You can draw here

# Physics 111 - Class 11
# Momentum & Impulse

Do not draw in/on this box!

November 15, 2021

You can draw here

You can draw here

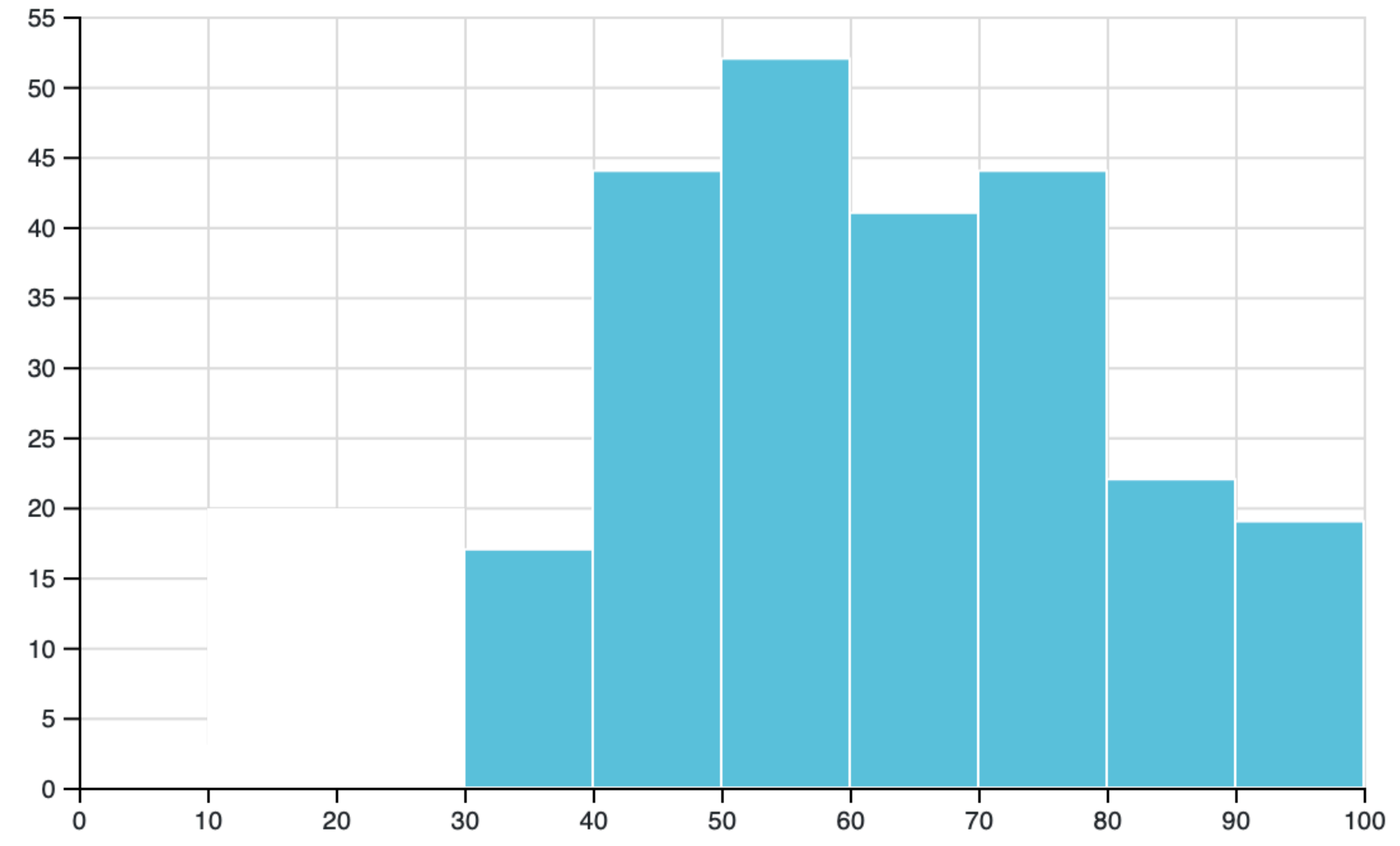
# Class Outline

- Logistics / Announcements
- Test 4 Reflection
- Chapter 9 Section Summary
- Collision Carts Demo
- Clicker Questions
- Worked Problems

# Logistics/Announcements

- Lab this week: Lab 7
- HW9 due this week on Thursday at 6 PM
- Learning Log 9 due on Saturday at 6 PM
- HW and LL deadlines have a 48 hour grace period
- Test/Bonus Test: Bonus Test 4 available this week (Chapters 7 & 8)
    - Test Window: Friday 6 PM - Sunday 6 PM

# Test 4 Reflection




| | |
|---|---|
| Number of students | 249 |
| Mean score | 61% |

- Test 4 was perhaps a bit long…
  - Several questions from previous homework assignments
  - Time was a factor, median time was 55 minutes
- A couple of key misconceptions…
- Test has been scaled: everyone gets +3

