

You can draw here

Physics 111 - Class 11

Momentum & Impulse

Do not draw in/on this box!

November 15, 2021

You can draw here

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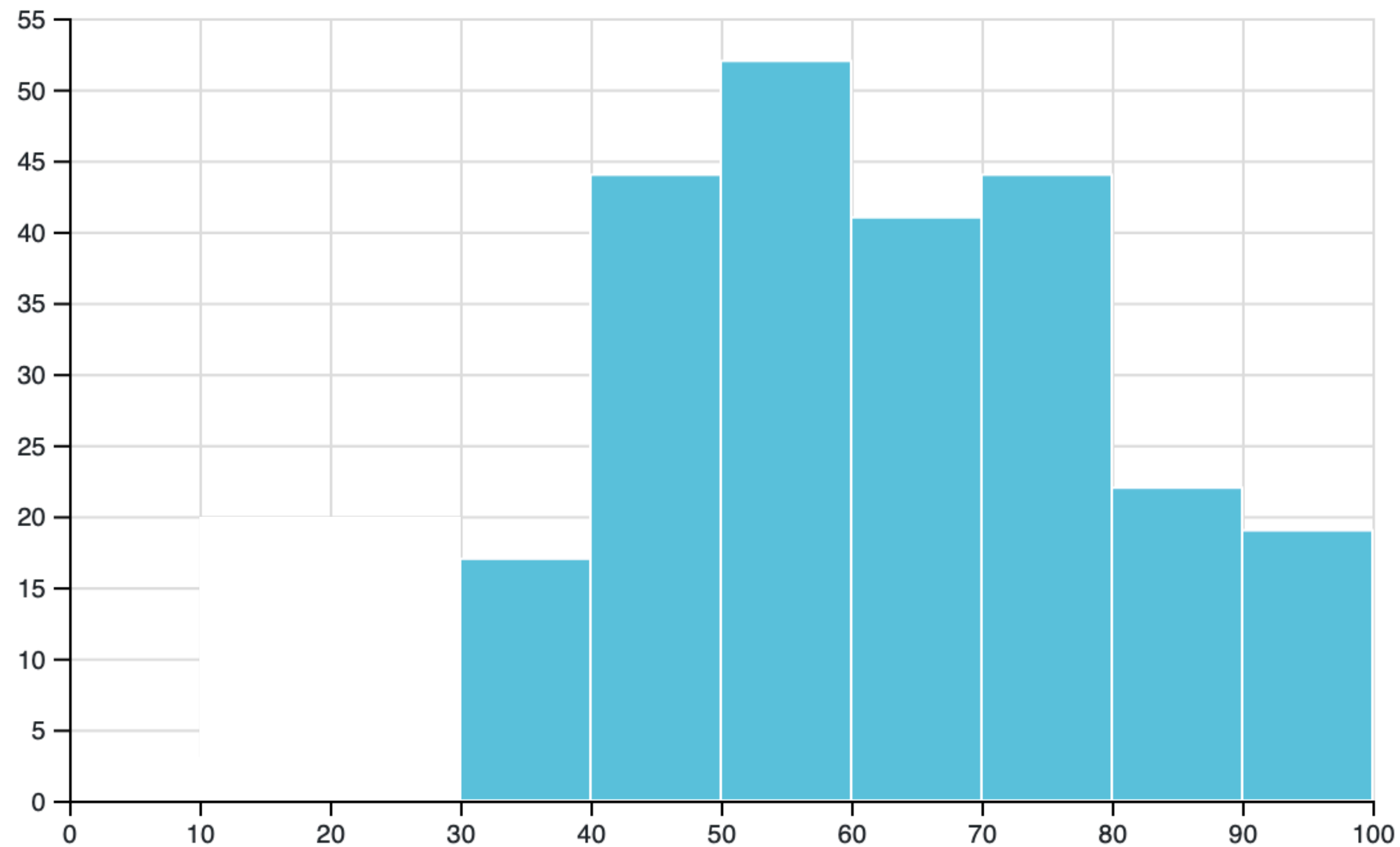
Class Outline

- 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.

