$p = mv$

UCIrvine
UNIVERSITY OF CALIFORNIA, IRVINE

Momentum

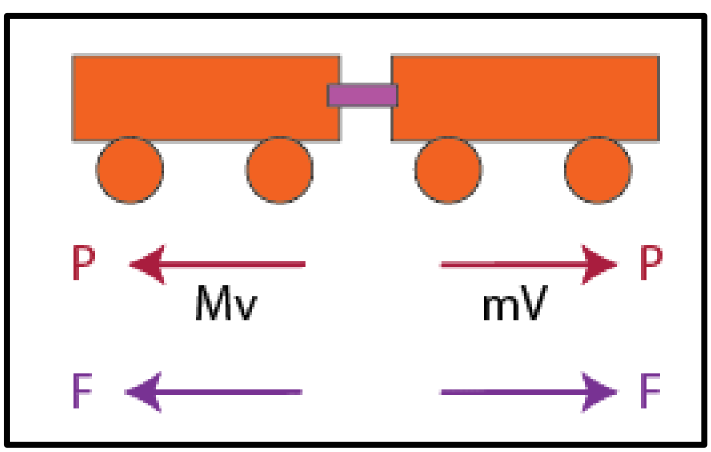
Grade 4 Science Lesson & Activities

Follow-Up to UCI Department of Physics School Assembly

Contents

Key Definitions for Momentum

- **Mass** - The amount of matter (stuff) in something.
    - Symbol: **m**
    - Example: **the mass of a rock is 2 kilograms (2 kg)**.
- **Velocity** – How fast (speed) and which direction something is moving.
    - Symbol: **v**
    - Example: **the rock is falling down with a speed of 2 meters/second (2 m/s)**.
- **Momentum** – Mass in motion
    - Symbol: **p**
    - Momentum equals mass times velocity, i.e., **p = mv**.
    - Example: **the rock is falling down with momentum (2 kg) x (2 m/s) = 4 kg m/s**
- **Conservation** – Saving something. The total momentum of a group of objects (that is not in contact with other objects) is always conserved (always stays the same)



$p = mv$ Momentum

Grade 4 Science Lesson & Activities—Follow-Up to UCI Department of Physics Outreach/School Assembly

Rationale The ideas of ***momentum*** and ***conservation*** are fundamental physics concepts that are employed at all levels from introductory physics to the forefront of current research.
At Grade 4, students can begin to organize and formalize the ideas about motion that they have developed playing with toys and moving objects in the world around them.

Objective Students will be able to describe the motion of objects propelled with equal force but varying in mass using both everyday language and specific vocabulary (mass, velocity, momentum, conservation) and demonstrate their knowledge by predicting the behavior of objects in a hypothetical test within the system.

Standards—NGSS

Performance Expectations:

- **4-PS3-1. Use evidence to construct an explanation relating the speed of an object to the energy of that object.** [Clarification Statement: Examples of evidence relating speed and energy could include **. . .** results of collisions.]
- **4-PS3-3. Ask questions and predict outcomes about the changes in energy that occur when objects collide.** [Clarification Statement: Emphasis is on the change in the energy due to the change in speed, not on the forces, as objects interact.]

Disciplinary Core Ideas:

- **PS3.A: Definitions of Energy** The faster a given object is moving, the more energy it possesses. (4-PS3-1)
- **PS3.B: Conservation of Energy and Energy Transfer** Energy is present whenever there are moving objects, sound, light, or heat. When objects collide, energy can be transferred from one object to another, thereby changing their motion. (4-PS3-3)
- **PS3.C: Relationship Between Energy and Forces** When objects collide, the contact forces transfer energy so as to change the objects' motions. (4-PS3-3)

Crosscutting Concepts:

- **Energy and Matter** Energy can be transferred in various ways and between objects. (4-PS3-1), (4-PS3-3)
- **CC2: Cause and Effect: Mechanism and Explanation** Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts. (NRC Framework 2012, p. 84)

Science and Engineering Practices:

- **Asking Questions and Defining Problems** Ask questions that can be investigated and predict reasonable outcomes based on patterns such as cause and effect relationships. (4-PS3-3)
- **Constructing Explanations and Designing Solutions** Use evidence (e.g., measurements, observations, patterns) to construct an explanation. (4-PS3-1)

Standards—CCSS

English Language Arts Standards » Writing

- **CCSS.ELA-LITERACY.W.4.2** -- **Text Types and Purposes:** Write informative/ explanatory texts to examine a topic and convey ideas and information clearly.