# Which Ball reaches the end first?

## Ball Race

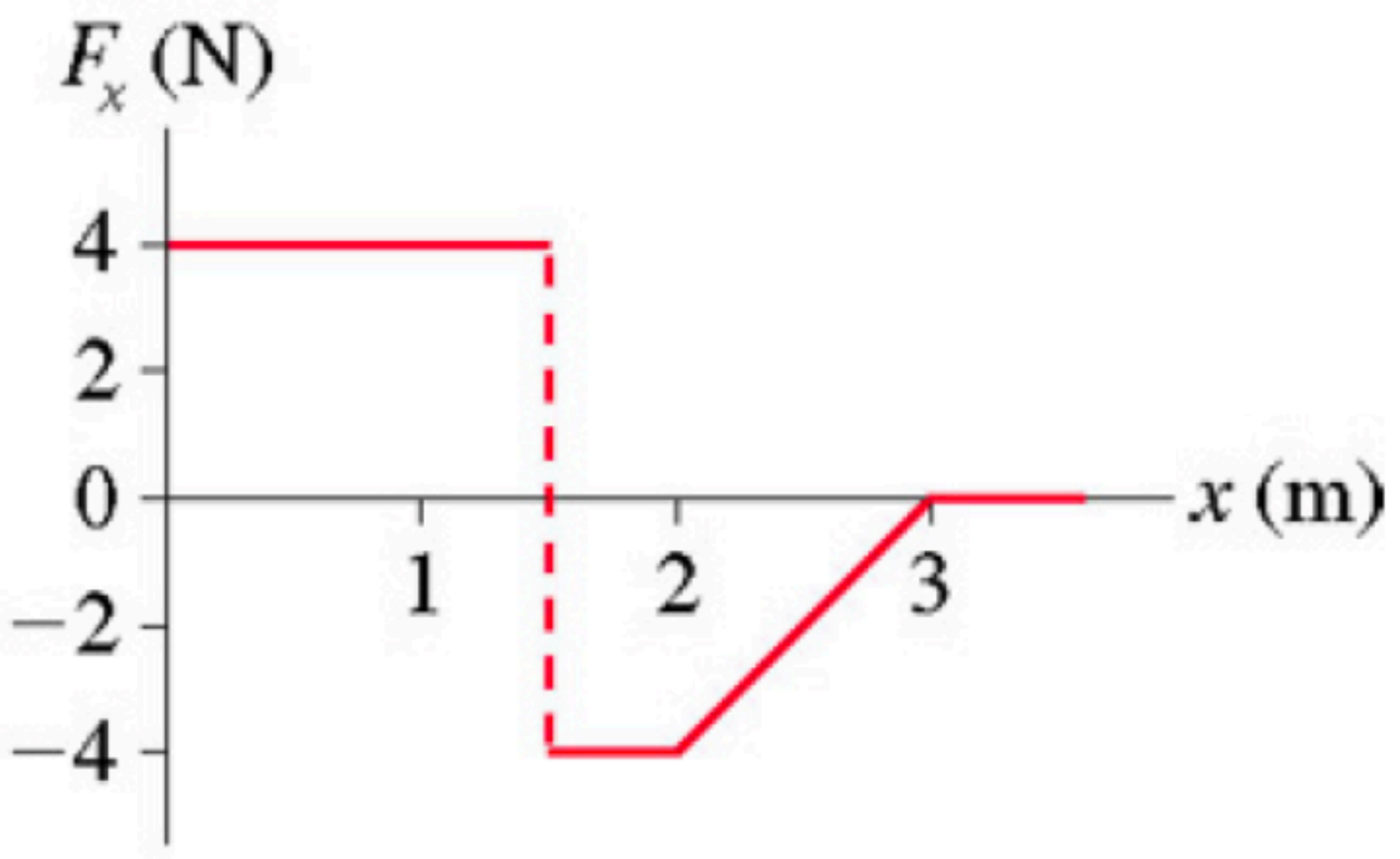
Two identical balls, Ball A and Ball B are launched with the same initial velocity $v$ along a pair of tracks. The first track with Ball A, is a straight track. The second track with Ball B, has a "U"-shaped dip in the middle so the ball goes down and then back up.


Which ball reaches the end of the track first, if friction is neglected?

# Force vs. Position Graph

## Force vs Position Graph

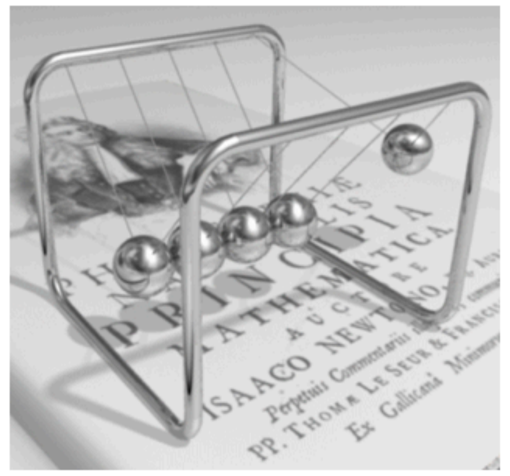
The graph below shows the net force on a particle as a function of its position. The mass of the particle is m = 2.5 $kg$.




### Part 1

If the particle has a velocity of $v_x =$ -1.5 m/s when $x =$ 0 $m$, what is the particle's speed when $x =$ 3.0 $m$?

