

You can draw here

Physics 111 - Class 11C

Momentum & Impulse

November 19, 2021

Do not draw in/on this box!

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Class Outline

- Logistics / Announcements
- Homework Reflection
- Chapter 9 Section Summary
- Clicker Questions
- Worked Problems
- Revisiting Bullet Block vs. Spinning Bullet Block

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



Physics 111

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Unsyllabus

ABOUT THIS COURSE

[Course Syllabus \(Official\)](#)

[Course Schedule](#)

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[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

Collisions: Crash Course Physics #10

Watch on YouTube

Copy link

Required Videos

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

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

Copy link

Checklist of items

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

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- ▶ 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

9.1 Linear Momentum

9.2 Impulse and Collisions

9.3 Conservation of Linear Momentum

Mon

9.4 Types of Collisions

Wed

9.5 Collisions in Multiple Dimensions

Fri

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](#)

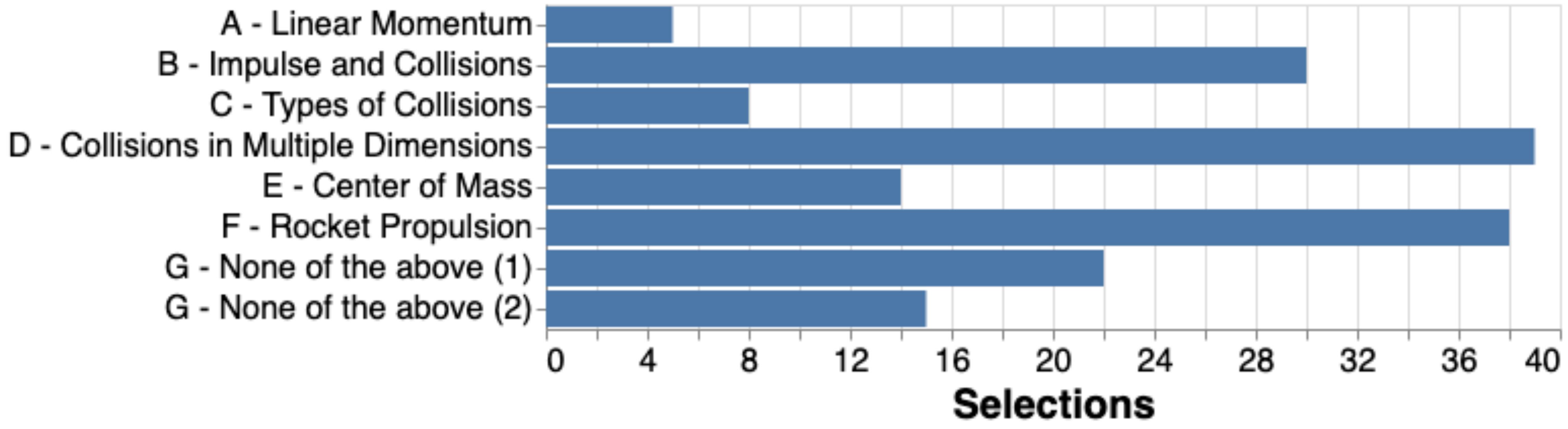
The concepts of work, energy, and the work-energy theorem are valuable for two primary reasons: First, they are powerful computational tools, making it much easier to analyze complex physical systems than is possible using

Friday Class

9.5 Collisions in multiple dimensions
9.7 Rocket Propulsion

HW 9 Reflection

Week 11 - Most Confusing Concepts
N = 86 Students



Most confusing concepts:

Rocket Propulsion Equations

Collisions in Multiple Dimensions

Zero Momentum Frame
(relative velocities & Momentum)

Not bad!

Momentum in multiple dimensions

PROBLEM-SOLVING STRATEGY

Conservation of Momentum in Two Dimensions

The method for solving a two-dimensional (or even three-dimensional) conservation of momentum problem is generally the same as the method for solving a one-dimensional problem, except that you have to conserve momentum in both (or all three) dimensions simultaneously:

1. Identify a closed system.
2. Write down the equation that represents conservation of momentum in the x -direction, and solve it for the desired quantity. If you are calculating a vector quantity (velocity, usually), this will give you the x -component of the vector.
3. Write down the equation that represents conservation of momentum in the y -direction, and solve. This will give you the y -component of your vector quantity.
4. Assuming you are calculating a vector quantity, use the Pythagorean theorem to calculate its magnitude, using the results of steps 3 and 4.

