PHYS101A/BL

Course Syllabus

Fall 2026

You may choose to print this Syllabus page or save it as a PDF:

1. Access this page via a web browser
2. Right-click (or [CTRL]-click on a Mac) on the content of this Syllabus page
3. Choose the "Print" option
4. Select "Save as PDF" or a printer for the printing destination

Contact Information

Instructor

Name: Robert Shirk

Contact Information

Email: shirk@msmary.edu

Phone: None

Office: SCI 208

Office Hours

M: 9:00 am - 10:45 am SCI 208 or 216

W: 9:00 am - 10:45 am SCI 208 or 216

F: 9:00 am - 10:45 am SCI 208 or 216

Other times by appointment

Course Meeting Time

Course Meeting Time:

PHYS 101A MWF 11:00 am - 11:50 am

PHYS 101BL M 1:00 pm - 3:50 pm

Course Format:

For course format descriptions:

msmary.edu/course-formats (https://msmary.edu/course-formats)

For student Zoom resources:

Zoom Resources (https://msmary.instructure.com/courses/2804/pages/zoom-resources-for-students)

Synchronous Location (if applicable):

In-person at the Emmitsburg Campus, SCI 216

Course Description

The topics covered in this algebra-based course include:

- Linear, Circular and Rotational Motion
- Newton's Laws and Their Application
- Work and Energy
- Momentum
- Periodic Motion
- Fluids

The labs for this course include (this is tentative and is subject to change):

- Kinematics and Free Fall
- Cart on a Ramp and Modern Galileo
- Vectors
- Friction
- Work and Energy
- Linear Momentum
- Rotational Equilibrium
- Springs and Simple Harmonic Motion (SHM)

Learning Objectives

Course Learning Objectives

College Physics I is designed to address specific course objectives and goals in the core program. These have been identified as follows:

1. One goal is to provide a mature overview of the basic principles and concepts of classical (Newtonian) mechanics.
2. Another goal of the course is for students to develop skills that allow them to illustrate the principles of these topics through numerous applications.
3. A third goal is to aid in the development of problem-solving ability (both numerical and conceptual) and in the enhancement of physical intuition.

Emphasis on problem solving makes this course excellent preparation for standardized tests such as the MCAT (contains a physical science section), the DAT and the GRE.

College Physics I facilitates the development of writing, critical thinking and speaking skills as they relate to skills needed to continue their career in the Sciences and Mathematics.

Department Program Goals

Department program goals are designed to function in the context of a major offered by the Department of Science. In particular, this course is designed to achieve the following goals:

1. Understand the fundamental concepts of science.
2. Ability to solve problems using physical concepts and/or the Scientific Method (including designing experiments, collecting data, and analyzing results.

3. Communicate effectively in oral and written form and in scientific format.
4. Able to work independently and in groups.

Undergraduate Program Goals

Achievement of the departmental/program goals addressed by this course contributes to achievement of the following undergraduate program goals.

1. Understand the purposes and concepts of at least one major field of study and become proficient in its methodology.
2. Master the skills of analysis, interpretation, communication, and problem solving.
3. Continue a life of learning, growth in faith and mature spirituality, and service to the common good.

Course objectives, major/core program goals, and overarching Undergraduate Program Goals are aligned as follow:

Course Objective	**Department Program Goal**	**Undergraduate Program Goal**
1	1,2	1,2
2	1,2,3	1,2
3	1,2,3,4	1,2

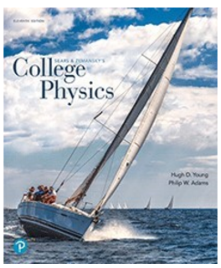
University Program Goals

As a Catholic University grounded in the liberal arts, we ask all students to complete a common, sequenced, and interdisciplinary core curriculum. The University intends the whole of its undergraduate program to enable students to:

- The Catholic Vision of the Human Person: Understand and articulate the Catholic vision of the human person, particularly as it relates to the nature of the good, the relationship between faith and reason, and the human relationship with God;
- The Western Tradition: Integrate diverse modes of human inquiry and expression through rigorous study of the Western tradition, including its American expression;
- Competencies: Master the skills of analysis, interpretation, communication, and problem solving;

- Major Field of Study: Understand the purposes and concepts of at least one major field of study and become proficient in its methodology;
- Social Justice in a Global Community: Understand the diversity of human cultures in a global community, to see and seek to respond with justice and solidarity to all in the global community, to protect human dignity, to work for peace and freedom, and to respect the integrity of creation;
- A Life Well-Lived: Continue a life of learning, growth in faith and mature spirituality, and service to the common good.

Textbooks & Reading Material



College Physics, 11th Edition (e-text with Mastering Physics)

Hugh D. Young - Emeritus Professor of Physics at Carnegie Mellon University

Phillip W. Adams - Assistant Professor of Physics and Astronomy at the

University of Louisville.

This course is part of our course material delivery program, ***Emmit's Book Pack.*** *The bookstore will provide each student with a convenient package containing all required physical materials and all digitally delivered materials for this course will be integrated into Canvas.*

You should have received an email from the bookstore confirming materials provided for each of your courses and asking you to select how you would like to receive any printed components (in-store pick up or home delivery). If you have not done so already, please confirm your fulfillment preference so the bookstore can prepare your materials.

For more information about ***Emmit's Book Pack,*** *please go to:*
https://msmary.edu/admissions/financial-aid/emmits-book-pack/index.html.html
(https://msmary.edu/admissions/financial-aid/emmits-book-pack/index.html.html)

Be sure to check out the student resources on Mastering Physics.

Course Policies

Assignment Policies

Homework assignments are made for practicing the skills discussed in class. Students are expected to complete each assignment. The only acceptable resources are the e-text and your notes. Use of online sites such as Chegg are dishonest and constitute cheating. Homework is done through Pearson Mastering Physics.

The due dates and times for the homework are listed on the Pearson site. Generally, the due dates are one week after a chapter of material has been completed in lecture. There is no credit for late submission. You are allotted one extension if requested prior to the due date.

Assignment scores for homework will be shown after the due date. The number of attempts per question is three. For multiple choice and True/False questions, the deduction is based on the number of choices. For True/False questions, all credit is lost for an incorrect answer.

For multiple choice questions, the deduction is based on the number of choices according to the formula below:

If there are 5 choices, then 25% would be deducted for each incorrect answer. For other types of questions, a 5% deduction for each incorrect answer is taken before the last attempt.

Hints and e-text review links can always be accessed. Completed questions can be re-worked for practice after the due date. This work will not be saved and will not affect the grade.

Grading on quizzes and exams will be mostly on how you solved the problem, rather than on the answer. This means you must show all your work. If you simply write down the answer, you will get 0 points for the problem, even if your answer is correct. If you show your work and make a simple arithmetic error (like 2 + 2 = 5), you will get almost all the points for the problem.

To be allowed to take a make-up a test (or quiz), the students must get permission from the instructor **BEFORE** the test (quiz). A test (quiz) score of 0 is assigned to unexcused absences on test (quiz) day.

Students should expect to spend about two hours on homework for every hour spent in the classroom. Questions on homework problems can be discussed in class or during scheduled review sessions.

Attendance/Participation

Students are expected to attend all cases and labs. Attendance will be taken regularly. Please contact me by e-mail **in advance** if you miss class. You are allowed one unexcused absence. After the first one, 5 points will be deducted from your point total for each additional unexcused absence. A doctor's note may be required for the absence to be excused depending on the circumstances of the absence. Please contact the Associate Provost's office for the following: (a) family emergencies (e.g., death in the family, car accidents, etc), (b) severe undisclosed illness/medical conditions that will result in extended absences, and (c) other conditions that require university support.