| $v =$ | number (rtol=0.05, atol=1e-08) | m/s | ? |
|---|---|---|---|



Physics 111

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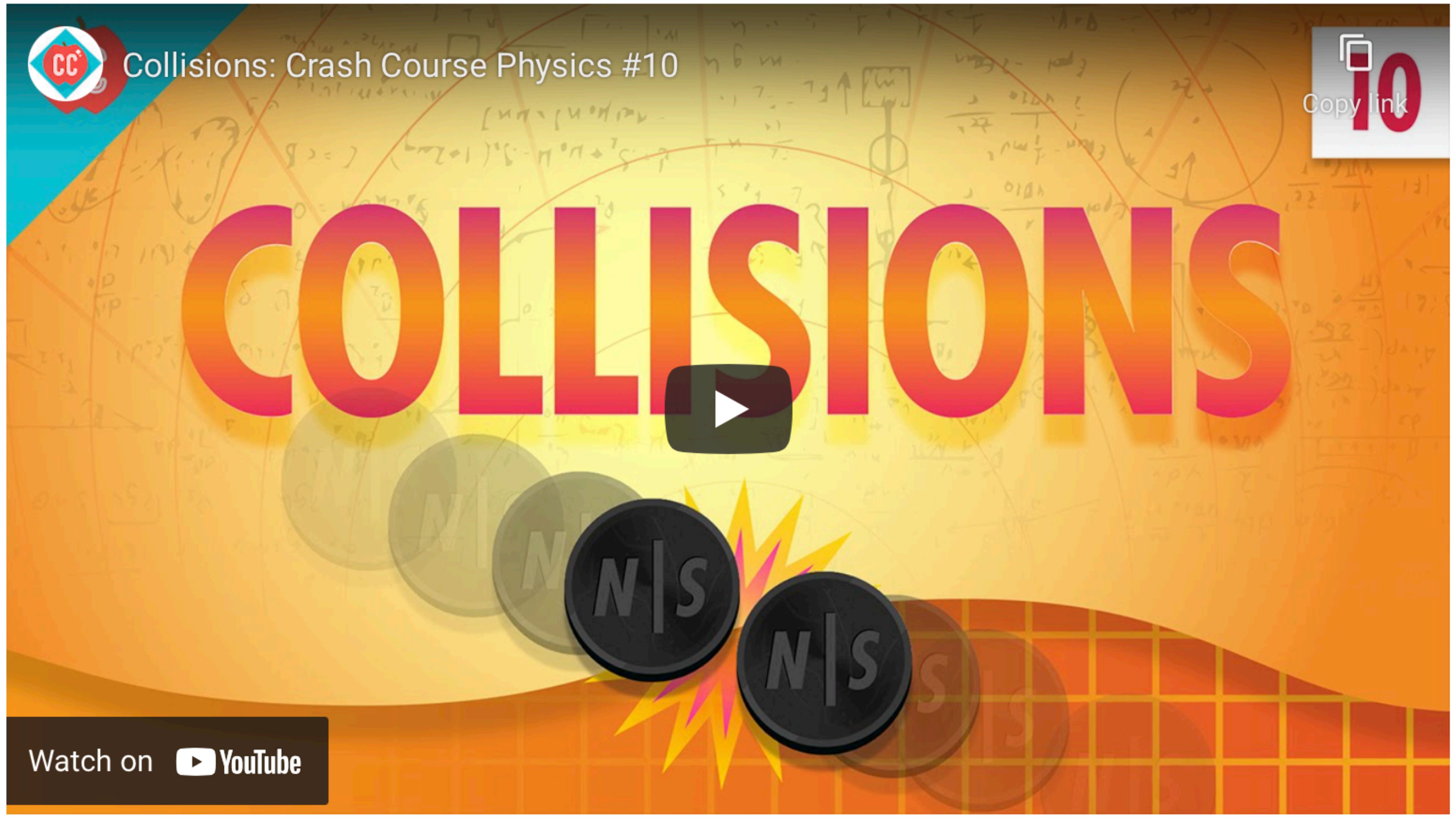
# Content Summary from Crash Course Physics

**Collisions**




**Checklist of items**

- Video 1
- Video 2
- Video 3
- Video 4
- Video 5
- Video 6
- Video 7
- Video 8
- Video 9
- Video 10

# Required Videos

**1. You Can't Run From Momentum! (a momentum introduction)**

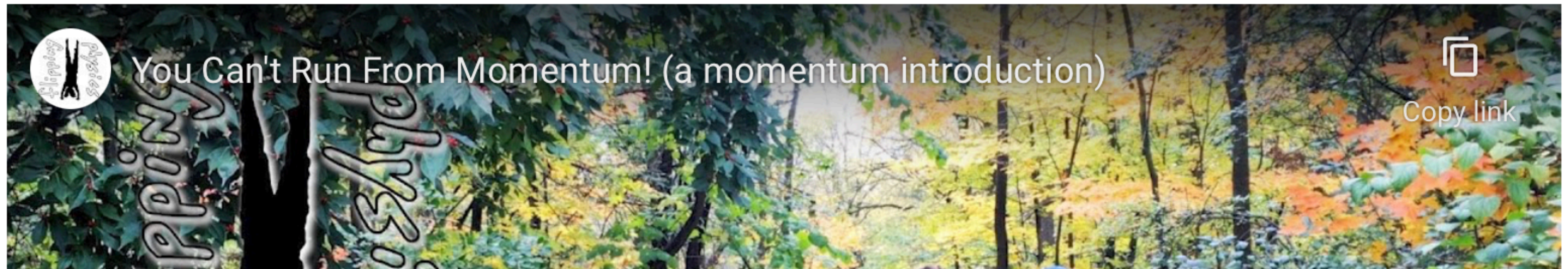


Table of contents

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My highlights



Mon

Fri

Wed

**Figure 9.1** The concepts of impulse, momentum, and center of mass are crucial for a major-league baseball player to successfully get a hit. If he misjudges these quantities, he might break his bat instead. (credit: modification of work by "Cathy T"/Flickr)

## Chapter Outline



The concepts of work, energy, and the work-energy theorem are valuable for two primary reasons: First, they are powerful computational tools, making it much easier to analyze complex physical systems than is possible using

# Monday’s Class

9.1 Linear Momentum
9.2 Impulse and Collisions
9.3 Conservation of Linear Momentum

# Momentum

- "Kinetic Energy" is a characteristic of the object's **mass** and **velocity$^2$**
- "Potential Energy" is a different form of energy that's characteristic of the object's **position**.
- As powerful as Energy is, it cannot help us solve many problems, such as the direction of velocity vectors
- For that, we need a new quantity...

