: careful with mass units!)

Cart	Mass of Cart (kg)	$\mathbf{V}_o$ (m/s)	$\mathbf{V}_f$ (m/s)
Red			
Blue			

**Table 1b: Momentum Before and After a Collision** (Note: careful with mass units!)

Cart	$\mathbf{P}_o$ (kg · m/s)	$\mathbf{P}_f$ (kg · m/s)	$\Delta \mathbf{P}$ (kg · m/s)
Red			
Blue			
	$\mathbf{P}_{(sys)o} =$	$\mathbf{P}_{(sys)f} =$	$\Delta \mathbf{P}_{sys} =$

15. Equation 6 says that  $\mathbf{p}_{(\text{red})o} + \mathbf{p}_{(\text{blue})o} = \mathbf{P}_{(\text{red})f} + \mathbf{P}_{(\text{blue})f}$ . How did that work out? Quote your numbers.

16. Equation 7 says that  $\mathbf{p}_{(\text{red})f} - \mathbf{p}_{(\text{red})o} = -(\mathbf{p}_{(\text{blue})f} - \mathbf{p}_{(\text{blue})o})$ . How did that work out? Quote your numbers.

## II. Elastic Collisions

With the spring plunger, the carts seemed to bounce nicely off of each other. Could this have been an elastic collision, that is, one where the Kinetic Energy of the system was unchanged during the collision? Let's do the math and see.

1. Tables 2a and 2b work just like Tables 1a and 1b and use the same data. By filling in the tables, you'll calculate the total KE of the system of two carts before ( $\text{KE}_{(\text{sys})o}$ ) and after ( $\text{KE}_{(\text{sys})f}$ ) the collision. You'll also calculate the change in kinetic energy of the system,  $\Delta\text{KE}_{\text{system}}$  which is  $\text{KE}_{(\text{sys})f} - \text{KE}_{(\text{sys})o}$ . Note that in the equation for KE, only the speed is considered. That is, KE has no direction associated with it. This actually doesn't matter in your calculations since all the  $v$ -terms are squared.

**Table 2a: Kinetic Energy Before and After a Collision**

Cart	Mass of Cart (kg)	$v_o$ (m/s)	$v_f$ (m/s)
Red			
Blue			

**Table 2b: Kinetic Energy Before and After a Collision**

Cart	$KE_o$ (J)	$KE_f$ (J)	$\Delta KE_{sys}$ (J)
Red			
Blue			
	$KE_{(sys)o} =$	$KE_{(sys)f} =$	$\Delta KE_{sys} =$

Show calculations of total  $KE_o$ , total  $KE_f$ , and  $\Delta KE$ .

2. Does the *kinetic energy* of the system appear to be conserved in this collision? How do you know? Quote your numbers.

### III. Totally Inelastic Collisions

1.b. Take a screenshot of the double graph from Grapher and upload it as "Mom\_III1.png". (Submit a file with a maximum size of 1 MB. *You will upload this file in the WebAssign question.*)

1.d. Explain how you know from the graph(s) that **momentum was conserved, but kinetic energy was not**. You should be able to tell just by looking at the graphs but you can use Grapher to assist you.

2.b. Take a screenshot of the double graph from Grapher and upload it as “Mom\_III2.png”. (Submit a file with a maximum size of 1 MB. *You will upload this file in the WebAssign question.*)

2.d. This one’s not so obvious. You’ll need some data and calculations to work with. Use Grapher to get the data you need. Use Tables 3a and 3b to record your data and calculated values.

**Table 3a: Momentum and Kinetic Energy Before and After a Collision**

Cart	Mass of Cart (kg)	$v_o$ (m/s)	$v_f$ (m/s)
Red			
Blue			

**Table 3b: Momentum and Kinetic Energy Before and After a Collision**

Cart	$p_o$ (kg · m/s)	$p_f$ (kg · m/s)	$KE_o$ (kg · m <sup>2</sup> /s <sup>2</sup> )	$KE_f$ (kg · m <sup>2</sup> /s <sup>2</sup> )
Red				
Blue				
	$P_{(sys)o} =$	$P_{(sys)f} =$	$KE_{(sys)o} =$	$KE_{(sys)f} =$

Show the calculations for  $\mathbf{p}_{(\text{sys})\text{o}}$ ,  $\mathbf{p}_{(\text{sys})\text{f}}$ ,  $\text{KE}_{(\text{sys})\text{o}}$ , and  $\text{KE}_{(\text{sys})\text{f}}$ .

3. Using your data, explain how you know that momentum was conserved, but kinetic energy was not conserved.

4. You should have found that the pair of carts moving as one with a mass of  $2 \times m_{\text{cart}}$  had half the speed of the single cart with a mass of  $1 \times m_{\text{cart}}$ . Why then is the kinetic energy less after the collision? **That is, why doesn't one cart with a speed of  $v$  have the same kinetic energy as two carts each with a speed of  $\frac{v}{2}$ ?** (Here's a head start to your answer: Before the collision, the object carrying all the momentum and KE had a mass of  $m_{\text{cart}}$  and a speed of  $v_0$ .)

5. For the situation in Graph III1, what fraction of the kinetic energy of the carts remains after the collision? That is, what is  $(\text{KE}_{\text{final}}/\text{KE}_{\text{initial}})$ ? You don't have any numbers to work with, but you don't need any.

6. For the situation in Graph III2, what fraction of the kinetic energy of the carts remains after the collision? That is, compute  $(KE_{\text{final}}/KE_{\text{initial}})$ . You'll need to use your numbers this time.

Show calculations of total  $KE_{\text{final}}/KE_{\text{initial}}$  here.