Lesson 6: Do our motion relationships help predict any of the interactions or outcomes in a collision?

Navigate

We have looked at how to prevent a collision and at factors that affect the ability to do so. But sometimes a collision still occurs.

With your class

1. What factors did we identify in our initial consensus model that we said might affect the severity of the outcome of a collision?

About 20% of crash fatalities are from a vehicle running into a fixed object like a tree, utility pole, or barrier.

With your class

2. Do we think the contact force (F) in these collisions has a similar relationship to the other 3 variables in our braking equations? Reference slide.

Make Initial Observations

With your class

3. Orient to how data were collected from a 0.6 kg cart before, during, and after a collision with a barrier. Reference slide.

Analyze and Interpret Data

With your class

4. What part of the graph is before the collision and what part is after? Reference slide.

5. How is the cart moving during each part of the graph? Reference slide.

Record Predictions

Predict what the graph will look like if we use the same mass cart (0.6 kg) but it is moving half as fast before it collides with the same barrier.

On your own

6. Sketch the predicted shape of your line on the same graph as the prior collision.

7. Label the value for the final velocity and the change in velocity (Δv) that you predict to see in this new collision. Reference slide.

Compare Predictions to Data

With a partner

8. How do the final velocity and the change in velocity (Δv) compare to your predictions?

Revise Our Models

With your class

9. Revise our motion relationship equations to use Δvelocity (Δv) rather than Δspeed.

Use a Model to Make Predictions

With your class

10. What are the known values for 3 of our variables in each collision?

11. Which equation should we use to determine the value of the 4th variable? Reference slide.

Calculate the Predicted Force

On your own

12. What would the force be for your collision? Reference slide.
- Record the equation you used and the calculations you carried out.
- Add the predicted value to the table.

Analyze and Interpret Data

With a partner

13. Compare the contact forces in each collision. Reference slide.
- What was surprising?
- What was not?

Compare to Our Predictions

With your class

14. How is our predicted force value related to the data points above and below it?

Compare the Averages to Our Predictions

With your class

15. How does the average force over this time period compare to our predictions? Reference slide.

Brainstorm How to Extend Our Model

In some vehicle collisions, the mass of the 2 vehicles is not the same.

With a partner

16. What changes would we need to make to one or both of these equations to keep track of the interactions and outcomes for both vehicles/carts?

Orient to the Two-Cart Collisions

With your class

17. Make initial observations of 3 collisions (D, E, and F) between 2 carts. Reference slide.

18. Collision D:
- The carts have equal mass.

19. Collisions E and F:
- One cart is double the mass of the other.

Make Predictions

Collision D: equal-mass carts, **Collisions E and F:** different-mass carts.

With your class

20. **Take a poll:** Predict how the contact force(s) will compare between collisions D, E, and F.
- There will be **equal**-magnitude forces on each cart in every collision.
- There will be **unequal**-magnitude forces on each cart in every collision.
- There will be **equal**-magnitude forces on each cart in some collision(s) and **unequal**-magnitude forces in other(s).

Analyze and Interpret Data

With your class

21. What patterns do you notice across the forces in the 3 collisions? Reference slide.

Navigate

With your class

22. What did we figure out last time?

23. Does what we figured out mean that different-mass vehicles should be equally safe if they collide with each other?

24. What evidence would we need to support or refute our arguments?

Student Content Advisory

Safety Precautions

25. We are about to look at data on fatalities related to collisions. If for any reason you need additional social or emotional support to engage with this content, please let your teacher know privately, so they can connect you to resources. If at any point in the unit you find you need additional support, let your teacher or another trusted adult know how you are feeling. Be aware that your teacher and/or classmates may have experienced trauma related to this topic. Approach conversations about car crashes and car safety with respect, guided by your class's Community Agreements.

Argue from Evidence

Turn and talk

26. What does this tell us about who is most at risk in a collision between a large truck and a smaller vehicle? Reference slide.

With your class

27. If we know that the forces on both vehicles will be equal in magnitude over the duration of the collision, then **why would large trucks be more dangerous for the other vehicles they collide with?**

Analyze and Interpret Data

With a partner

28. Discuss and annotate any patterns you notice across the new graphs for the 3 collisions. Reference slide.

With your class

29. How does the Δv compare? Reference slide.

Use Mathematical Thinking

With a partner

30. How does the Δv for each cart compare? Reference slide.

31. How does the Δv for each cart compare? Reference slide.

Develop a Mathematical Model

With your class

32. Apply contact force symmetry to help isolate the only variables that can be different in these 2-vehicle collisions. Reference slide.