**MOMENTUM**

The momentum *p* of an object is the product of its mass and its velocity:

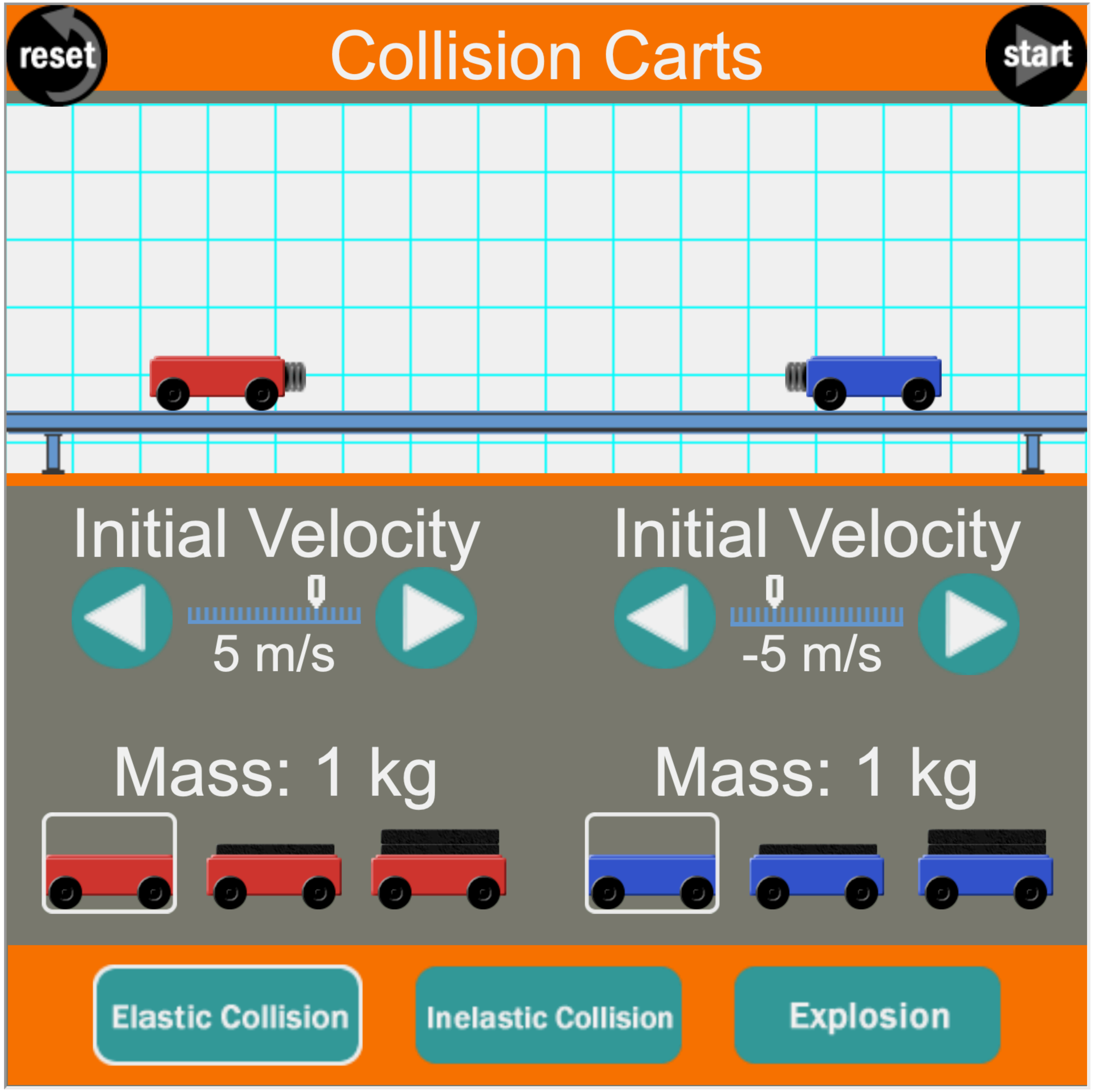
$$\vec{\mathbf{p}} = m\vec{\mathbf{v}}. \tag{9.1}$$

# Properties of Momentum

- Momentum is a vector quantity (it has a direction from $v$)
- The total momentum of a "system" is **conserved** if:
    - Total mass of the system remains constant
    - Net external force on the system is 0
- Momentum is yet another accounting system that helps us solve problems with collisions and explosions.

# Deriving Momentum from Newton's Laws

# Collision Carts



# The “System”

A **system** (mechanical) is the collection of objects in whose motion (kinematics and dynamics) you are interested. If you are analyzing the bounce of a ball on the ground, you are probably only interested in the motion of the ball, and not of Earth; thus, the ball is your system. If you are analyzing a car crash, the two cars together compose your system (Figure 9.15).