EXAMPLE 9.15

Momentum in multiple dimensions

Exploding Scuba Tank

A common scuba tank is an aluminum cylinder that weighs 31.7 pounds empty ([Figure 9.25](#)). When full of compressed air, the internal pressure is between 2500 and 3000 psi (pounds per square inch). Suppose such a tank, which had been sitting motionless, suddenly explodes into three pieces. The first piece, weighing 10 pounds, shoots off horizontally at 235 miles per hour; the second piece (7 pounds) shoots off at 172 miles per hour, also in the horizontal plane, but at a 19° angle to the first piece. What is the mass and initial velocity of the third piece? (Do all work, and express your final answer, in SI units.)



Figure 9.25 A scuba tank explodes into three pieces.

Rocket Propulsion Derivation



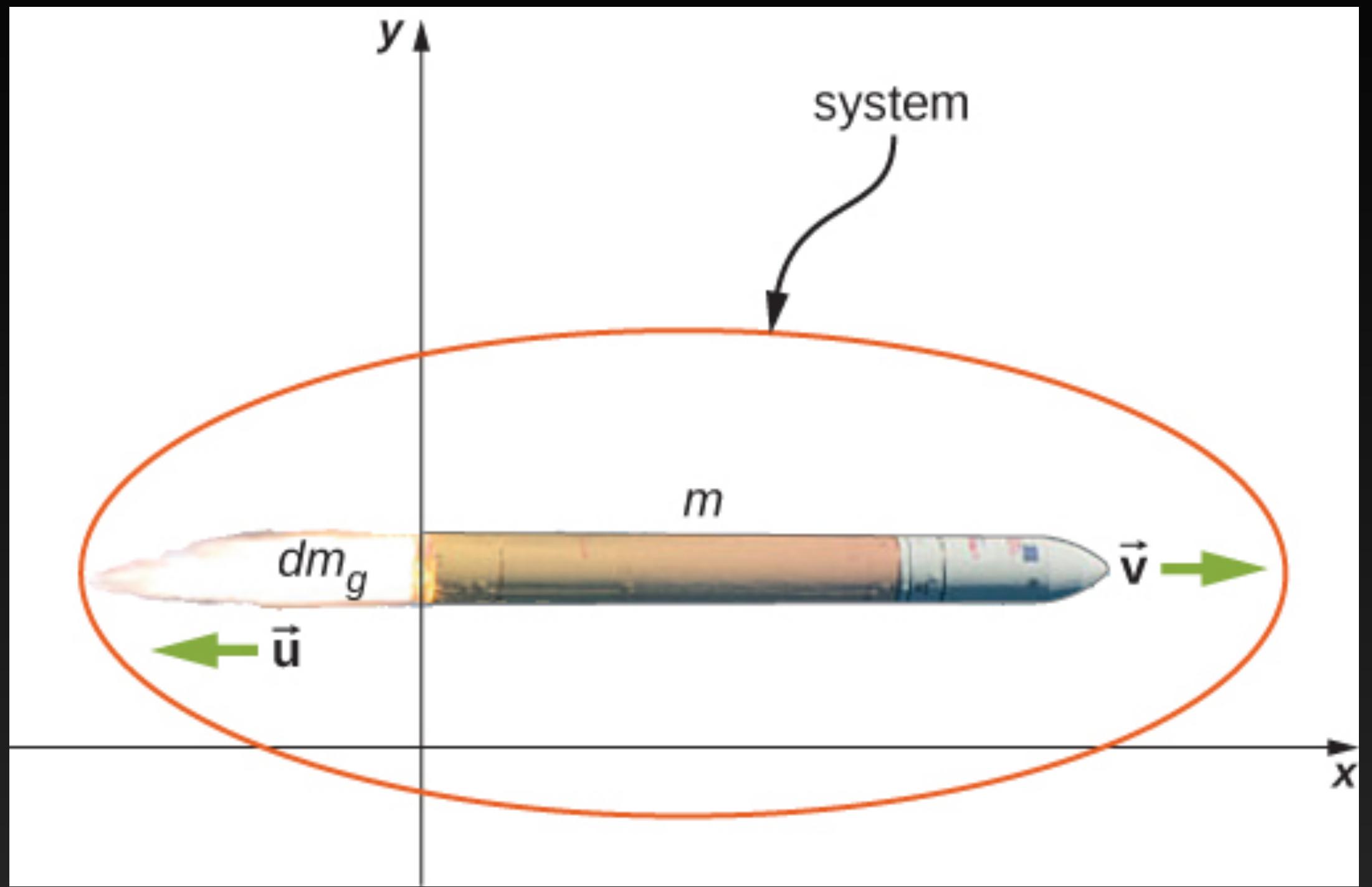
Physical Analysis

Here's a description of what happens, so that you get a feel for the physics involved.

- As the rocket engines operate, they are continuously ejecting burned fuel gases, which have both mass and velocity, and therefore some momentum. By conservation of momentum, the rocket's momentum changes by this same amount (with the opposite sign). We will assume the burned fuel is being ejected at a constant rate, which means the rate of change of the rocket's momentum is also constant. By [Equation 9.9](#), this represents a constant force on the rocket.
- However, as time goes on, the mass of the rocket (which includes the mass of the remaining fuel) continuously decreases. Thus, even though the force on the rocket is constant, the resulting acceleration is not; it is continuously increasing.