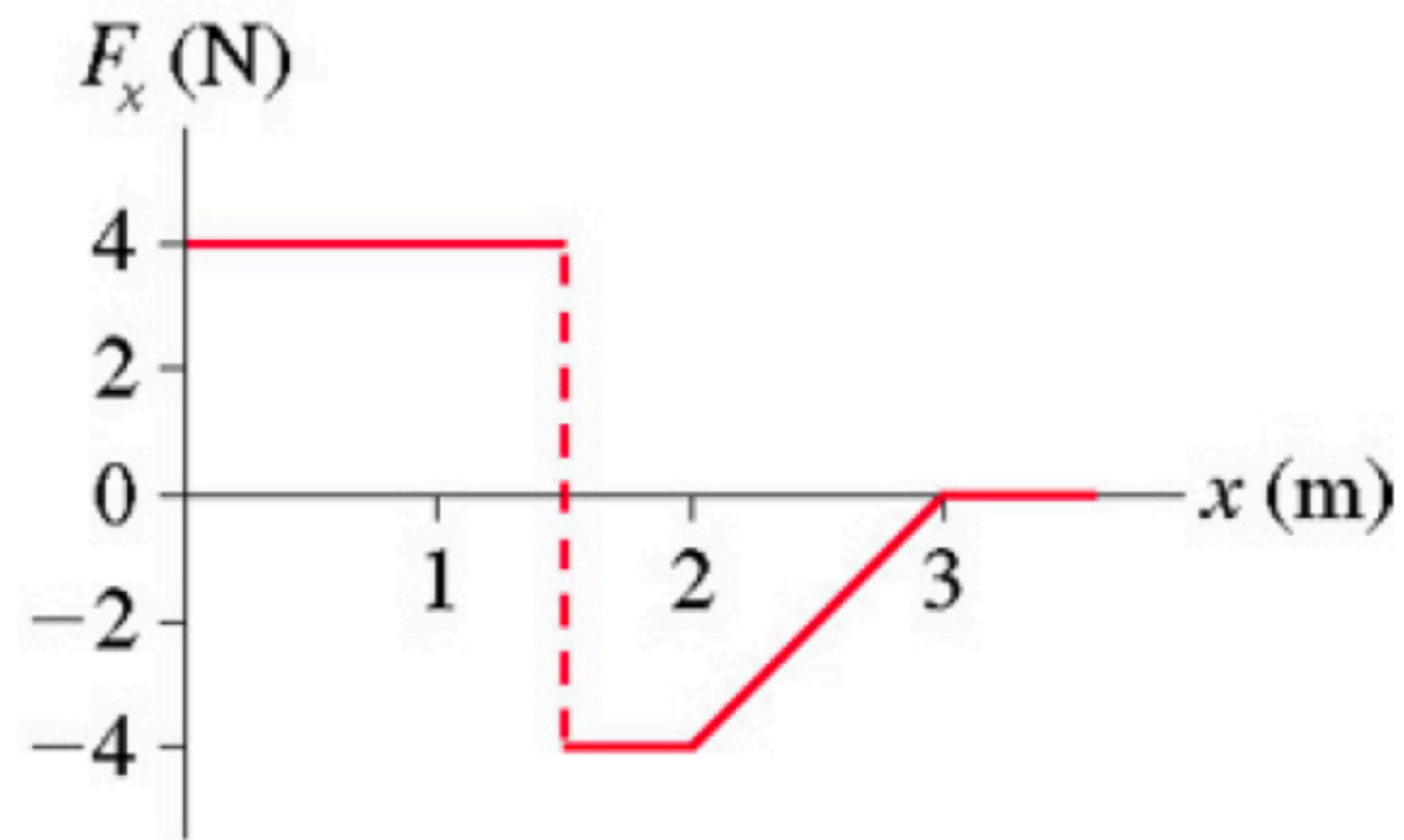


Which ball reaches the end of the track first, if friction is neglected?

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 $m = 2.5 \text{ kg}$.



Part 1

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

$v =$

number (rtol=0.05, atol=1e-08)

m/s





Physics 111

Search this book...

Unsyllabus

ABOUT THIS COURSE

Course Syllabus (Official)

Course Schedule

Accommodations

How to do well in this course

GETTING STARTED

Before the Term starts

After the first class

In the first week

Week 1 - Introductions!