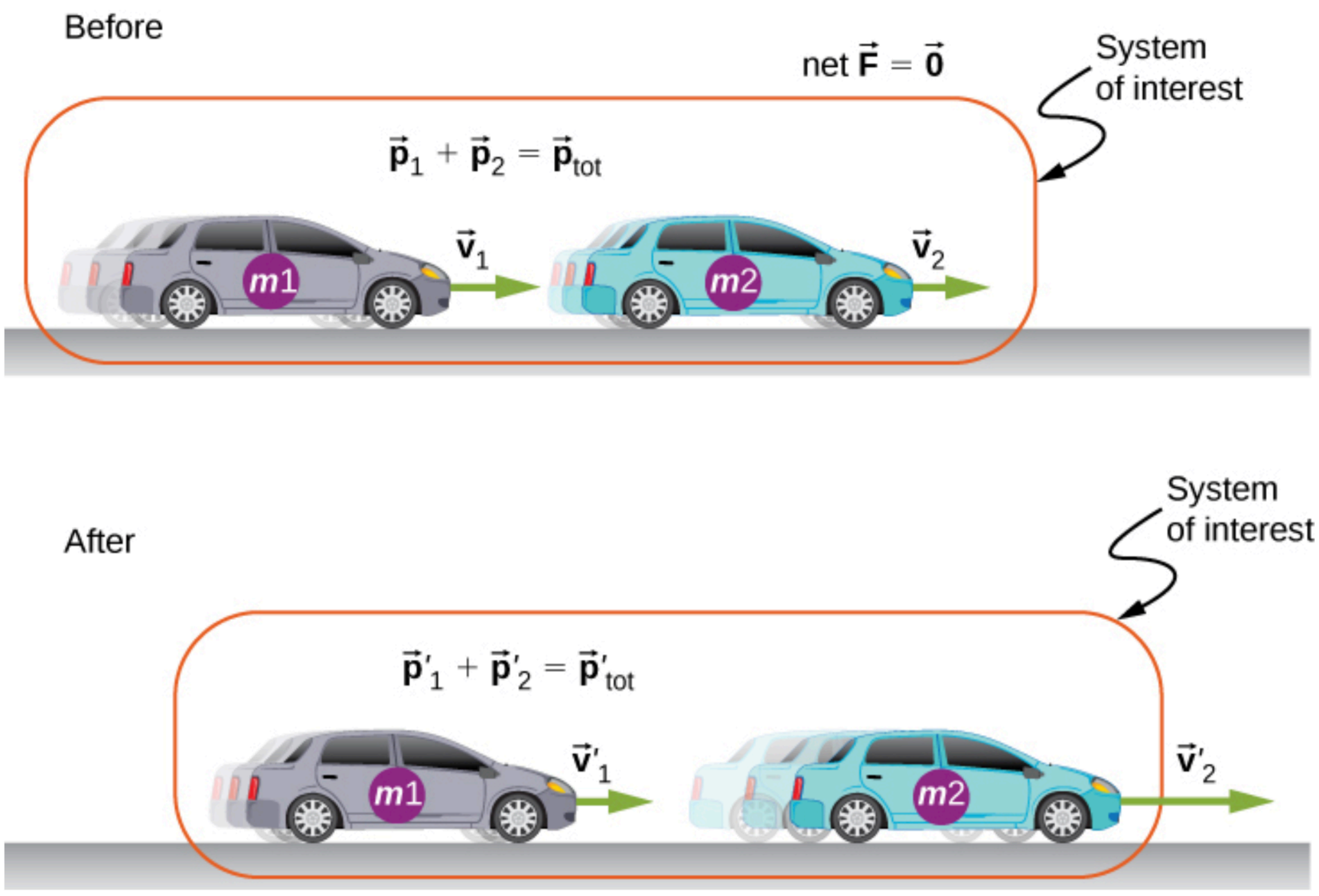



**Figure 9.15** The two cars together form the system that is to be analyzed. It is important to remember that the contents (the mass) of the system do not change before, during, or after the objects in the system interact.

# Conservation of Momentum

A system of objects that meets these two requirements is said to be a **closed system** (also called an isolated system). Thus, the more compact way to express this is shown below.

**LAW OF CONSERVATION OF MOMENTUM**

The total momentum of a closed system is conserved:

$$\sum_{j=1}^{N} \vec{\mathbf{p}}_{\mathrm{j}} = \text{constant.}$$

This statement is called the **Law of Conservation of Momentum**. Along with the conservation of energy, it is one of the foundations upon which all of physics stands. All our experimental evidence supports this statement: from the motions of galactic clusters to the quarks that make up the proton and the neutron, and at every scale in between. *In a closed system, the total momentum never changes.*

# Solving Conservation of Momentum problems

PROBLEM-SOLVING STRATEGY

## Conservation of Momentum

Using conservation of momentum requires four basic steps. The first step is crucial:

1. Identify a closed system (total mass is constant, no net external force acts on the system).
2. Write down an expression representing the total momentum of the system before the “event” (explosion or collision).
3. Write down an expression representing the total momentum of the system after the “event.”
4. Set these two expressions equal to each other, and solve this equation for the desired quantity.