Standards for Mathematical Practice

- **CCSS.MATH.CONTENT.3.MD.B.4 Represent and interpret data.** Generate measurement data by measuring lengths using rulers . . . **.**
- **CCSS.MATH.CONTENT.4.MD.A.2 Solve problems involving measurement and conversion of measurements.** Use the four operations to solve word problems involving distances **. . .** masses of objects **. . .** Represent measurement quantities using diagrams such as number line diagrams that feature a measurement scale.

$p=mv$ Momentum

Grade 4 Science Lesson & Activities—Follow-Up to UCI Department of Physics Outreach/School Assembly

Resources/Materials

Manipulatives

- Momentum cars, connectors, masses (metal plates), and 2-meter sticks provided on loan from UCI Physics Outreach following assembly.

Video Resources

- A succinct, age-appropriate review of momentum and collisions is https://www.youtube.com/watch?v=Xe2r6wey26E This video is part of a series, Engineering Technology Simulation Learning Videos. It was developed for Eastern Iowa Community College District by Lucid Way www.lucidway.com
- **BrainPop's** science videos include ***Newton's Laws of Motion*** with clear examples and grade-appropriate vocabulary. Additional BrainPop videos on ***Gravity***, ***Acceleration***, and ***Forces*** go well beyond grade level, but will capture student interest with exciting examples (space exploration, skateboards, and sky diving, respectively).

- **Discovery Education Streaming** has many videos that are appropriate to explore concepts of motion and forces: Introductory—*How Things Move* is a 16 minute video with 9 segments. A companion FUN-DAMENTAL is an interactive selection titled *Making Things Move*. Another video that explores forces, motion, and Newton's laws is *Real World Science: Forces*. The video runs 19 minutes with 6 segments.

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LESSON OUTLINE

Explore--Preparation

- Set up many measuring stations (at least 4). Students will work in groups of four. As much as possible, orient the stations so the floor is level.
    - Place two 2-m sticks in a straight line. The cars will be launched from the center of the two sticks.
    - *[Optional]* Fasten meter tapes or meter sticks on floor.
- Post or project the "Key Definitions for Momentum."
- *[Optional]* Prepare to display the youtube (or other brief) video.

Explore—Review Assembly [50 min]

1. Ask students to recall the assembly and discuss the term "momentum" in their groups. After discussing, they should be ready to provide the group's definition of momentum in everyday language. Record one or two student definitions or ideas on chart paper. [10 min]
2. *[Optional]* Show the YouTube (or other) video.
3. Display the "Key Definitions for Momentum" slide.
4. Show the students two cars. Explain (or demonstrate) that, when they release the spring, the cars will push apart. Ask
   a) "How much momentum do the two cars have before they are released?" *[Zero—they aren't moving]*
   b) "When the two cars are released, they push each other with equal and opposite forces and they also have equal and opposite momentum, as in this diagram *(on bottom of "Key Definitions for Momentum" slide).* What is the total momentum of the

two cars when they are moving in opposite directions? *[Zero because the negative and positive numbers cancel.]* Why is the total momentum the same as it was before the cars were released? *[Conservation of momentum]*

5. Introduce the momentum cars and masses. Set expectations for careful handling of the equipment. Mention that the cars are on loan and need to be returned in good condition.
    a. Caution students to be careful not to pull on or entangle the springs.
    b. Show the masses. Note that each mass is the same as the mass of one car.
    c. Caution students to handle the masses carefully; they are quire heavy and should be set, not dropped, into the cars. Also, don't drop them on a foot or toe—it will hurt.
6. Demonstrate how the momentum cars are operated.
    a. Instead of colliding, the force is generated by the compression of a spring when the cars are joined and held together with a connector.
    b. When the connector is lifted, the cars spring apart. Students will record the distance each car travels. Later we will analyze those distances to see how they compare for cars with different masses.

