9-1 Physics Lab

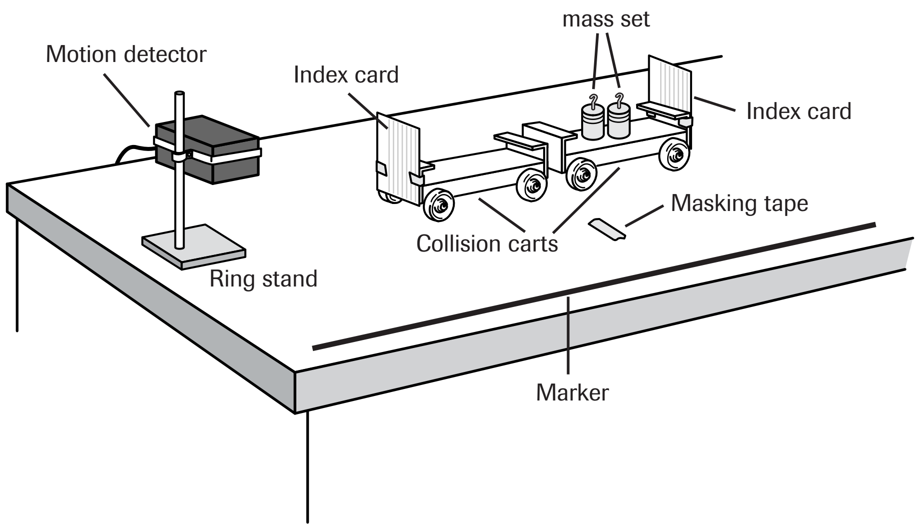
Conservation of Momentum

Objectives

- **Measure** the masses and velocity of two carts.
- **Calculate** the momentum of the two carts.
- **Apply** the conservation of momentum to a system.
- **Demonstrate** conservation of momentum for an interaction.

The law of conservation of momentum states: The momentum of any closed, isolated system does not change. This law is true regardless of the number of objects or directions of the objects before and after they collide. In a collision or interaction, the momentum before the collision equals the momentum after the collision.

The change in an object's momentum is equal to the product of the force acting on the object and the interval of time the force acts. In this investigation, two carts will be pushing away from each other. Thus, from Newton's third law of motion, each cart will give the other an equal, but opposite, impulse. The change of momentum from the first cart will equal the change of momentum of the second cart. The two carts in this investigation will have unequal masses. The two carts will be placed together compressing a spring in one of the carts. The carts will move apart when the spring is released.



Materials

- safety goggles
- 2 collision carts, one with a spring-mechanism
- balance
- meterstick
- CBL unit
- ultrasonic motion detector
- link cable
- graphing calculator
- set of masses
- masking tape
- index cards, 5 × 7 inches
- ring stand
- clamp

Procedure

1. Select a counter space having 2–3 meters of clear space. Place a piece of masking tape in the middle of this space.
2. Tape an index card onto each of the collision carts. This will make the carts more easily seen by the ultrasonic motion detector. Mass each cart and record this value in Table 1. Using your mass set, add enough masses to cart 2 so its mass is twice the mass of cart 1. It is desirable to have the mass of cart 2 within 5% of twice its original mass. Record the mass added to cart 2 in Table 1. Secure the masses to the cart with a small piece of masking tape. Compress the spring mechanism and place the carts centered over the tape marker.

3. Mount the ultrasonic motion detector on a ring-stand clamp, using tape if necessary. Adjust the height of the sensor so it is at the same height as the middle of the index card. Place the motion detector about 1.5 meters away from the masking-tape marker.
4. Connect the CBL unit to the calculator, using the unit-to-unit link cable and the link ports on the calculator and CBL unit. Connect the ultrasonic motion detector to the SONIC port of the CBL unit.
5. Turn on the CBL unit and graphing calculator. If not already loaded into your calculator, load the program PHYSICS and its subprograms into your calculator from another calculator or download them from a computer. Start the program PHYSICS on your graphing calculator.
6. Select the option SET UP PROBES from the MAIN MENU. Enter 1 for the number of probes. Then from the SELECT PROBE menu, choose MOTION from the list.
7. Select the MONITOR INPUT option from the COLLECT DATA menu. This will allow you to check and see if the motion detector is working properly by displaying the distance between the motion detector and the vehicle on the CBL unit. Press the "+" to quit the sampling test.
8. You are ready to begin the experiment. Select the COLLECT DATA option. In DATA COLLECTION, select TIME GRAPH. The calculator will prompt you to ENTER TIME BETWEEN SAMPLES IN SECONDS. Enter 0.03 for the time between samples. Enter 99 for the number of samples. (A TI-82 can collect only 99, a TI-85 can collect only 55, while a TI-83 can collect 120.) Check the values you entered and press ENTER. If the values are correct, select USE TIME SETUP to continue. If you have made a mistake entering the values, then select MODIFY SETUP and reenter the values before continuing.
9. On the TIME GRAPH menu, select NON-LIVE DISPLAY.
10. Press ENTER. The READY EQUIPMENT command should appear. While preventing the carts from moving, one student should press ENTER on the graphing calculator. When the motion detector begins to click, depress the spring-release mechanism to release the carts. Stop the carts before one strikes the motion detector or falls on the floor.
11. When the motion detector has stopped clicking and the CBL unit displays DONE, press ENTER on the graphing calculator. From the SELECT GRAPH menu, select DISTANCE to plot a graph of the distance in meters against the time in seconds.
12. The displacement graph will initially show a horizontal line until the cart begins to move. The beginning of the graph will show where the cart accelerated as the spring was released. Use the right arrow key to move along the graph to the middle section where the cart was moving at a relatively constant speed. Select a point near the beginning of this middle section and one near the end. Record the distance (y-value) and the time (x-value) into your data table for each point. Press ENTER to return to the SELECT GRAPH menu.
13. Rotate the two carts so the second cart is facing the motion detector. Repeat the experiment collecting data for the second cart.
14. Repeat the experiment for a second trial.

Name ______________________________

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Data and Observations

Table 1		
	Mass	**Mass Added (kg)**
Cart 1		--
Cart 2		

Table 2							
	Begin *t*	**End *t***	**Δt**	**Begin *d***	**End *d***	**Δd**	**Average velocity**
Cart 1-trial 1							
Cart 1-trial 2							
Cart 2-trial 1							
Cart 2-trial 2							

Analysis and Conclusions

1. For each trial, find the average velocity of each cart and enter these in Table 2.

2. For each trial, calculate the momentum of each cart.

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3. Calculate the total momentum of the two carts before the spring mechanism was released.

4. Was the velocity of the carts equal before and after the spring-mechanism release?

5. Calculate the final total momentum. Compare the initial and final momentum of the carts.

Extension and Application

1. While playing baseball with your friends, your hands begin to sting after you catch several fast balls. What method of catching the ball might prevent this stinging sensation?

2. If an incident ball A hit two target balls, B and C, at an angle, predict what would happen to the total momentum of the system after the collision. Give a reason for your answer and write an equation that proves your answer.

3. When an incident ball, A, collides at an angle with a target ball, B, of equal mass that is initially at rest, the two balls always move off at right angles to each other after the collision. Use a familiar equation for a right triangle to show that this statement is true. *Hint:* Since the collision is elastic, kinetic energy is conserved and

$$\frac{1}{2}m\boldsymbol{v}_{\mathrm{A1}}^2 = \frac{1}{2}m\boldsymbol{v}_{\mathrm{A2}}^2 + \frac{1}{2}m\boldsymbol{v}_{\mathrm{B2}}^2.$$