- So, the total change of the rocket's velocity will depend on the amount of mass of fuel that is burned, and that dependence is not linear.

The problem has the mass and velocity of the rocket changing; also, the total mass of ejected gases is changing. If we define our system to be the rocket + fuel, then this is a closed system (since the rocket is in deep space, there are no external forces acting on this system); as a result, momentum is conserved for this system. Thus, we can apply conservation of momentum to answer the question ([Figure 9.33](#)).

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Key Equations

Definition of momentum	$\vec{p} = m\vec{v}$
Impulse	$\vec{J} \equiv \int_{t_i}^{t_f} \vec{F}(t)dt \text{ or } \vec{J} = \vec{F}_{ave}\Delta t$
Impulse-momentum theorem	$\vec{J} = \Delta\vec{p}$
Average force from momentum	$\vec{F} = \frac{\Delta\vec{p}}{\Delta t}$
Instantaneous force from momentum (Newton's second law)	$\vec{F}(t) = \frac{d\vec{p}}{dt}$
Conservation of momentum	$\frac{d\vec{p}_1}{dt} + \frac{d\vec{p}_2}{dt} = 0 \text{ or } \vec{p}_1 + \vec{p}_2 = \text{constant}$
Generalized conservation of momentum	$\sum_{j=1}^N \vec{p}_j = \text{constant}$
Conservation of momentum in two dimensions	$p_{f,x} = p_{1,i,x} + p_{2,i,x}$ $p_{f,y} = p_{1,i,y} + p_{2,i,y}$
Rocket equation	$\Delta v = u \ln \left(\frac{m_i}{m} \right)$

Activity: Worked Problems

35 . Train cars are coupled together by being bumped into one another. Suppose two loaded train cars are moving toward one another, the first having a mass of 1.50×10^5 kg and a velocity of $(0.30 \text{ m/s})\hat{i}$, and the second having a mass of 1.10×10^5 kg and a velocity of $-(0.12 \text{ m/s})\hat{i}$. What is their final velocity?