[5 min]

7. Point out how the measuring stations are set up. Explain that in this activity—
    a. Each trial will begin with the cars joined at the zero point.
    b. When the connector is lifted, the distances that the cars move will be recorded.
8. Distribute recording sheet for "Momentum Car Distances." Two versions are provided—one is a data table and the other is a number line recording page.
    a. Review the focus question—"**How will changing the mass of the cars affect their momentum?**" Demonstrate an example of how to record the data.

[5 min]

9. Students work through several different trials, varying the masses from 1 (the car itself), to two or three, depending on how many masses are stacked in the car. [20 min]
    a. Teacher circulates to assist with connecting and positioning cars.
    b. Remind students to record their measurements.
10. Wrap up. Assign one or two students to check the equipment as it is turned in—two momentum cars, two additional masses, two 2-meter sticks, and one connector from each group. [5 min]

Explain—Activity [approximately 10 minutes]

1. Ask—Do we have enough information in these trials to find the momentum of the cars?
    a. Ask—Do we know the masses involved?—yes—so mass was controlled.
    b. Ask—Since velocity is a combination of speed and direction, which parts do we know?
        i. The direction of the cars when released was exactly opposite.
        ii. We don't know the speed exactly.
    c. Explain—Speed is distance over time. We didn't time how long it took the cars to stop. But we do know the distance each car traveled, so we can look at how that distance relates to the mass. The faster car travels farther.

2. Ask—Which car traveled farther: The heavier car or the lighter car? *[Lighter]* Why is that expected? *[The momentum of the two cars is the same so, if one car has more mass, it has less velocity]*

3. Discuss the results and look for a pattern. Do the distances traveled by the two cars relate 1 to 1? 1 to 2? 1 to 3? *[Note: In an ideal experiment, the distances would be inversely proportional to the masses but, since floors are not perfectly even and distances are not exactly equivalent to velocities, the proportions will be approximate.]*

Evaluate

1. Assess student data tables or number line comparisons. These would be formative assessments, as recording the data is part of the experimental process. Emphasis should be on complete work showing focus and effort.

   For example, on the collisions with balls pages, student diagrams should be labeled. On the number line pages the distances should be labeled with car number.

   A simple grading scheme of 4-3-2-1 is appropriate for these pages.
   [4=above grade level expectation; 3=grade level; 2=approaching grade level; 1=below grade level]

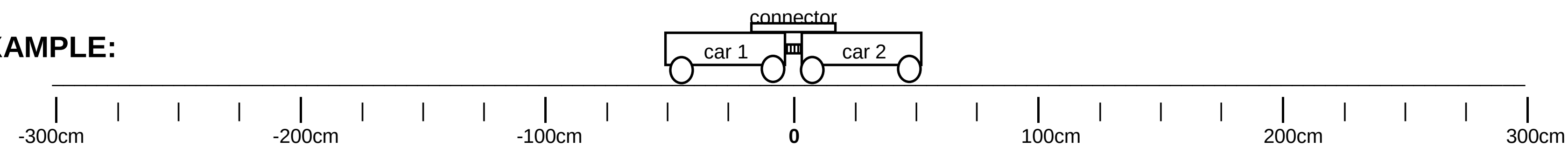
2. The analysis page can be used after completing either the data table or the number line recordings of distances. If desired, this page can be used as a summative assessment.

Name _______________ Date ______________

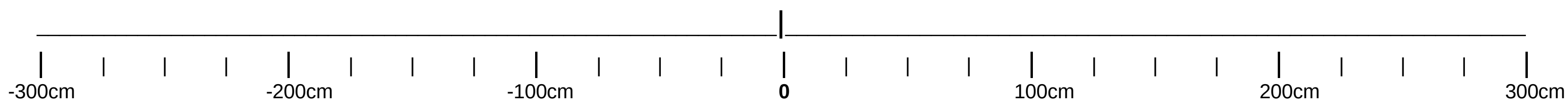
$p=mv$ Momentum Car Distances — Number Line Comparison

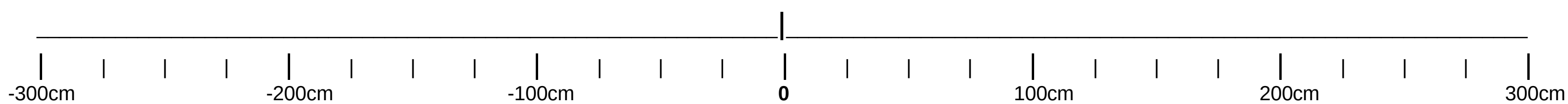
Both cars start at 0. Each car has a mass of 1. Each metal rectangle mass = 1 (same as car). Do each test three times.