PART 1 - KINEMATICS

Week 2 - Chapter 2

Week 3 - Chapter 3

Week 4 - Chapter 4

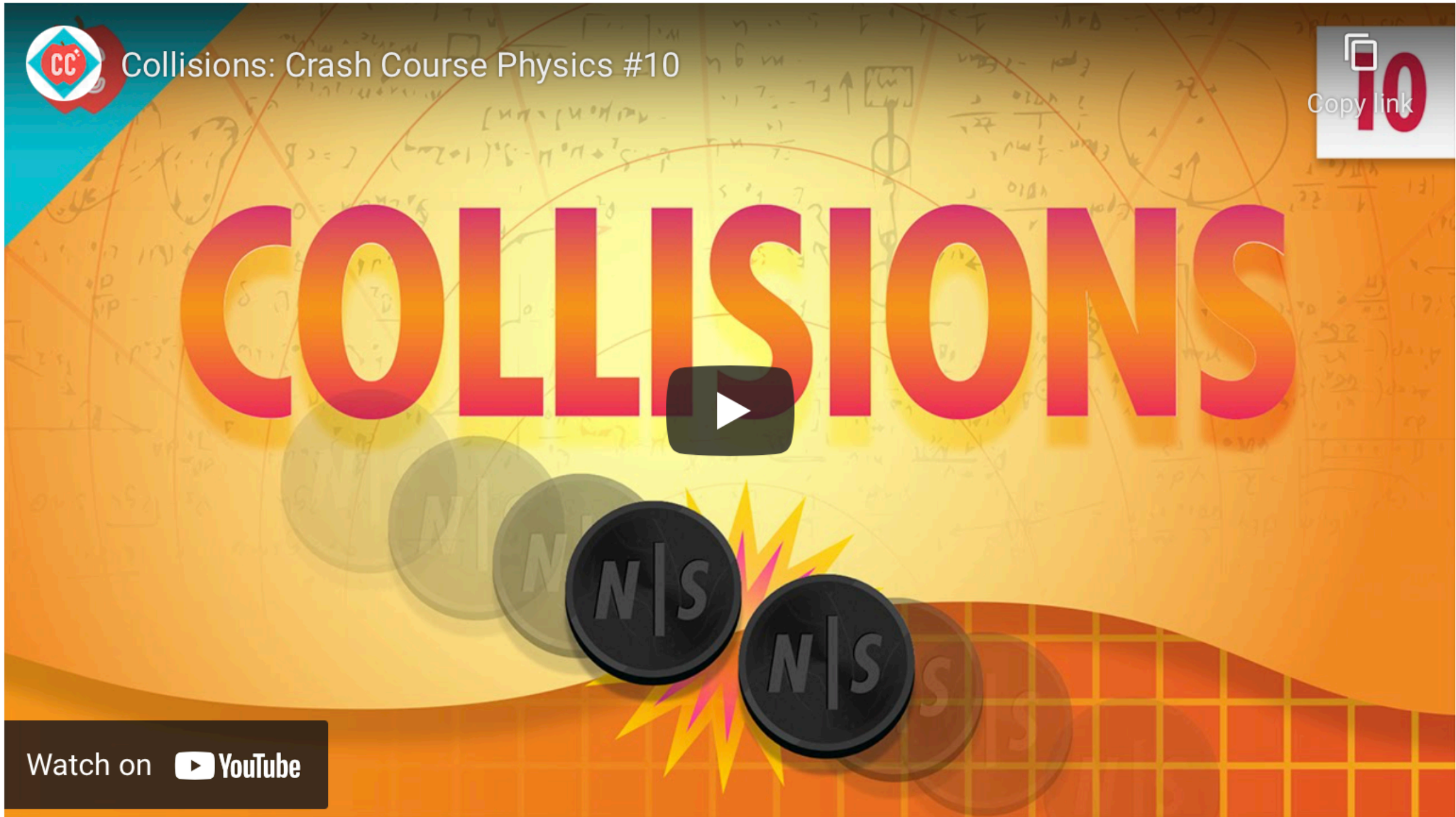
PART 2 - DYNAMICS

Week 5 - Chapter 5

Week 6 - Week Off !!

Content Summary from Crash Course Physics

Collisions

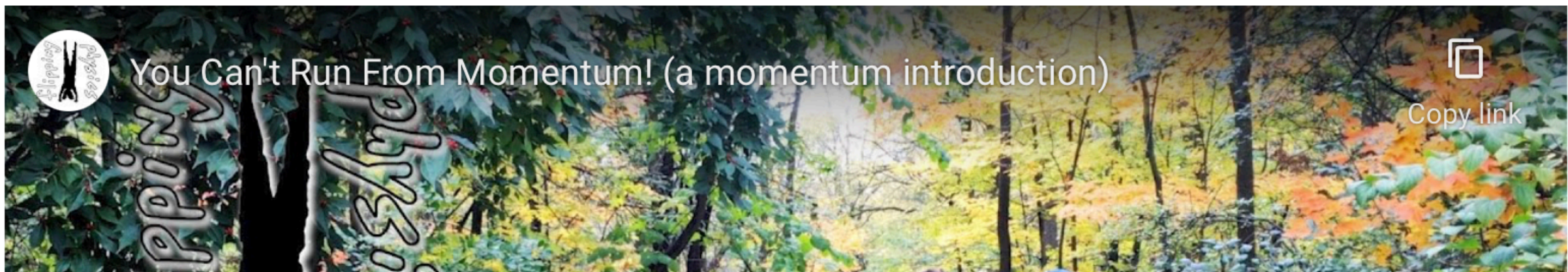


Checklist of items

- ☐ 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)



