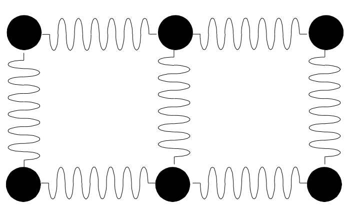
Pre-Session Questions

1. Why does it hurt more to be struck by a hard object than by a soft object with the same mass and velocity?

2. During a collision between a car and a large truck, suppose the truck exerts an average force F on the car. How much force does the car simultaneously exert on the truck? (More, less, same, indeterminate?)

3. One way to imagine the chemical bonds that hold atoms to each other in solids is as tiny springs connected between tiny atomic balls. Describe the sequence of events when two blocks of this sort of material collide and bounce off of each other.



Collisions

In your study of collisions so far, you have probably only looked at the initial and final states of the "system", while skipping over the actual collision process entirely. What goes on *during* the collision? How do the objects behave? Where do the forces they exert on each other come from? The purpose of this exercise is to try to learn some of these answers. The computer simulates two carts which can be set to collide with each other. When they come into contact, the computer will "slow down" time and allow you to observe the details of how the collision works.

In the activities that follow, we would like you to think about the questions, discuss them with your group, and make a prediction before trying things out in the simulation. The questions are similar in each of the four cases we are asking you to look at, but there are some variations, so please read carefully!

- Think about the forces that are felt and applied by two objects which are colliding with each other. In the space below, make a list of all the variables describing the objects and the collision that you can think of that might go into determining the sizes of these forces. For each variable, decide whether increasing that variable would result in larger forces, or smaller forces.

Case 1 – equal m; equal k; right cart stationary

In this first case we'll keep things as simple as possible. Suppose two carts have equal masses and their bumpers have equal stiffness. The cart on the right is stationary, and the cart on the left strikes it with a positive velocity. Try to answer these questions, but don't run the simulation yet.

<u>Predictions</u>

- As the two carts are in the process of colliding and deforming, how will the forces the carts feel change? When will the forces be strongest? Weakest? Sketch graphs of the forces *felt* by both carts during the collision as a function of time. (Not the forces exerted *by* the carts.)

- During the collision, the left cart slows down and the right cart speeds up. Based on the force sketches you have already made, sketch the carts' velocities as a function of time. Will the v graphs of the two carts be symmetrical to each other? (That is, reflections without changes in amplitude, shape, spacing, etc.) What does it mean when the two velocity graphs cross each other? At what value of v will this occur? What else is happening at this instant?

Case 1 – cont.

Now set up a simulation for the situation described and run it.

Simulations

- As the two carts are in the process of colliding and deforming, how do the forces the carts feel change? When are the forces be strongest? Weakest? Sketch graphs of the forces felt by both carts during the collision as a function of time. What is the maximum value of the force between the carts?

- Sketch the carts' velocities as a function of time. Are the *v* graphs of the two carts symmetrical to each other? In the instant that the carts have the same velocity, what else is going on? At what value of *v* does this occur?

Case 2 – equal m; right cart has 2k; right cart stationary

This time, consider what will happen if we stiffen one of the carts. That is, we're going to increase its “spring” constant, also known as *elasticity*. Suppose we run the left cart into the right cart, as before, but now the right cart (the “target”) has twice the *k* of the left one. Try to answer these questions, but don't run the simulation yet.

<u>Predictions</u>

- How will the forces in this situation differ from before, if at all? As the two carts are in the process of colliding and deforming, how will the forces the carts feel change? Sketch graphs of the forces felt by both carts during the collision as a function of time. Will the same amount of time elapse during this collision as during Case 1?

- As before, during this collision the left cart slows down and the right cart speeds up. Sketch the carts' velocities as a function of time. Will the *v* graphs of the two carts be symmetrical to each other? In the instant that the carts have the same velocity, what else is going on? At what value of *v* will this occur? Is this the same, or different, than before?

Case 2 – cont.

Now set up a simulation for the situation described by doubling the right cart's elasticity, and run the simulation. For easy comparisons between cases, we recommend keeping the same values for parameters other than the one you are investigating (in this case, the elasticity).