Example 9.7

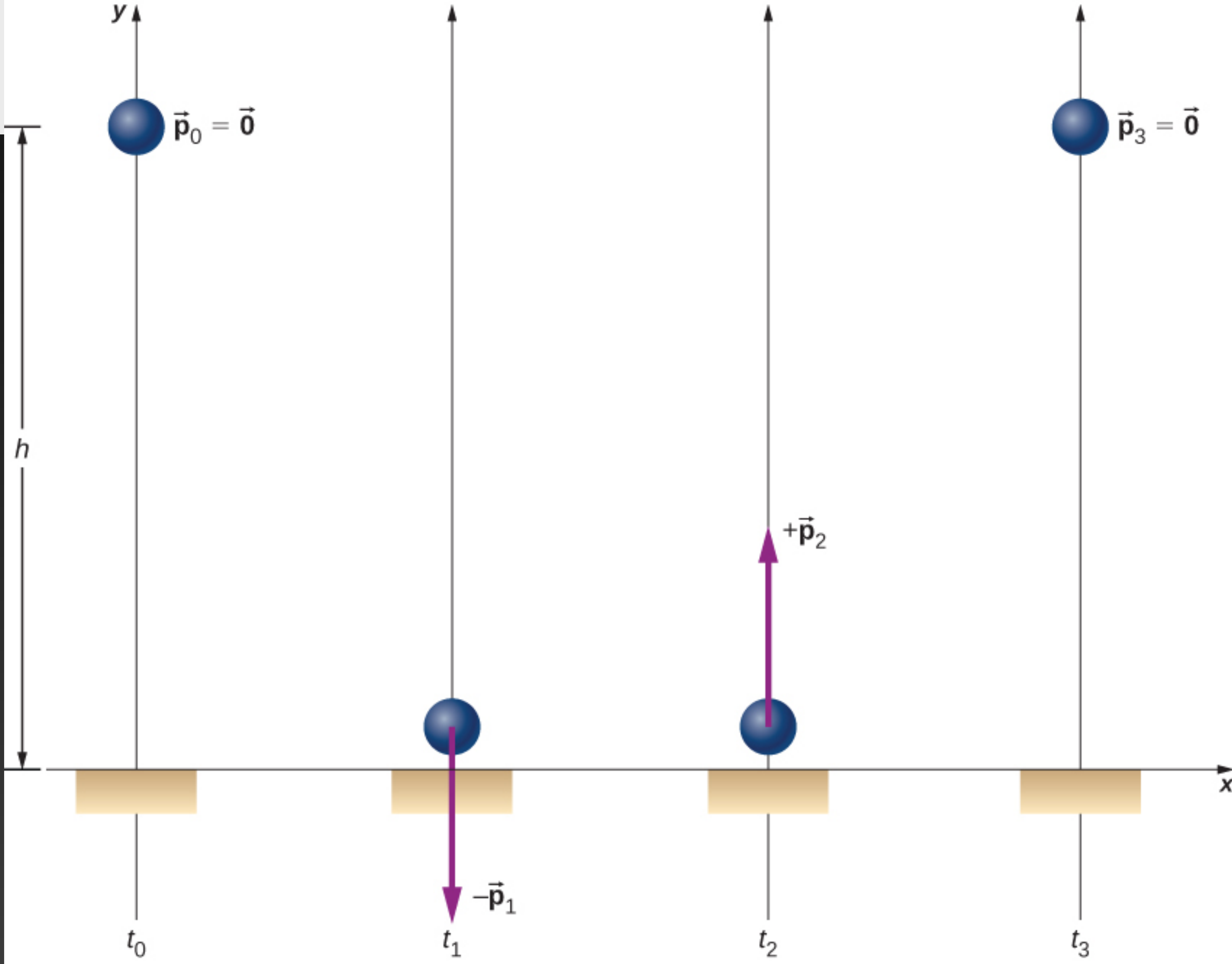
EXAMPLE 9.7

## A Bouncing Superball

A superball of mass 0.25 kg is dropped from rest from a height of $h = 1.50\ \mathrm{m}$ above the floor. It bounces with no loss of energy and returns to its initial height (Figure 9.17).

a. What is the superball's change of momentum during its bounce on the floor?
b. What was Earth's change of momentum due to the ball colliding with the floor?
c. What was Earth's change of velocity as a result of this collision?

(This example shows that you have to be careful about defining your system.)



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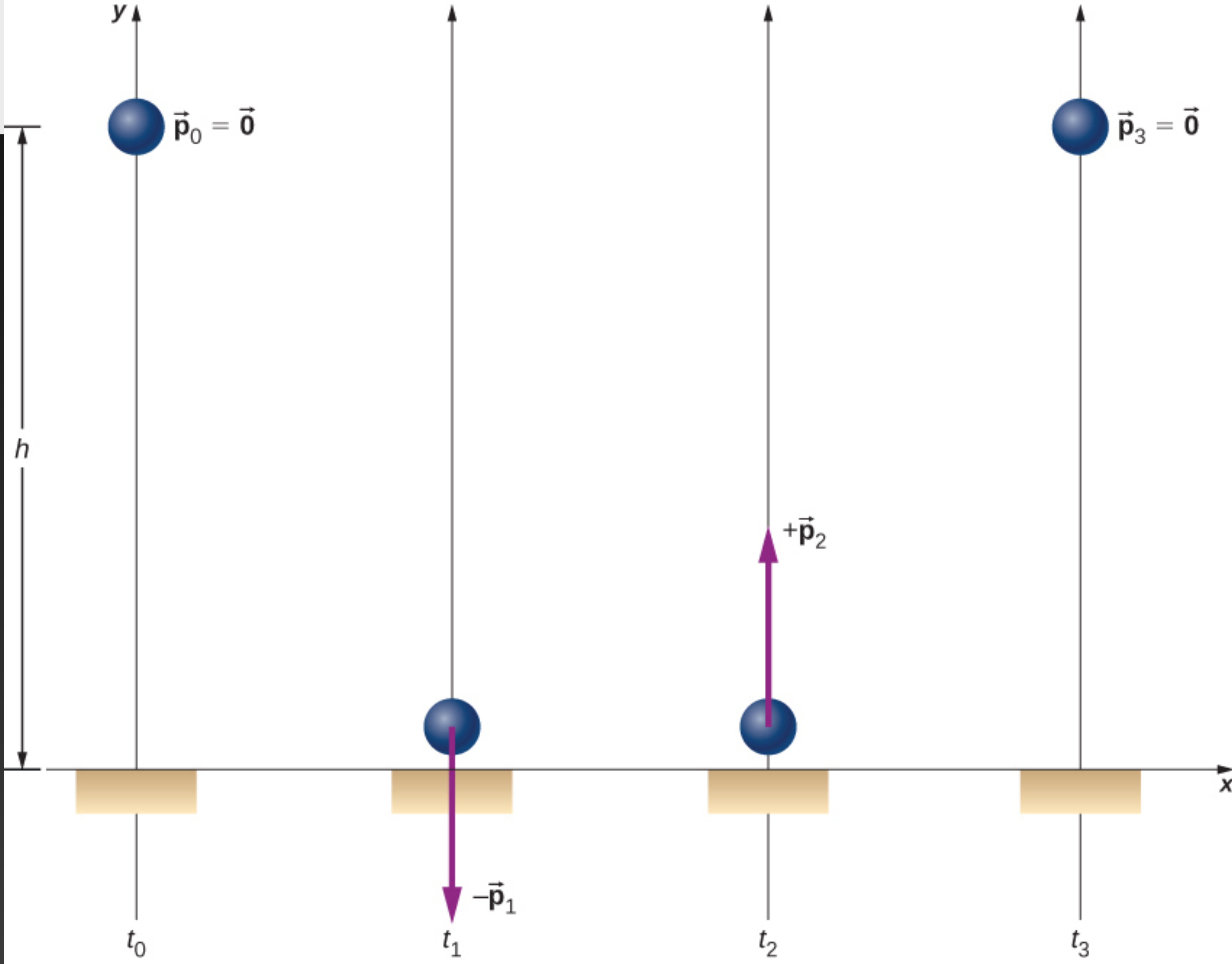
A