Lateness is disrespectful to your fellow students and to your instructor. The lectures will start on time. You are late whether you are 3 seconds late, 30 seconds late, or 3 minutes late. After the first occurrence, 5 points will be deducted from your point total for each additional lateness.

Use of cell phones during lecture or lab is not allowed After the first occurrence, 5 points will be deducted from your point total for each additional cell phone use occurrence.

Science Department Policy of Lab Attendance

The MSMU Science Department offers in-person labs because the development of experiential, hands-on, skills-based learning is the focus of a program goal in each of our majors. In our majors, we expect that students will apply the process of science in a laboratory setting through quantitative reasoning, experimental design, data collection and analysis, and presentation of results. Students in our lab courses should understand the following:

There is a requirement that students attend a minimum of **80%** of all lab meetings. Students failing to meet this minimum attendance requirement will not pass the course. Because lab-bearing courses at MSMU constitute a single 4-credit course, this means that the students not passing the lab will not pass the course as a whole.

The precise number of missed labs will vary by course, as some courses meet twice weekly for lab, some meet once weekly, and some have other scheduling scenarios. This requirement applies to **both excused and unexcused absences** including, but not limited to, absences for athletics, illness, accommodations, and travel.

However, since PHYS101BL has only eight (8) hands-on labs, students are required to attend a minimum of six (6) hands-on labs. This requirement applies to **both excused and unexcused absences** including, but not limited to, absences for athletics, illness, accommodations, and travel.

Recreating labs for students to make up is difficult for the following reasons:

1. Biological and chemical reagents expire. The department does not have the budget to re-order supplies for students who miss lab. Laboratory reagents are expensive, and this is one of the reasons why there is such a high cost of delivery for science courses.
2. Living specimens die or change such that it is not always possible to recreate laboratories at a later date or time.
3. Lab work is often collaborative, and it is not possible to recreate the experience or the data in a one-on-one setting. For example, an individual student's work may fit into a larger class-acquired experiment. One student/group's data alone might be meaningless without the larger context and thus may not be possible to be analyzed.
4. Faculty do not have the person-hours to schedule one or more additional 3-hour lab blocks to recreate labs for students who miss them. Doing this with a student TA in charge is not always a good solution because of safety issues.

In the case of university-sanctioned, excused absences, a make-up laboratory opportunity may be possible, but may have to take a different format from the missed lab for the reasons described above. Students should understand that attending a lab make-up session or arranging for an alternative activity with the course instructor does not make up for the ***absence*** of an in-person lab session; however, such arrangements will provide the opportunity for a student with an excused absence to complete missed assignments such that their grade is not affected. There are no make-up lab opportunities for unexcused absences.

Students should recognize that being on time to lab and prepared for lab is critical. Labs typically begin with a review of safety considerations specific to the lab and missing this can put the student and others in the lab at risk of injury. For this reason, being late to lab may preclude a student's ability to participate in the lab, which would count as a laboratory absence.

Similarly, students leaving early are at risk of being considered absent for the lab period. Students who come unprepared (without required items like safety goggles, lab coats, closed-toed shoes, etc.) will not be able to participate in the lab, and will therefore be marked absent.

Grade Scale Table

Category	Point Value	Grade Scale
Homework	100	A 92.5 - 100
3 Quizzes @ 50 pts each	150	A- 89.5 - 92.4
Lab Sheets	100	B+ 87.5 - 89.4
Formal Lab Report	100	B 81.5 - 87.4

Exam 1	150	B- 79.5 - 81.4
Exam 2	200	C+ 77.5 - 79.4
Final Exam	200	C 71.5 - 77.4
		C- 69.5 - 71.4
Total Points	1000	D+ 67.5 - 69.4
		D 61.5 - 67.4
		D- 59.5 - 61.4
		F 0 - 59.4

Grading Description

HOMEWORK

The number of homework points is calculated by taking the homework percentage times 100. For example, if a student had a total of 105 points out of a possible 130 points, the percentage would be 80.8%. Thus, 80.8 points would be included in the students point total.