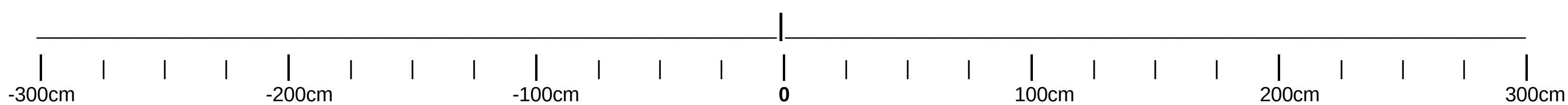
EXAMPLE:



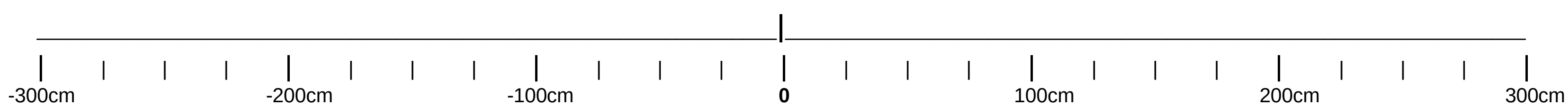
TEST 1: **car 1 mass = 1** **car 2 mass = 1** Both cars empty. Mark the number line where each car stops (**facing ends** of car).

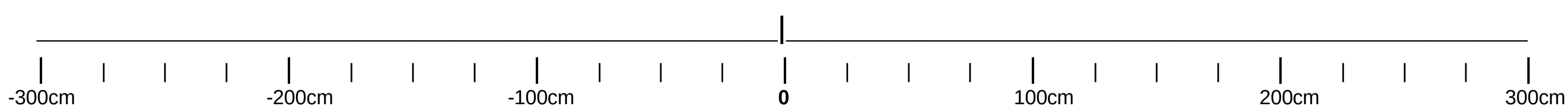


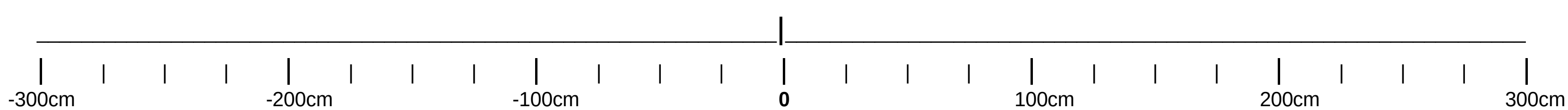




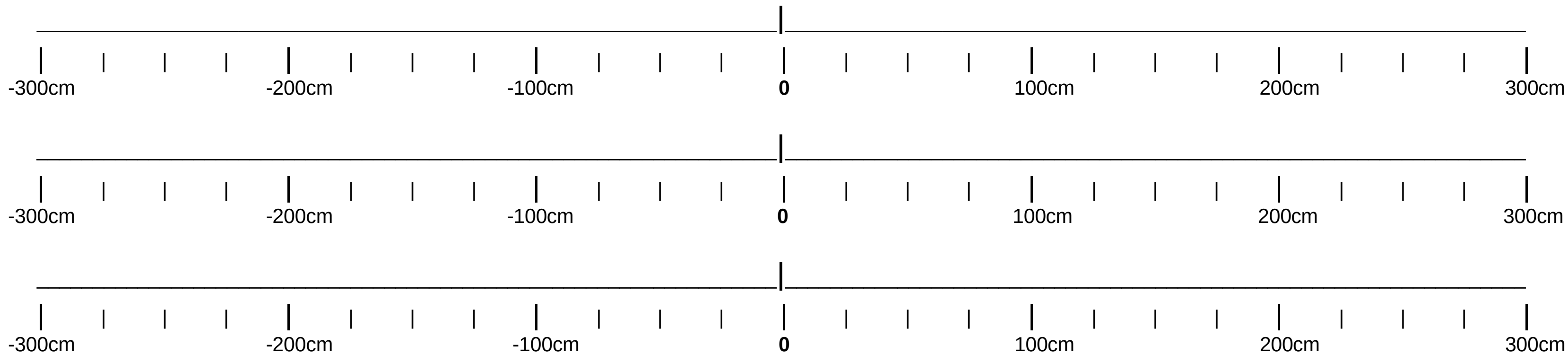
TEST 2: **car 1 mass = 2** **car 2 mass = 2** Add one metal rectangle to each car. Mark the number line where each car stops.