<u>Simulations</u>

- How do the forces in this situation differ from before, if at all? As the two carts are in the process of colliding and deforming, how do the forces the carts feel change? Sketch graphs of the forces felt by both carts during the collision as a function of time. Does the same amount of time elapse during this collision as during Case 1? What is the maximum value of the force between the carts?

- Sketch the carts' velocities as a function of time. Are the v graphs of the two carts symmetrical to each other? In the instant that the carts have the same velocity, what else is going on? At what value of v does this occur? Is this the same, or different, than before?

Case 3 – right cart has 2m; equal k; right cart stationary

This time, consider what will happen if one car is more massive. Suppose the carts have equal stiffness and we run the left cart into the right cart again, but now the right cart (the "target") has twice the mass of the left one. Try to answer these questions, but don't run the simulation yet.

<u>Predictions</u>

- How will the forces in this situation differ from before, if at all? As the two carts are in the process of colliding and deforming, how will the forces the carts feel change? Sketch graphs of the forces felt by both carts during the collision as a function of time. How will the elapsed time compare to Case 1?

- As before, during the collision the left cart slows down and the right cart speeds up. Sketch the carts' velocities as a function of time. Will the *v* graphs of the two carts be symmetrical to each other? In the instant that the carts have the same velocity, what else is going on? At what value of *v* will this occur? Is this the same, or different, than before?

Case 3 – cont.

Now set up a simulation for the situation described and run it.

Simulations

- How do the forces in this situation differ from before, if at all? As the two carts are in the process of colliding and deforming, how do the forces the carts feel change? Sketch graphs of the forces felt by both carts during the collision as a function of time. How does the elapsed time compare to Case 1? What is the maximum value of the force between the carts?

- Sketch the carts' velocities as a function of time. Are the *v* graphs of the two carts symmetrical to each other? In the instant that the carts have the same velocity, what else is going on? At what value of *v* does this occur? Is this the same, or different, than before?

Case 4 – equal m; equal k; left cart overtakes right cart

Lets go back to thinking about identical carts, but instead of having one of them be stationary, suppose both are moving in the positive direction although with different speeds, so that the cart on the left will "catch up" and strike the other cart from behind. Try to answer these questions, but don't run the simulation yet.

Predictions

- How will the forces in this situation differ from before, if at all? As the two carts are in the process of colliding and deforming, how will the forces the carts feel change? Sketch graphs of the forces felt by both carts during the collision as a function of time.

- Now think about the velocity graphs. Sketch the carts' velocities as a function of time. Will the v graphs of the two carts be symmetrical to each other? What is different between this Case and Case 1? In the instant that the carts have the same velocity, what else is going on? At what value of v will this occur? Is this the same, or different, than before?

Case 4 – cont.

Now set up a simulation for the situation described and run it.

Simulations

- How do the forces in this situation differ from before, if at all? As the two carts are in the process of colliding and deforming, how do the forces the carts feel change? Sketch graphs of the forces felt by both carts during the collision as a function of time. What is the maximum value of the force between the carts?

- Sketch the carts' velocities as a function of time. Are the *v* graphs of the two carts symmetrical to each other? What is different between this Case and Case 1? In the instant that the carts have the same velocity, what else is going on? At what value of *v* does this occur? Is this the same, or different, than before?

Wrap Up

- Look back over the list of variables you made at the beginning of the session. Are there any that you looked at during the session that you hadn't thought of initially? Do you need to amend any of your predictions about the effect these variables would have on the collisions?

Session Evaluation

- Did you find this exercise interesting? Did you find it educational? Which do you think is in more need of improvement: the software's capabilities, or the “lab” we have written to go with it?

- What, if anything, would you like to investigate using this software?

Post-Session Questions

1. Why does it hurt more to be struck by a hard object than by a soft object with the same mass and velocity?

2. During a collision between a car and a large truck, suppose the truck exerts an average force F on the car. How much force does the car simultaneously exert on the truck? (More, less, same, indeterminate?)

3. One way to imagine the chemical bonds that hold atoms to each other in solids is as tiny springs connected between tiny atomic balls. Describe the sequence of events when two blocks of this sort of material collide and bounce off of each other.