QUIZZES

Each quiz is worth 50 points.

LABS

The number of lab points is calculated by taking the lab percentage times 100. For example, if a student had a total of 55 points out of a possible 80 points, the percentage would be 78.6%. Thus, 78.6 points would be included in the students point total.

FORMAL LAB REPORT

The formal lab report is worth 100 points.

EXAMS

The first exam is worth 150 points. The second exam and final exam are each worth 200 points. The exams are graded on a percentage basis out of 100%. If a student scores an exam grade of 80% on exam 1, then 120 points are included in the student’s total number of points. If a student scores an exam grade of 80% on the second or final exam, then 160 points are included in the student’s total number of points.

POINT ADJUSTMENT

Point adjustments are tracked here. They go directly into a student's point total. Positive points for extra credit assignments and class participation.

Negative points for unexcused absences, lateness, and cell phone use.

Student Responsibilities

Students are expected to arrive promptly and to be prepared. Prepared means bringing your notebook, pencil, black pen, and calculator to all classes.

There is no eating during lectures or labs. Drinking is allowed. Talking, texting, or looking at texts/emails during class is disrespectful to your professor and your classmates and will not be tolerated.

Ask questions and actively participate in class. Do not allow yourself to fall behind. Please ask questions in class and schedule help session with me if you are having trouble. See Learning Services for a peer tutor.

Refer to the Resources section of this course for information on the Library, Writing Center (useful for Formal Lab Report), and Learning Services.

Do not copy answers from others. Do not put your name on someone else's work. This is unethical and will not be tolerated. Homework, quizzes, tests, and formal lab reports are to be individual work. **Any evidence of cheating will result in a grade of zero and you will be reported for Academic Dishonesty. Refer to the Mount's Academic Honesty Policy.**

Proctored Exams

Proctored Exams

Quizzes and Exams will be proctored in the classroom by the instructor or in Learning Services by Learning Services personnel or in the case of athletics by the athletic department.

AI Use Policy

There may be an AI Use Policy for student work and submissions in this course. If so, see below for important information on student AI use.

Assignments and Descriptions

Assignments in addition to quizzes and exams include e-text reading assignments, online homework assignments, lab sheets and a formal lab report. These are described under Assignment Policies.

Course Calendar

The instructor reserves the right to adjust the assignments or schedule. This may also change the date(s) of one or more of the exams. Any affected assignment due dates may also be adjusted. In the event the schedule is adjusted, the student will be notified and remain responsible for all the assignments listed in this syllabus.

August 26 Mount opens for classes/First PHYS101A class

September 7 Labor Day (No classes)

October 2 - 6 Fall Break

October 12 First Exam on Chapters 1, 2, and 3

November 16 Second Exam on Chapters 4, 5, 6, 7 and 8

November 25 – 29 Thanksgiving Break

December 11 Last Day of Classes

December 14 Final Exam (Chapters 9, 10, 11 and 13) 12:00 - 2:30 pm

Technology Requirements

Technology tools and skills needed to be successful in your courses:

- Understand basic computer hardware and software
- Know how to use a keyboard and a mouse

- Be able to manage files and folders using operations such as save, copy, rename, delete etc.
- Be competent in the use of Microsoft Office or applications similar to Word, Excel, PowerPoint
- Be able to send and download files and attachments.
- Know how to communicate using live.msmary.edu email
- Know how to use the Internet to access your course, perform online research, and use search engines and databases.

Technology Requirements:

Please review the Information Technology Support Center's (ITSC) **minimum software and hardware requirements** **(https://msmaryedu.sharepoint.com/ITSC/Shared%20Documents/Laptop%20Specifications.pdf)** . Please note that courses often cannot be successfully completed on a Chromebook, tablet, or cellular device. Consistent access to a reliable computer and Internet connection are required for all courses.

Additional information on using Canvas, Microsoft Office, and web conferencing tools can be found on the "Student Resources" link available from the course home page.