Preface

▼ Mechanics

- ▶ 1 Units and Measurement
- ▶ 2 Vectors
- ▶ 3 Motion Along a Straight Line
- ▶ 4 Motion in Two and Three Dimensions
- ▶ 5 Newton's Laws of Motion
- ▶ 6 Applications of Newton's Laws
- ▶ 7 Work and Kinetic Energy
- ▶ 8 Potential Energy and Conservation of Energy
- ▼ 9 Linear Momentum and Collisions

Introduction

Mon

Fri

Wed

- 9.1 Linear Momentum
- 9.2 Impulse and Collisions
- 9.3 Conservation of Linear Momentum
- 9.4 Types of Collisions
- 9.5 Collisions in Multiple Dimensions
- 9.6 Center of Mass
- 9.7 Rocket Propulsion

▶ Chapter Review



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

- [9.1 Linear Momentum](#)
- [9.2 Impulse and Collisions](#)
- [9.3 Conservation of Linear Momentum](#)
- [9.4 Types of Collisions](#)
- [9.5 Collisions in Multiple Dimensions](#)
- [9.6 Center of Mass](#)
- [9.7 Rocket Propulsion](#)

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 velocity²
- “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:

$$\vec{p} = m\vec{v}.$$

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

reset

Collision Carts

start

The simulation interface features a top orange bar with a 'reset' button (circular arrow icon), the title 'Collision Carts', and a 'start' button (play icon). Below this is a grid background with a horizontal track. A red cart is on the left and a blue cart is on the right. Below the track, there are two control panels. The left panel is for the red cart, showing 'Initial Velocity' with a slider set to 5 m/s (indicated by a vertical line on a horizontal scale) and 'Mass: 1 kg' with three red cart icons, the first of which is highlighted with a white border. The right panel is for the blue cart, showing 'Initial Velocity' with a slider set to -5 m/s and 'Mass: 1 kg' with three blue cart icons, the first of which is highlighted. At the bottom, there are three buttons: 'Elastic Collision', 'Inelastic Collision', and 'Explosion'.

Initial Velocity

◀

5 m/s

▶

Initial Velocity

◀

-5 m/s

▶

Mass: 1 kg

Mass: 1 kg

Elastic Collision

Inelastic Collision

Explosion

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](#)).