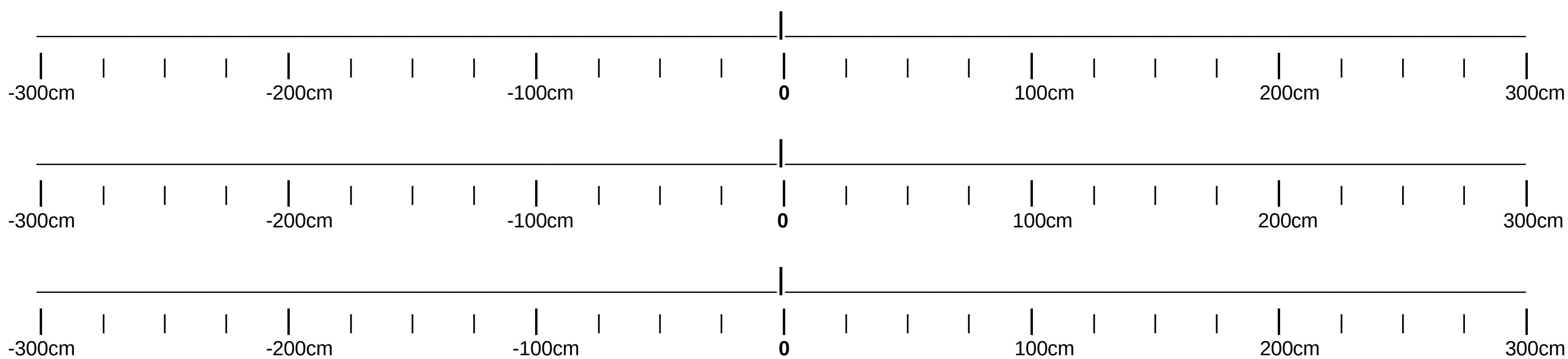




TEST 3: **<u>car 1</u> mass = 1** **<u>car 2</u> mass = 2** Car 1 empty. Add one metal rectangle to car 2. Mark the number line where each car stops.



TEST 4: **<u>car 1</u> mass = 1** **<u>car 2</u> mass = 3** Car 1 empty. Add two metal rectangles to car 2. Mark the number line where each car stops.



$p = m v$

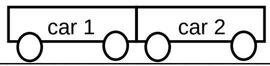
SCIENCE - Grade 4

Name ________________ Date _______________

Momentum Car Distances — Number Line Comparison

Both cars start at 0. Each car has a mass of 1. Each metal rectangle mass = 1 (same as car).

EXAMPLE:



300cm 200cm 100cm **0** 100cm 200cm 300cm

TEST 1: **<u>car 1</u> mass = 1** **<u>car 2</u> mass = 1** Both cars empty. Mark the number line where each car stops (front edge of car).