If students have technical difficulties submitting assignments in Canvas, they should contact Canvas Help for assistance *before* the due date/time. Representatives from Canvas will provide technical support and an email confirmation regarding the status of the request. Students must forward the email to the professor along with their assignment to earn full credit if the problem cannot be resolved prior to the deadline.

If you have computer issues or are unable to access your Mount e-mail contact ITSC at 301-447-5805 or submit a support ticket by emailing **itsc@msmary.edu (mailto:itsc@msmary.edu)** .

Mount Policies & Info

Academic Integrity

An academic community, regardless of delivery modality (e.g., in-person, online), must operate with complete openness, honesty and integrity. Responsibility for maintaining this atmosphere lies with the students, faculty and administration. Therefore, the achievement of personal and academic goals through dishonest means will not be tolerated. Academic misconduct includes but is not limited to:

1. **Cheating**: the unauthorized use, access, or exchange of information before or during a quiz, test or semester examination. Unauthorized collaboration on a class assignment, submitting the same work in two courses without the professor's permission, and buying or selling work for a course are also forms of cheating.
2. **Plagiarism**: the representation of someone else's words or ideas as one's own. The various forms of plagiarism include but are not limited to copying homework, falsifying lab reports, submitting papers containing materials written by another person, and failing to document correctly in one's written assignment words, arguments or ideas secured from other sources including content available from websites, and/or generated through A.I. without the instructor's permission. Plagiarism detection software may be used with assignment submissions to verify original work.
3. **Providing or receiving assistance in a manner not authorized by the professor** in the creation of work to be submitted for academic evaluation including papers, projects and examinations; presenting as one's own the ideas or words of another (including those generated from A.I.) for academic evaluation without proper acknowledgement and permission from the instructor.
4. **Doing unauthorized academic work** for which another person will receive credit or be evaluated.
5. **Misrepresenting student identity**: posing as another or having someone pose as you is an act of academic misconduct. Identity verification may be required to complete course activities and assessments.
6. **Attempting to influence one's academic evaluation** by means other than academic achievement or merit including unauthorized access to computer systems.
7. **Assisting in misconduct**: cooperation with another in an act of academic misconduct. A student who writes a paper, posts a paper or exam questions online, or does an assignment for another student is an accomplice and will be held accountable just as severely as the other. Any student who permits another to copy from his or her own paper, examination, or project shall be held as accountable as the student who submits the copied material. Students are expected to safeguard their work and should not share papers, projects, homework, or exam answers with other students unless specifically directed to by their professors.

8. **Failure to protect University accounts and computer systems** such as sharing of accounts, passwords, and other assigned resources whether with intention or through negligence.

Canvas Information

Canvas is where course content, grades, and communication will reside for this course. Should you need assistance using Canvas click on the "Help" icon on the far left of your screen at the bottom of your blue navigation menu. From that link you will have access to:

- A Frequently Asked Questions (FAQs) document with direct links to support
- Canvas Guides for Students
- Live chat with Canvas Help Desk (24/7). MSMU has the premium subscription. Please don't hesitate to contact them for help.
- Live phone support, also 24/7
- For Canvas passwords or any other computer-related technical support contact the **ITSC Help Desk (https://inside.msmary.edu/more/information-technology/itsc.html)**.
  - **ITSC@msmary.edu (mailto:ITSC@msmary.edu)**
  - 301-447-5805

Classroom Accommodations for Students with Disabilities

If you are a student with a documented disability who requires an academic adjustment, auxiliary aid, or similar accommodation, please contact Mount St. Mary's Learning Service director to discuss eligibility for accommodations and academic adjustments at 301-447-5006 (V/TTD).

Mount Report: Campus-wide Reporting

In the spirit of providing students a quality education and ensuring student success, offering an appropriate array of support services, and supporting student concerns, Mount St. Mary's University takes seriously concerns and complaints brought to its attention.