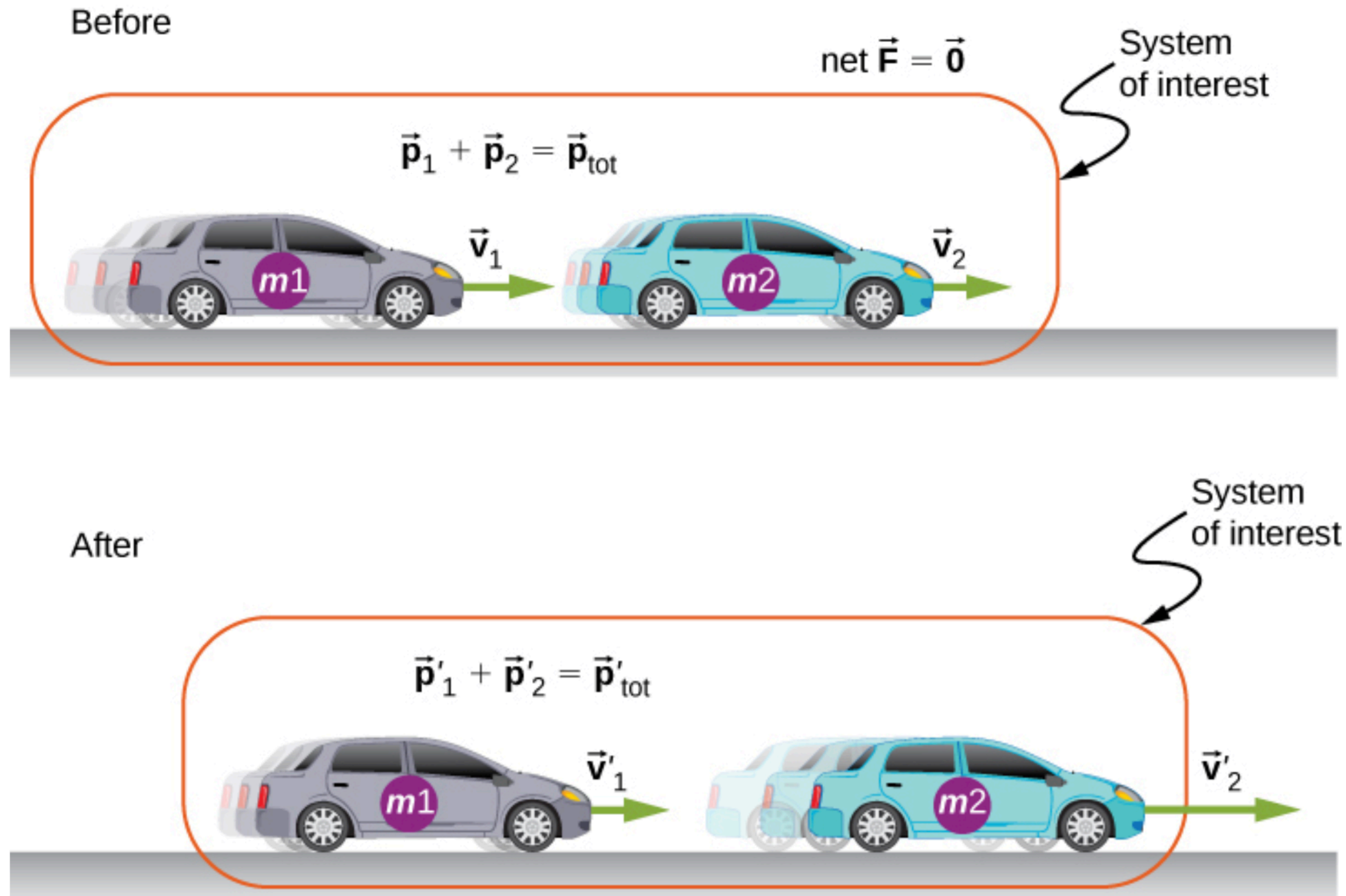


Figure 9.15 The two cars together form the system that is to be analyzed. It is important to remember that the contents (the mass) of the system do not change before, during, or after the objects in the system interact.

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:

$$\sum_{j=1}^N \vec{p}_j = \text{constant.}$$

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

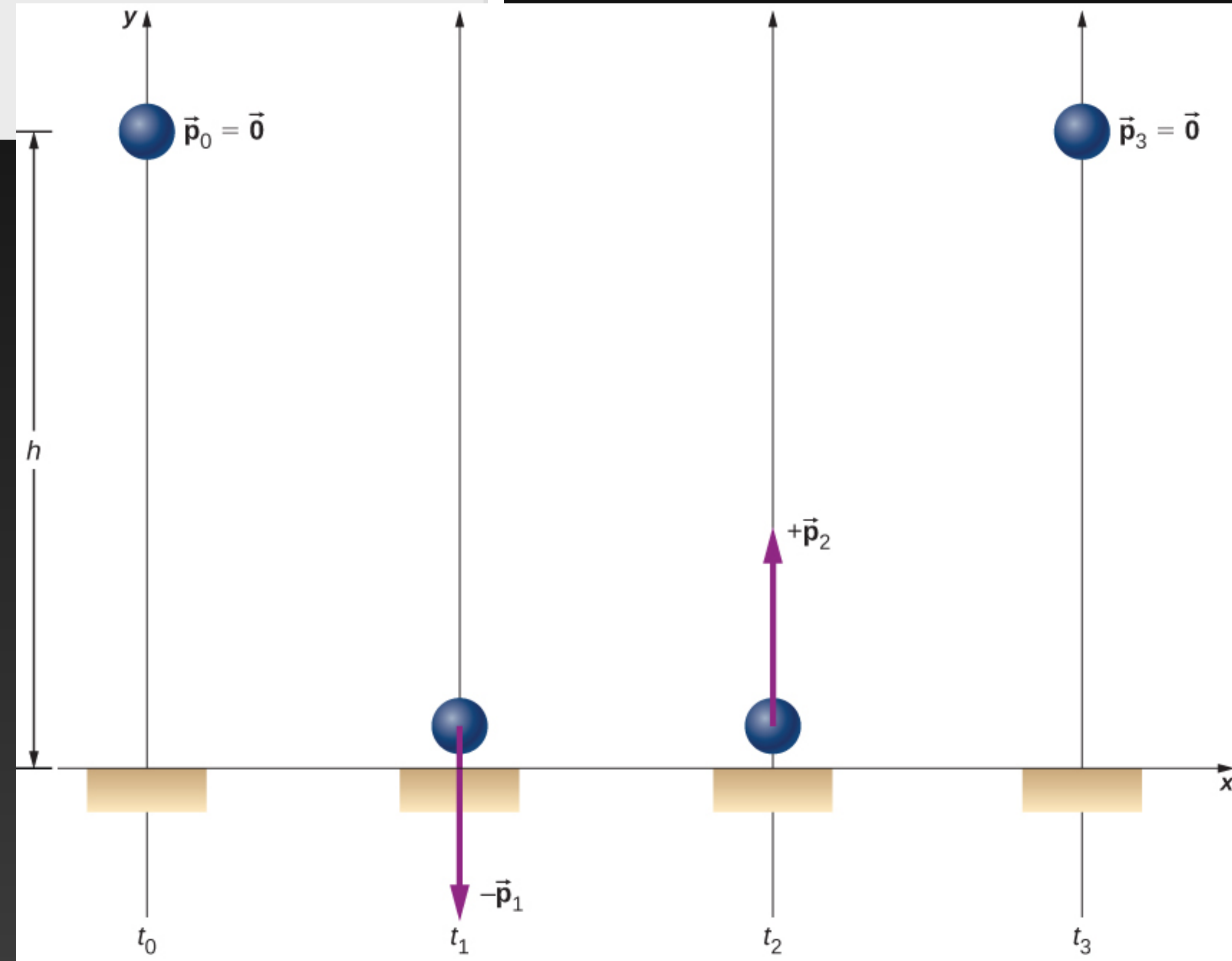
A Bouncing Superball

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

- What is the superball's change of momentum during its bounce on the floor?
- What was Earth's change of momentum due to the ball colliding with the floor?
- 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.)

Example 9.7



EXAMPLE 9.7

A Bouncing Superball

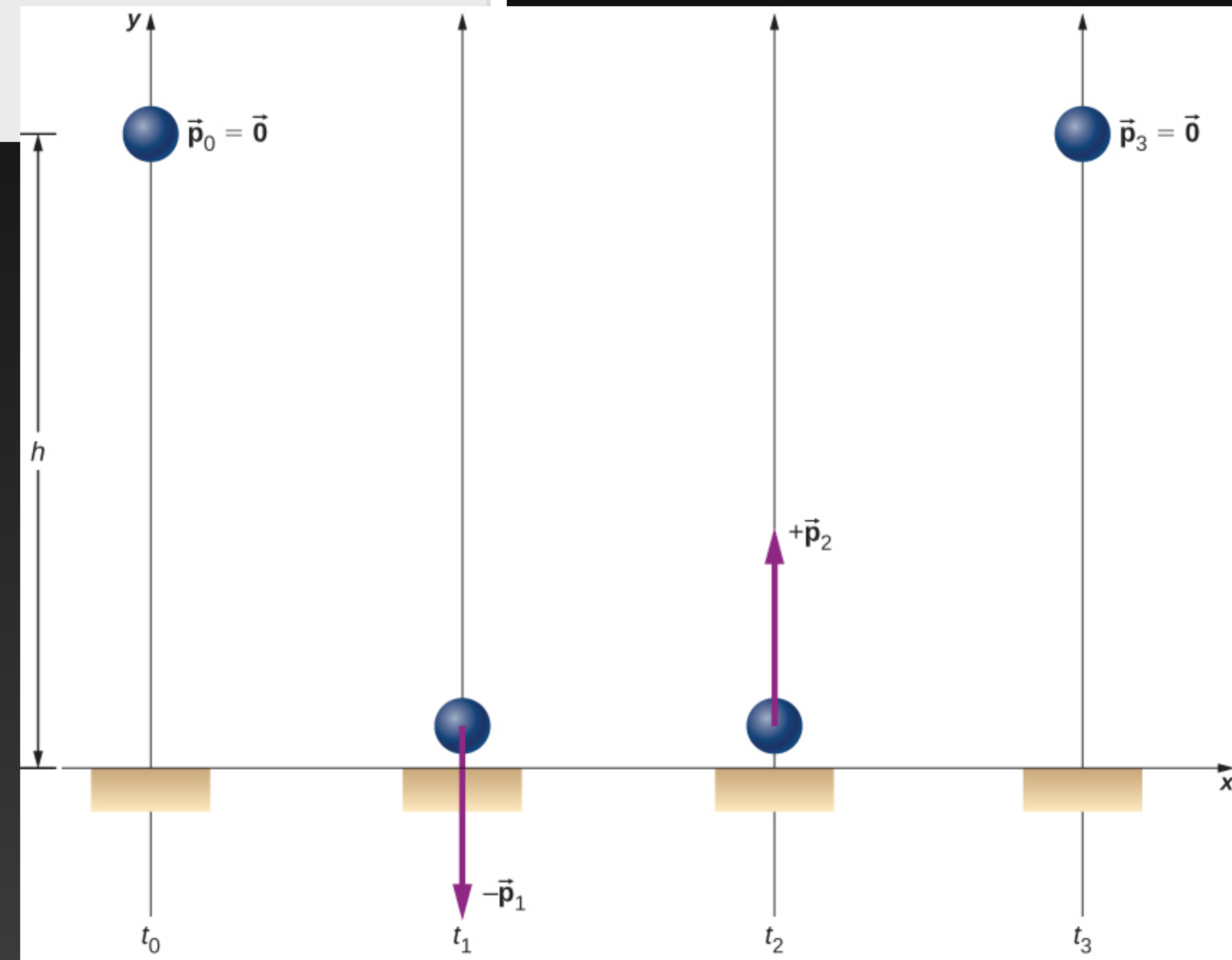
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$$\begin{aligned}\Delta \vec{p} &= \vec{p}_2 - \vec{p}_1 \\ &= (1.4 \text{ kg} \cdot \text{m/s}) \hat{\mathbf{j}} - (-1.4 \text{ kg} \cdot \text{m/s}) \hat{\mathbf{j}} \\ &= + (2.8 \text{ kg} \cdot \text{m/s}) \hat{\mathbf{j}}.\end{aligned}$$