$$\vec{v}_{1,i} = (0.30 \text{ m/s})\hat{i}$$



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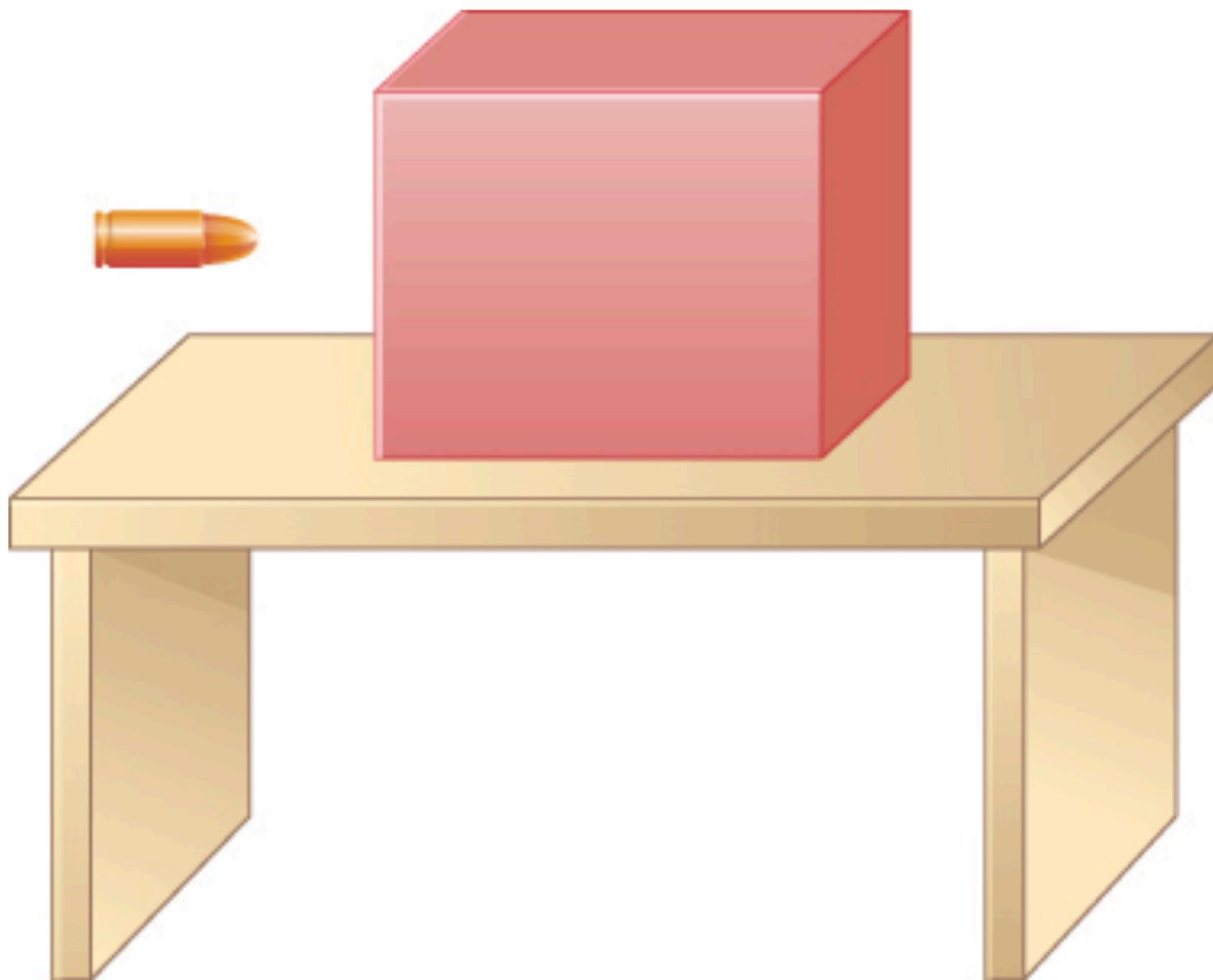
$$\vec{v}_{2,i} = -(0.12 \text{ m/s})\hat{i}$$



$$(0.122 \text{ m/s})\hat{i}$$

37 . The figure below shows a bullet of mass 200 g traveling horizontally towards the east with speed 400 m/s, which strikes a block of mass 1.5 kg that is initially at rest on a frictionless table.