As such when a student encounters a problem on campus or feels they have been treated unfairly, the student should first attempt to resolve the issue informally with the employee, department, service, process or administrative procedure involved. Many issues can be resolved by making an appointment and honestly communicating the concern(s).

If a student is not satisfied after working to resolve the matter directly, they may use the **Mount Report** (https://msmary.edu/reporting.html) process to file a formal student complaint.

Mount Report Link (https://msmary.edu/reporting.html)

> The Student Complaint Process does not apply to grade appeals, complaints of sexual harassment, or any student-to-student complaints.

> The Mount Report process can be used for reporting violations of Title IX policy*. Please refer to the **Mount St. Mary's University Catalog** (http://catalog.msmary.edu/), **Policy on Title IX Sexual Harassment** (https://msmary.edu/title-ix-sexual-harassment-discrimination-policy/index.html), or **Student Code of Conduct** (https://inside.msmary.edu/student-affairs/files/msmu-student-code-of-conduct.pdf), respectively, for procedures regarding these types of complaints.

Intellectual Property

The use of copyrighted materials in this course to support teaching and learning is done so with permission from the copyright holder or according to Fair Use Guidelines and the TEACH Act. As such, you are permitted to download a copy of copyrighted works posted in our secured course site in Canvas for your personal use, but you are not authorized to redistribute to others (e.g., make copies to distribute, forward as attachments). Similarly, the intellectual property of students (e.g., presentations/posts in discussion forums) should not be shared with or redistributed to others.

Netiquette

Please consider these guidelines as you actively participate in our course.

Be constructive: Our goal is to develop a safe, collaborative, and constructive learning community. Constructive posts are encouraged. Often sharing a differing perspective or opinion advances our shared learning. When responding to a classmate, respectfully indicate why you do or do not agree with their view. If you would not make a comment face-to-face, please do not do so online. Refrain from using any offensive or foul language, always discuss or respectfully debate content, but never attack a member of our learning community. Try not to dominate any discussion, but do regularly share your experiences and knowledge.

Be considerate: Though mobile technologies have enhanced our ability to access course content from anywhere and at any time, we should not expect instantaneous responses to our posts or questions. Give others a reasonable amount of time to respond within the participation guidelines established by the course instructor. Once you have posted or replied in a discussion thread, regularly check the thread for new comments, and respond accordingly.

Be professional: Often in the online environment, facial expressions and body language are absent and what you intended to be constructive may be interpreted otherwise. In addition to spelling and grammar considerations, you will want to read your comments before you post to ensure that your intent is accurately conveyed. Often a bit of politeness goes a long way, so if someone helps out, thank that person online just as you would face-to-face. Refrain from using all caps as that is perceived as shouting in the online setting. If you receive a private message, reply in private. There may be a reason the other participant chose to comment in private. You should not forward to another or post publicly.

Be respectful: This institution and its instructors embrace learners from diverse backgrounds and seeks to develop and support an inclusive learning community. Please be sensitive to the diversity of all members in our learning community and ensure your comments are inclusive to all members. Learning is about sharing ideas and concepts. We do not all have to agree with an opinion or comment, but we should be open to and respectful of others' ideas and comments. MSMU supports open discussion, but does not tolerate sexist, bigoted, racist, or demeaning content. Your instructor can and will censor or remove a post if he/she deems it violates institutional guidelines or course expectations. You will be contacted in the event of any such censorship to identify how the content violated guidelines and to discuss supportive roles in our learning community.

Be appropriate: When participating in synchronous conferences or posting video to the LMS remain professional and appropriate in your setting and in your attire at all times.

Stay positive: Keeping a positive attitude can go a long way to building a supportive learning community and toward reducing personal stress. If you are having any difficulties or concerns with the course (e.g., using Canvas, understanding an assignment or activity, comfort with a discussion) please contact your instructor or a peer for support. Often early communication and requests for assistance can alleviate larger issues later.

