UNIT IX: IMPULSIVE FORCE MODEL

INSTRUCTIONAL GOALS

1. **Momentum**

   Define momentum and distinguish between momentum and velocity.

   momentum = (mass)(velocity)

2. **Conservation of Momentum**

   Show that momentum before an collision is equal to the momentum after the collision

   Show that the total system momentum after a explosion remains zero.

   Distinguish between elastic and inelastic collisions ($\Delta E_{k1} \neq \Delta E_{k2}$)

   Show that the system momentum before a collision is equal to the system momentum after the collision.

   Use conservation principles to solve momentum problems involving elastic and inelastic collisions for initial velocity, final velocity or mass, given the other values.

   system momentum = constant

3. **Impulse**

   Define impulse; distinguish between impulse and force.

   Determine the impulse acting on an object

   via a F vs t graph

   given the change in momentum.

   Determine the force acting on an object, given its change in momentum.

$$F = \frac{m\Delta v}{\Delta t}$$

LAB NOTES

APPARATUS -- Cart Explosions

Two dynamics carts (PASCO recommended)
ULI and Vernier's ULI Timer program
masses
Photogates
Dual photogate adapter

PRE-LAB DISCUSSION -- Cart Explosions

- Demonstrate the explosion apparatus on the carts. Elicit observations concerning the variables that would affect the motion of the two carts before the collision vs after the collision. Be sure the students say mass, velocity, force and time.
- Discuss the fact that the force exerted on both carts must be the same (i.e., Newton's third law) and the time the carts act on each other is the same.
- Discuss lab setups for determining the relationship between the mass and velocity of the carts before the collision and after the collision.
- Discuss the use of photogates to determine the instantaneous velocity of the carts.

LAB PERFORMANCE NOTES -- Cart explosions

- You will need to open the ULI timer program (gate timing: two gates) Be sure that the students pay attention to the direction of the carts. The photogates will only give the magnitude of the velocity; the students will have to assign the direction.
- Be sure that the carts, with attached flags (about 1.5 cm in width) are placed as close as possible to the photogates without blocking the gates.
- Have the students run several scenarios -- same mass carts, cart A with twice the mass of B, etc.

POST-LAB DISCUSSION -- Cart Explosions

- For the scenario with one cart having twice the mass of the others, the students will easily see that the double mass cart has one-half the speed of the less massive cart. There is the possibility that no group will come up with the equation:

$$m_1\Delta v_1 + m_2\Delta v_2 = \text{ constant (0, in the case of stationary explosions)}$$

  Therefore, you may need to help the students deduce the above relationship.
- Define mass times velocity as momentum.
- The final mathematical model the students should leave with is that the momentum before the explosion is equal to the momentum after the explosion.

DEPLOYMENT -- Cart Collisions

APPARATUS -- Cart Collisions

Two dynamics carts (PASCO recommended)
Graphical Analysis
masses
photogates with Apple IIe connections or ULI with photogates

PRE-LAB DISCUSSION -- Cart Collisions

- Review the cart explosion lab.
- Ask the students for examples of types of collisions. Record the examples then divide them into inelastic vs elastic collisions.
- Ask the students to perform an investigation to check the validity of the model from the preceding lab for colliding carts.

LAB PERFORMANCE NOTES -- Cart Collisions

- Have each group of students perform about thirty different cart collisions. They must record the mass of the carts, the magnitude and the direction. You need to be aware that each photogate may record several speeds during one collision. Keeping track of the direction and speed of each cart during a collision requires some concentration.
- You can either allow the photogates to only give the time the gate is blocked or allow the software to calculate the speed for each cart. If you choose to allow the computer to calculate the speed don't forget to enter the width of your flags.
- Be sure that the collision between the carts, with attached flags (about 1.5 cm in width) takes place as close as possible to the location of the photogates.
- To save time you could have each group perform several collisions such that the entire class does at least 30 collisions total.

POST-LAB DISCUSSION -- Cart Collisions

- The students should graph system momentum after the collision vs system momentum before the collision. This graph should be linear with a slope of approximately one.
- The students will need to decide what this slope means; generally, when the units cancel and the value of the slope approaches unity, the variables are equal. In this case,the system momentum remains unchanged no matter what type of collision occurs.

DEPLOYMENT -- Impulsively Stopping

APPARATUS -- Impulsively Stopping

One dynamics cart (PASCO recommended)
one student force sensor attached to a ring stand
ULI with Vernier's MacMotion software
masses
Motion Detector
Graphical Analysis

PRE-LAB DISCUSSION -- Impulsively Stopping

- Review the conservation of momentum and Newton's Second Law.
- Rearrange Newton's Second Law such that the students can see that:

$$F = m\frac{\Delta v}{\Delta t}$$

$$F\Delta t = m\Delta v$$

- Define impulse as:

$$\text{Impulse} = F\Delta t$$

therefore; impulse change equals a change in momentum

- To validate the above equation with explosions you may want to refer back to the Cart Explosion lab and discuss how the force on each cart and the time of contact were the same.
- Ask the students to test whether this relationship holds true for elastic and inelastic collisions.

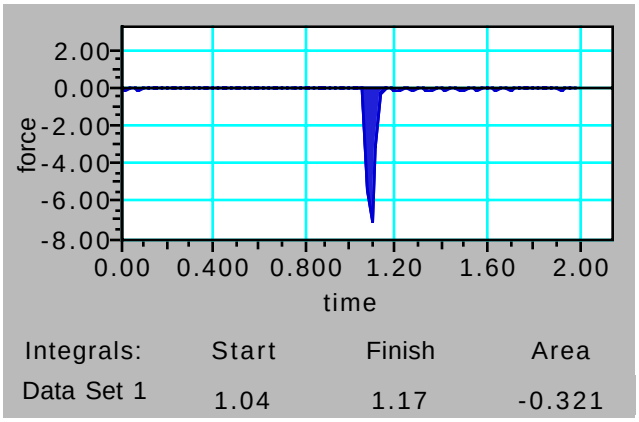
LAB PERFORMANCE NOTES -- Impulsively Stopping

- Have each group perform about six collisions of the cart running into the force probe tab using a motion detector and force probe at the same time. (all collisions must stay in the recording range of the force probe:)
- The students can try different types of collisions: they could attach magnets to the cart and the force probe so that they repel each other, they could attach Styrofoam to the force probe to increase the time of the interaction, etc.
- They should compare the impulse (found from the area under the curve) to the change in momentum during the collision (calculated by tracing along graph to determine the velocity at the start of the collision and the velocity at the end of the collision). The easiest way to compare these values is to calculate the percent difference between the two readings.
- Be sure to caution the students to watch the signs on their velocity readings when calculating the change in velocity or momentum
- After the data has been uploaded into Graphical Analysis it will be easier for the students to visualize the graph if they deselect the point protectors and choose connecting lines in the graph menu.

- When taking the area under the curve be sure not to select too much force data from the start of the interaction nor from the end of the interaction.

- At right is a force time graph of the collision obtained from Graphical Analysis.

- The velocity data can be found under the data menu in MacMotion.



Integrals:	Start	Finish	Area
Data Set 1	1.04	1.17	-0.321

POST-LAB DISCUSSION -- Impulsively Stopping

- The students should achieve percent differences between the impulse and the change in momentum that have a magnitude below 10%. They should be able to experimentally show that this relationship holds true in all cases.
- The students should have a print out of the force graph to validate their experiment.