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CONSERVATION OF LINEAR MOMENTUM I

PREDICTIONS AND OBSERVATIONS

OBJECTIVE

To study collisions by examining the linear momentum before and after the collision.

DISCUSSION

We want to examine collisions between two objects moving along a straight line (linear motion) in an environment where frictional forces are kept to a minimum. We will use the air tracks for this purpose.

When two objects interact, or collide, the total momentum of the system, defined by

$$\mathbf{P} = m_1\mathbf{v}_1 + m_2\mathbf{v}_2,$$

is the same after the collision as it was before the collision. This statement is the law of conservation of momentum and can be used together with the law of energy conservation to predict the final velocities of colliding objects if their initial velocities are known. Since some energy may be lost in the collision process (even the air track is not totally free from friction) there may be a small difference between the predicted and measured velocities. However, for moderate velocities the error should be quite small.

ACTIVITY 1

1. Weigh the two gliders. If they have unequal masses, add weights until they are of equal mass. **Record the final glider masses.**

2. Place both gliders on the track about 0.5 meters apart.

3. Turn on the air to the track and observe the gliders. If they move in one direction or the other, you will need to level the track by adjusting the leveling screws underneath the track. Be sure that the gliders are balanced lest uneven air-flow causes them to move.

4. When the track is level, place one glider at the center of the track so that it remains at rest

ACTIVITY 2

5. Imagine that you have a motion probe attached to one end of the track and only one glider on the track.

6. If you give the glider a push *away* from the probe, **how do you think the graph of its position vs. time will look? Draw a sketch of your prediction. How will its velocity vs. time graph look? Draw a sketch of your prediction.**

7. If you give the glider a push *towards* the motion probe, **how do you think the graph of its position vs. time will look? Draw a sketch of your prediction. How will its velocity vs. time graph look? Draw a sketch of your prediction.**

8. Mount a motion probe so that it senses motion along the air track. Connect the probe to the computer and take measurement of position and velocity for the glider moving *away* from the probe and *toward* the probe. **Label your graph and print it .**

ACTIVITY 3

9. Place one glider at rest in the center of the track and the other near one end. **Draw a diagram of the track with gliders on it as seen from the side. Label the glider near the end 1 and the glider near the center 2.**

10. **Predict what will happen if you push glider one from the end toward glider two?** (Give a description of what you would see with your eyes, not computer graphs.)

11. Now imagine that you have motion probes attached to both ends of the track, and two carts are on the track. Predict how their position vs. time graphs will look when the moving glider collides with the stationary glider of equal mass. **Draw a sketch of your prediction being sure to label the path of each glider.**

12. **Draw a prediction of the velocity vs. time graph for the two gliders.**

13. Mount Motion Probes near both ends of the air track. Connect both probes to the computer. Place glider two in the center of the track. Push glider one gently from the end of the track towards the stationary glider two in the middle. **What did you observe when**

they collided? Discuss your computer graphs. Print a sample one.

ACTIVITY 4

14. **What do you predict will happen when a heavy glider collides with a stationary light glider? How will their position vs. time graphs look? Draw a sketch of your prediction labeling the path of each glider.**

15. **Draw a prediction of the velocity vs. time graph.**

16. Add 200 g to glider one and push it towards the stationary glider two. **What did you observe with the motion probes? How does your prediction compare with the computer graphs of velocity?**

ACTIVITY 5

17. **What do you predict will happen when the lighter glider collides with a stationary heavier glider? How will their position vs. time graphs look? Draw a sketch of your prediction labeling the path of each glider.**

18. **Draw a prediction of the velocity vs. time graph.**

19. Place the heavier glider in the middle of the track and record the behavior of the collision when struck by the lighter moving glider. **What did you observe with the motion probes? How does your prediction compare with the computer graphs of velocity?**

SUMMARY

In this experiment we have taken pains to minimize friction and outside forces. If the collisions are elastic, then we have another conservation rule to apply: Conservation of Kinetic Energy. When both conservation rules apply to a collision between two objects that move along the same line, the final velocities are unique. That is, if we know the masses and the initial velocities, then the two final velocities can be uniquely computed.

Elastic Collisions: When the masses are identical and one object is at rest, our prediction is that the incoming object stops and the struck one recoils with the velocity that the incoming car had initially. Similarly, if the masses are unequal, there are definite predictions regarding velocities after the collision, as you have observed.

Inelastic Collisions: When the collisions are inelastic, some kinetic energy is lost and we can no longer make an accurate prediction of the outcome. However, if the collision is perfectly elastic and the two objects stick together, there is only one final velocity and it is uniquely determined by the masses and the incoming velocity.

You should be comfortable with the qualitative predictions of collisions from today's observations. Feel free to repeat the collisions or to experiment with variations to help get the ideas firmly fixed. Next week you will make measurements of the velocities in order to check the conservation law quantitatively.

Data sheets to hand in. Name ____________________

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PREDICTIONS AND OBSERVATIONS DATA SHEET

ACTIVITY 1

Record the final glider masses.

Glider	**Mass (g)**
Glider 1	
Glider 2	

ACTIVITY 2

Predict the motion by drawing a graph of position *vs.* time for (a) the glider moving away from the probe and (b) toward the probe.

(a) Away from probe **(b) Toward the probe**

Draw a sketch of your predicted velocity *vs.* time.

(a) Away from probe **(b) Toward the probe**

Be sure to print out your graph to include with your work.

ACTIVITY 3

Draw and label a diagram of the track and gliders. Label the two carts as instructed. Go back and indicate which mass corresponds to which cart (in Activity 1).

Predict what will happen when the moving glider collides with a stationary glider of equal mass. (Describe what you see.)

Predict their position *vs.* time graphs by drawing a sketch. Be sure to label the path of each glider.

Predict their velocity *vs.* time graphs by drawing a sketch. Be sure to label the path of each glider.

Push glider one towards stationary glider two. What did you observe? (Give both a verbal description as well as discussion of the graphs.)

ACTIVITY 4

What do you predict will happen when a heavy glider collides with a stationary light glider?

Predict their position *vs.* time graphs by drawing a sketch.

Predict their velocity *vs.* time graphs by drawing a sketch.

Add 200 g to glider one and push it towards the stationary glider two in the middle. What did you observe with the probes?

ACTIVITY 5

What do you predict will happen when a light glider collides with a stationary heavy glider?

Predict their position *vs.* time graphs by drawing a sketch.

Predict their velocity *vs.* time graphs by drawing a sketch.

Interchange the two gliders so that the heavier one is in the middle of the track. Push the lighter glider towards the heavier stationary glider in the middle. What do you observe?