$$\begin{aligned}\Delta\vec{\mathbf{p}} &= \vec{\mathbf{p}}_2 - \vec{\mathbf{p}}_1 \\ &= (1.4\ \mathrm{kg\cdot m/s})\,\hat{\mathbf{j}} - (-1.4\ \mathrm{kg\cdot m/s})\,\hat{\mathbf{j}} \\ &= +(2.8\ \mathrm{kg\cdot m/s})\,\hat{\mathbf{j}}.\end{aligned}$$



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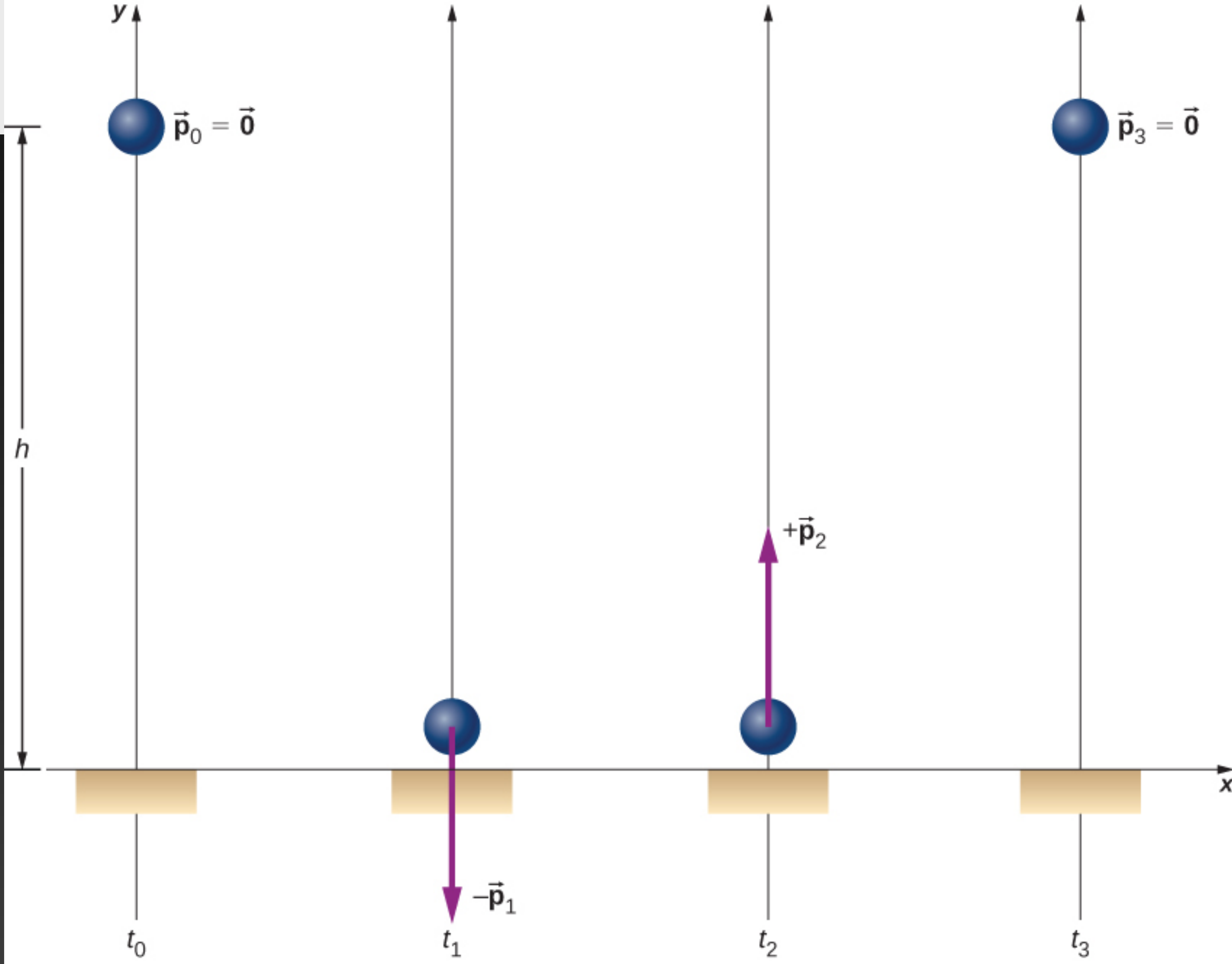
B

$$\Delta\vec{\mathbf{p}}_{\text{Earth}} = -2.8\ \text{kg}\cdot\text{m/s}\hat{\mathbf{j}}.$$