WP 11.2

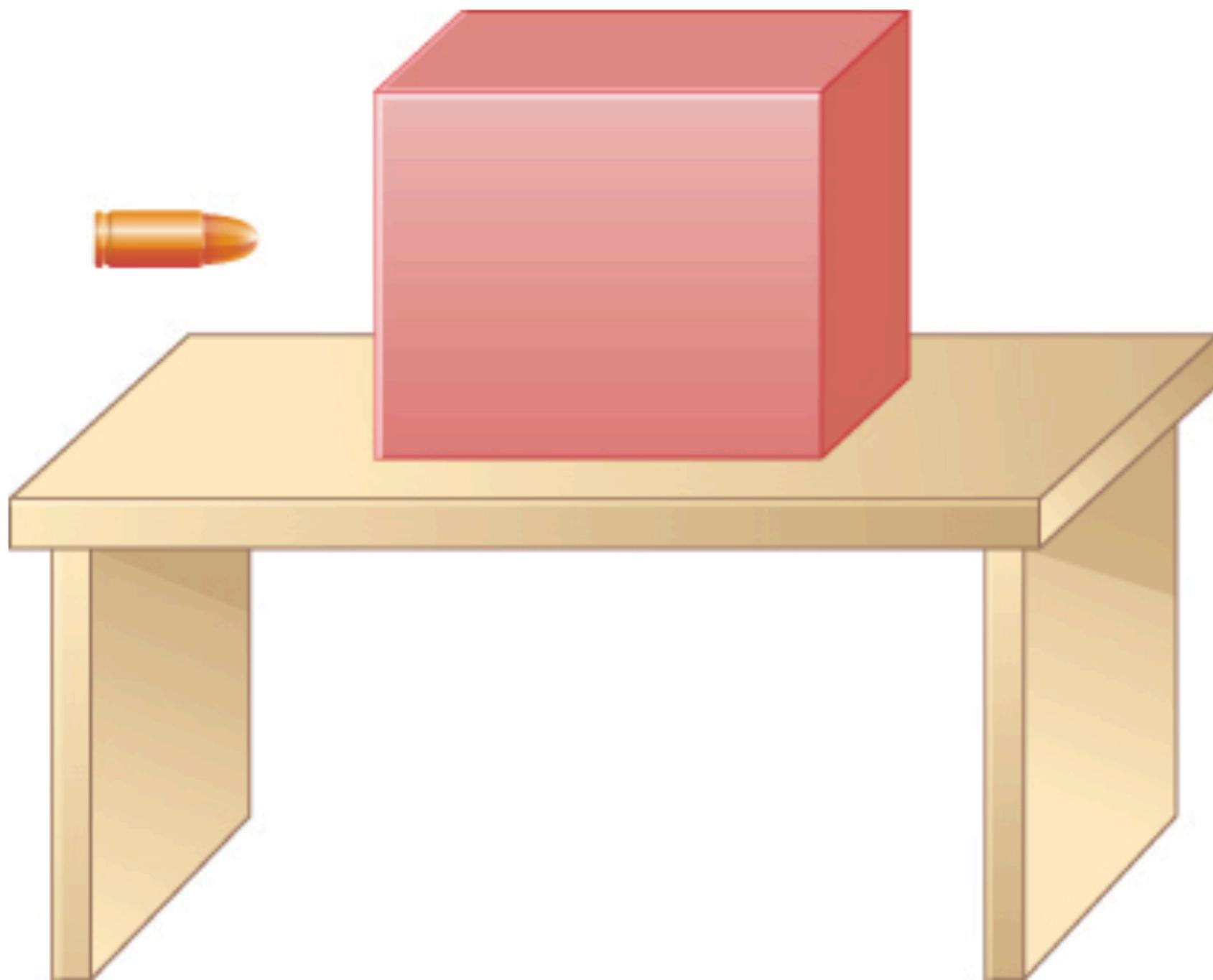


After striking the block, the bullet is embedded in the block and the block and the bullet move together as one unit.

- a. What is the magnitude and direction of the velocity of the block/bullet combination immediately after the impact?
- b. What is the magnitude and direction of the impulse by the block on the bullet?
- c. What is the magnitude and direction of the impulse from the bullet on the block?
- d. If it took 3 ms for the bullet to change the speed from 400 m/s to the final speed after impact, what is the average force between the block and the bullet during this time?

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Revisiting the Bullet Block problem...

Preview of what's left



**Did we just violate
Conservation of Energy?**

See you next class!

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