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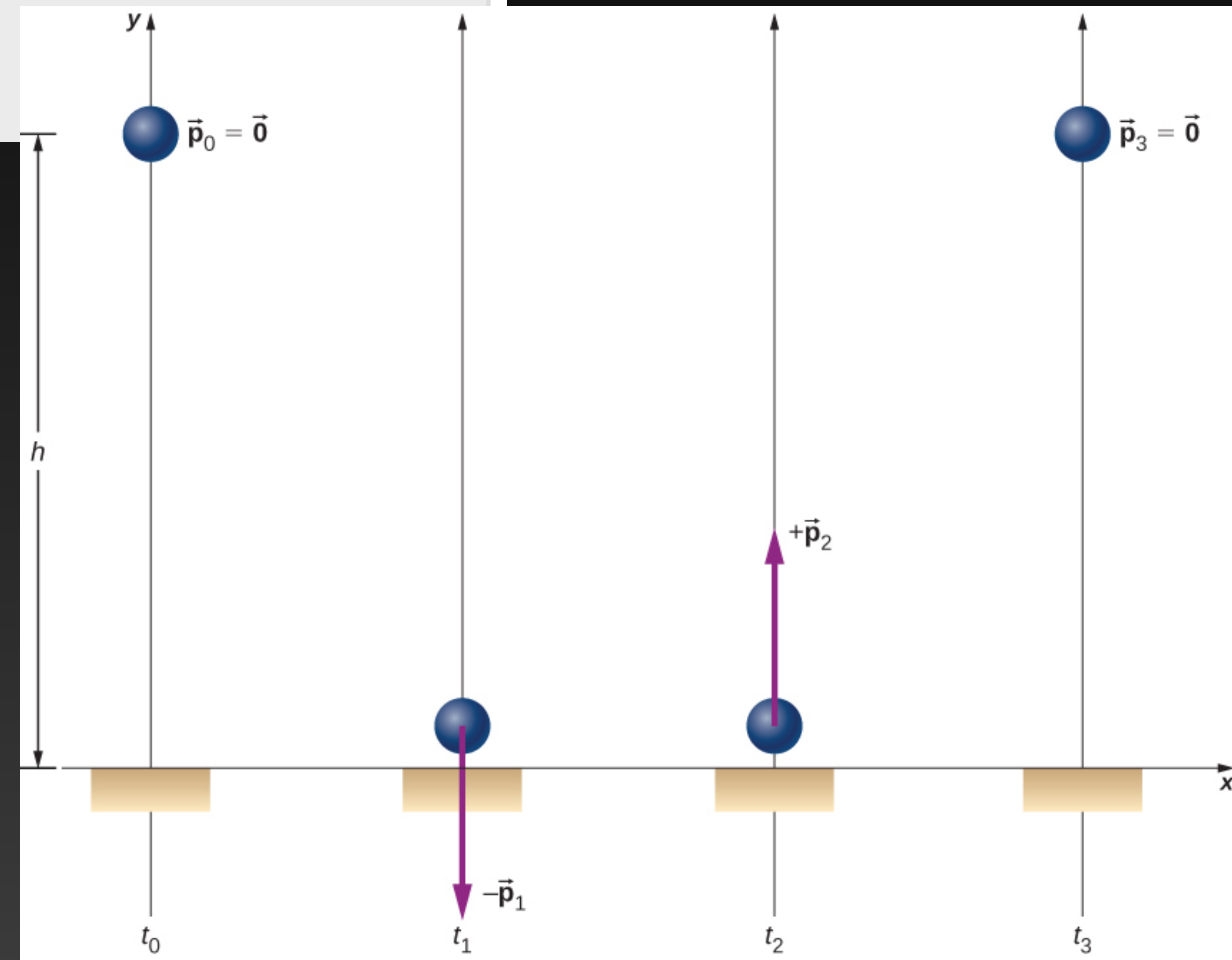
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B