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B

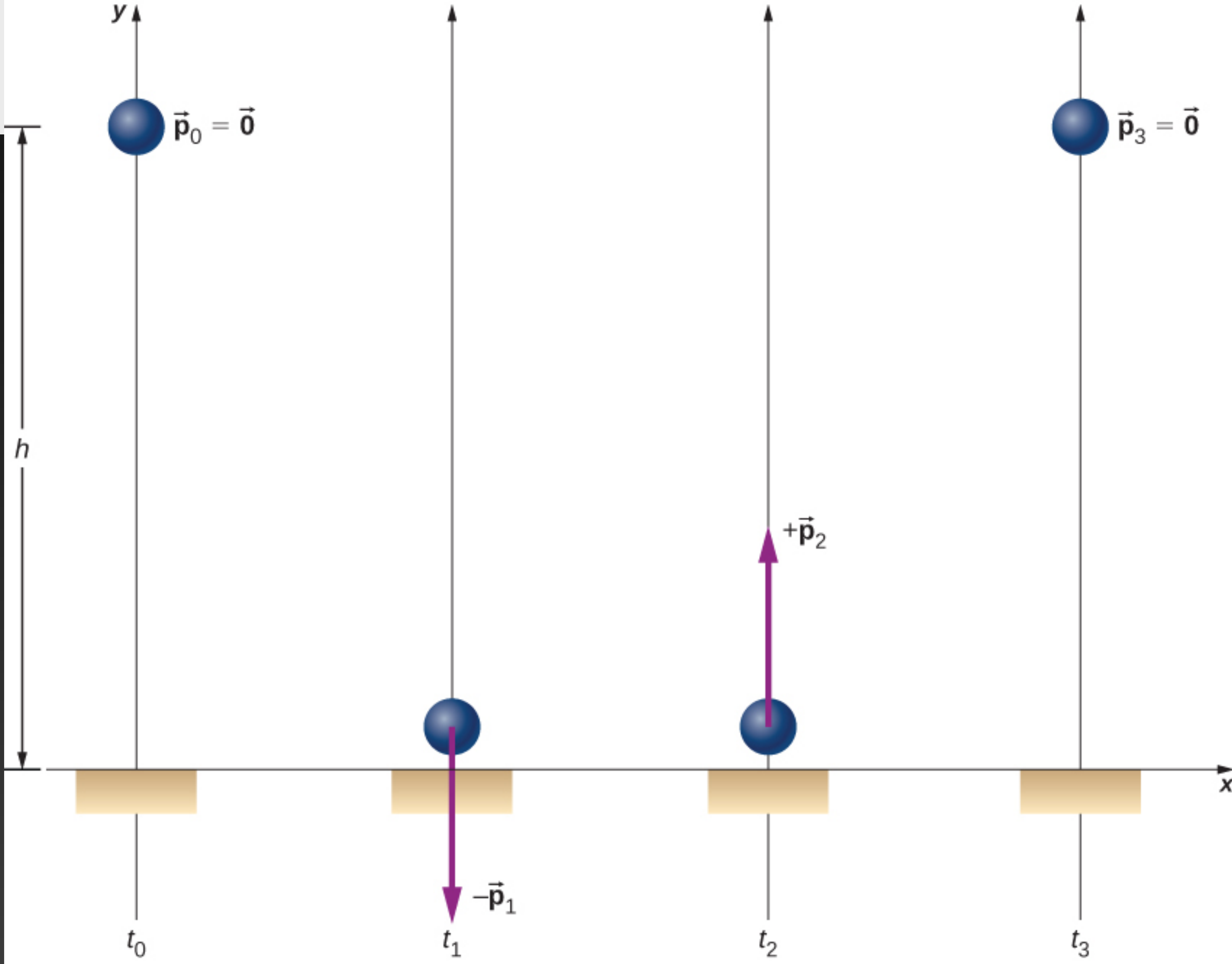
$$\Delta\vec{\mathbf{p}}_{\text{Earth}} = -2.8\ \text{kg}\cdot\text{m/s}\hat{\mathbf{j}}.$$

C

What was Earth's change of velocity as a result of this collision?
This is where your instinctive feeling is probably correct:

$$\begin{aligned}\Delta\vec{\mathbf{v}}_{\text{Earth}} &= \frac{\Delta\vec{\mathbf{p}}_{\text{Earth}}}{M_{\text{Earth}}} \\ &= -\frac{2.8\ \text{kg}\cdot\text{m/s}}{5.97\times10^{24}\ \text{kg}}\hat{\mathbf{j}} \\ &= -\left(4.7\times10^{-25}\ \text{m/s}\right)\hat{\mathbf{j}}.\end{aligned}$$

This change of Earth's velocity *is* utterly negligible.



# See you next class!

# Attribution

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