Test Our New Mathematical Model

$m_1 * \Delta v_1 + m_2 * \Delta v_2 = 0$

With your class

33. Does our new equation predict these Δv values? Reference slide.

Use a Mathematical Model

$m_1 * \Delta v_1 + m_2 * \Delta v_2 = 0$

Individual think time

34. If these carts collide, how would the change in velocity of these carts compare if the green cart were **4 times** more massive than the blue one? Reference slide.

Orient to a Simulation

With your class

35. Orient to a simulation that we can use to collect data on various collision conditions. Reference slide.

Carry Out an Investigation

With a partner

36. (5 minutes) Use the simulation to test at least 1 elastic collision and 1 inelastic collision. Reference slide.

37. For each collision, record the following:

- type of collision (elastic or inelastic)
- mass of each cart (m_1 and m_2)
- velocities of each cart (starting and final)

Test Our Model

$m_1 * \Delta v_1 + m_2 * \Delta v_2 = 0$

With a partner

38. Does the mathematical relationship we developed above hold for none, one, or both of the collisions you tested in the simulation?

39. Document the calculations using the equation above for 1 collision. Write large enough so these are easily visible to share with the class.

Argue from Evidence

$m_1 * \Delta v_1 + m_2 * \Delta v_2 = 0$

With your class

40. Does the mathematical relationship we developed above hold for none, some, or all of the collisions we tested in the simulation?

Consider Other Conserved Quantities

$m_1 * \Delta v_1 + m_2 * \Delta v_2 = 0$

Turn and talk

41. Based on our work in prior units, what are some other physical quantities that are conserved?

Use Mathematical Thinking

Prepare to develop a **geometric way** to visualize why adding these together cancels them out:
$m1 * \Delta v1 + m2 * \Delta v2 = 0$

Turn and talk

42. What **shapes** have we used in math class to represent a quantity that is the product of 2 variables (a * b)?

Consider this new scenario:
A 3-kg cart is stationary at first. It has a velocity of +4 m/s after a collision with another cart.
$m_1 * \Delta v_1 + m_2 * \Delta v_2 = 0$

With your class

43. Use the shapes you chose to represent the amount of change that occurs for each cart (m * Δv).

Evaluate the Geometric Model

With your class 44. What did the geometric representations help us visualize?

45. What were some limitations of the geometric representations?

Use Mathematical Thinking

$m_1 * \Delta v_1 + m_2 * \Delta v_2 = 0$

- $m * \Delta v$ is the **change in momentum.**
- It has 2 variables as well as a Δ symbol.
- Let us consider what **momentum** is by recalling how we determine the change (Δ) for a single variable.

With your class 46. How did we use data to determine the change in a single variable (i.e., Δt, Δv)?

Add to Your Personal Glossary

In your notebook 47. Add to or record a new definition for any of the following terms in your Personal Glossary:

- *velocity*
- *elastic collision*
- *inelastic collision*
- *momentum*

Use Mathematical Thinking

$m_1 * \Delta v_1 + m_2 * \Delta v_2 = 0$

$m_{1\text{-start}} * v_{1\text{-start}} + m_{2\text{-start}} * v_{2\text{-start}} = m_{1\text{-end}} * v_{1\text{-end}} + m_{2\text{-end}} * v_{2\text{-end}}$

In your notebook 48. Use either of the conservation of momentum equations to solve for an unknown variable in 1 of the 3 collision scenarios.

Orient to the Self-Assessment and Reflection

With your class 49. Orient to the key and the related questions.

50. Discuss its role in helping to identify parts of the process you feel confident about and parts you would like additional practice or help with before our next assessment.

Use and/or Reflect on Mathematical Thinking

Home learning

51. Complete each practice problem and check your work with the key before trying another.

52. Complete questions A-C in the self-assessment and reflection.

53. Turn these in on the agreed-upon due date.

Navigate

Constants in a collision between different-mass vehicles:
- the magnitude of contact forces on both vehicles at the same points in time
- the total momentum in the system

With your class

54. What is changing in a collision between a large truck versus a small car that could affect passenger safety?

55. What new questions does this raise for us?

Turn and talk

56. Watch this crash test of a car hitting a fixed object. What do you notice? Reference slide.

57. Would you model this collision as
- *a bounce?*
- *a sudden stop?*

Make Initial Observations

With your class

58. A "sensor cart" can measure velocity and force with sensors. In a real-life crash, we cannot usually measure force directly, but we can model it.

59. How could we use our sensor cart to collect the data we need to model force predictions about real car crashes?

Analyze and Interpret Data

With your class

60. Analyze the graph to find Δ speed and Δt and calculate force. Reference slide.
- How would we know if this value is valid?

Make Initial Observations

With your class

61. Orient to how data were collected from a 0.6 kg cart before, during, and after a collision with a barrier. Reference slide.