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

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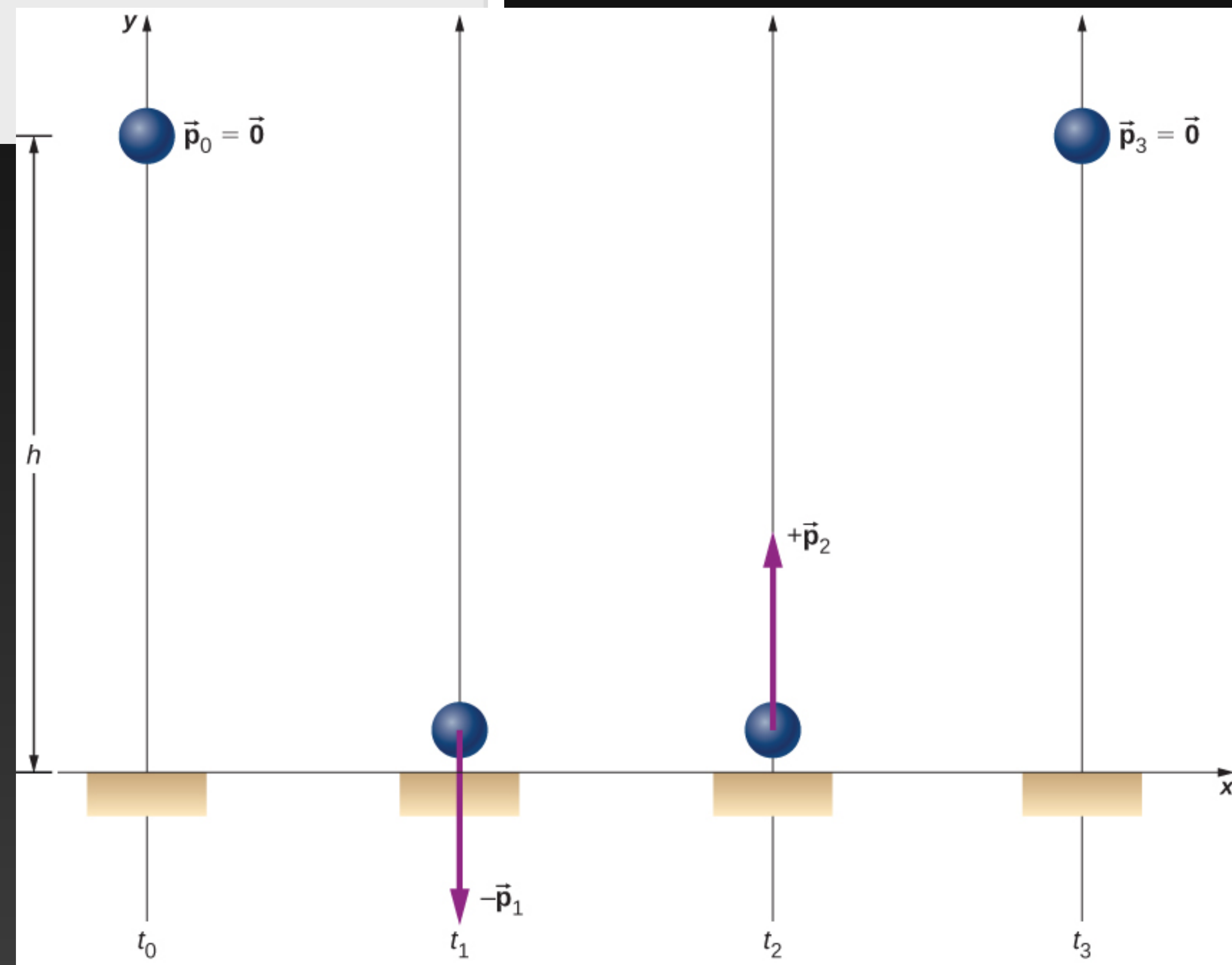
C

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

$$\begin{aligned}\Delta \vec{v}_{\text{Earth}} &= \frac{\Delta \vec{p}_{\text{Earth}}}{M_{\text{Earth}}} \\ &= -\frac{2.8 \text{ kg} \cdot \text{m/s}}{5.97 \times 10^{24} \text{ kg}} \hat{j} \\ &= - (4.7 \times 10^{-25} \text{ m/s}) \hat{j}.\end{aligned}$$

This change of Earth's velocity is utterly negligible.

Example 9.7



See you next class!

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