300cm 200cm 100cm **0** 100cm 200cm 300cm

300cm 200cm 100cm **0** 100cm 200cm 300cm

300cm 200cm 100cm **0** 100cm 200cm 300cm

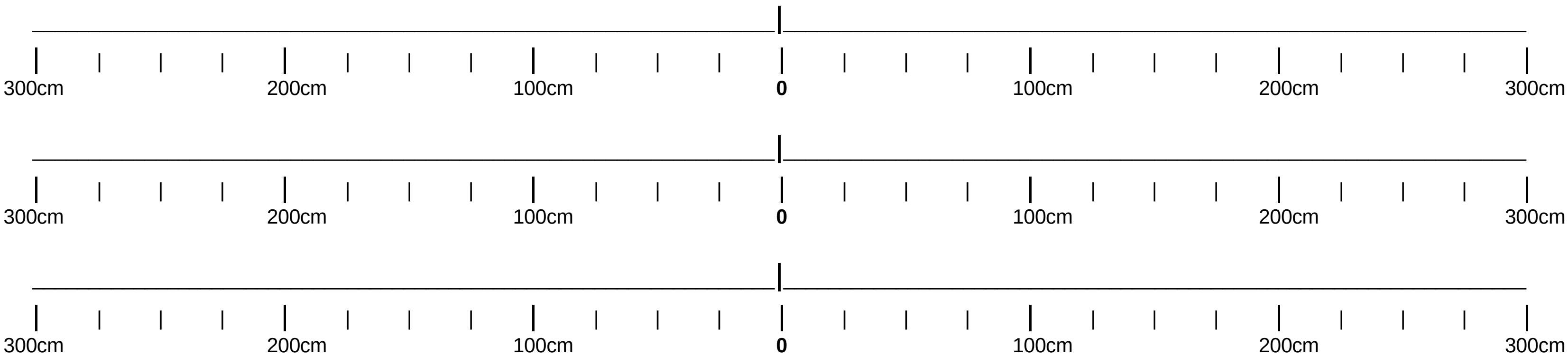
TEST 2: **<u>car 1</u> mass = 2** **<u>car 2</u> mass = 2** Add one metal rectangle to each car. Mark the number line where each car stops.

300cm 200cm 100cm **0** 100cm 200cm 300cm

300cm 200cm 100cm **0** 100cm 200cm 300cm

300cm 200cm 100cm **0** 100cm 200cm 300cm

TEST 3: **<u>car 1</u> mass = 1** **<u>car 2</u> mass = 2** Car 1 empty. Add one metal rectangle to car 2. Mark the number line where each car stops.



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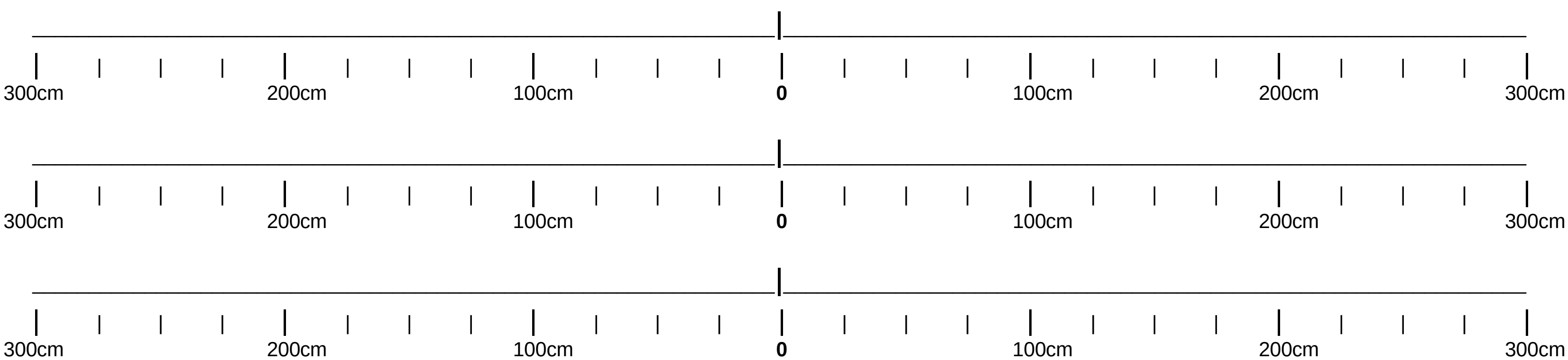

$p = mv$

SCIENCE - Grade 4 Name ______________ Date ______________

Momentum Car Distances

Analysis:

1. State a rule for how a car behaves if you increase its mass: ______________________________

____

____

2. What evidence supports your rule? ____

____

____

3. Describe any pattern you see when you add mass to only one of the cars: ___________________

____

____

4. What evidence supports this pattern? ____

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