Privacy Policy

To ensure your privacy and security with communications, assignment submissions, and assessment feedback, only the Canvas Learning Management System (course communications, grading) and MSMU email (other written communication) will be used.

Wed, Aug 26

- 11:00am
  PHYS 101 A & BL: College Physics I Fall 2026

Fri, Aug 28

- 11:00am
  PHYS 101 A & BL: College Physics I Fall 2026

Mon, Aug 31

- 11:00am
  PHYS 101 A & BL: College Physics I Fall 2026

Wed, Sep 2

- 11:00am
  PHYS 101 A & BL: College Physics I Fall 2026

Fri, Sep 4

- 11:00am
  PHYS 101 A & BL: College Physics I Fall 2026

Mon, Sep 7

- 11:00am
  PHYS 101 A & BL: College Physics I Fall 2026

Wed, Sep 9

- 11:00am
  PHYS 101 A & BL: College Physics I Fall 2026

Fri, Sep 11

- 11:00am
  PHYS 101 A & BL: College Physics I Fall 2026

Mon, Sep 14

- 11:00am

PHYS 101 A & BL: College Physics I Fall 2026

Wed, Sep 16

- 11:00am
  PHYS 101 A & BL: College Physics I Fall 2026

Fri, Sep 18

- 11:00am
  PHYS 101 A & BL: College Physics I Fall 2026

Mon, Sep 21

- 11:00am
  PHYS 101 A & BL: College Physics I Fall 2026

Wed, Sep 23

- 11:00am
  PHYS 101 A & BL: College Physics I Fall 2026

Fri, Sep 25

- 11:00am
  PHYS 101 A & BL: College Physics I Fall 2026

Mon, Sep 28

- 11:00am
  PHYS 101 A & BL: College Physics I Fall 2026

Wed, Sep 30

- 11:00am
  PHYS 101 A & BL: College Physics I Fall 2026

Fri, Oct 2

- 11:00am
  PHYS 101 A & BL: College Physics I Fall 2026

Mon, Oct 5

-

11:00am
PHYS 101 A & BL: College Physics I Fall 2026

Wed, Oct 7

- 11:00am
  PHYS 101 A & BL: College Physics I Fall 2026

Fri, Oct 9

- 11:00am
  PHYS 101 A & BL: College Physics I Fall 2026

Mon, Oct 12

- 11:00am
  PHYS 101 A & BL: College Physics I Fall 2026

Wed, Oct 14

- 11:00am
  PHYS 101 A & BL: College Physics I Fall 2026

Fri, Oct 16

- 11:00am
  PHYS 101 A & BL: College Physics I Fall 2026

Mon, Oct 19

- 11:00am
  PHYS 101 A & BL: College Physics I Fall 2026

Wed, Oct 21

- 11:00am
  PHYS 101 A & BL: College Physics I Fall 2026

Fri, Oct 23

- 11:00am
  PHYS 101 A & BL: College Physics I Fall 2026

Mon, Oct 26

- 11:00am
  PHYS 101 A & BL: College Physics I Fall 2026

Wed, Oct 28

- 11:00am
  PHYS 101 A & BL: College Physics I Fall 2026

Fri, Oct 30

- 11:00am
  PHYS 101 A & BL: College Physics I Fall 2026

Mon, Nov 2

- 11:00am
  PHYS 101 A & BL: College Physics I Fall 2026

Wed, Nov 4

- 11:00am
  PHYS 101 A & BL: College Physics I Fall 2026

Fri, Nov 6

- 11:00am
  PHYS 101 A & BL: College Physics I Fall 2026

Mon, Nov 9

- 11:00am
  PHYS 101 A & BL: College Physics I Fall 2026
- Due 11:59pm
  Formal Lab Report

Wed, Nov 11

- 11:00am
  PHYS 101 A & BL: College Physics I Fall 2026

Fri, Nov 13

-

11:00am
PHYS 101 A & BL: College Physics I Fall 2026

Mon, Nov 16

- 11:00am
  PHYS 101 A & BL: College Physics I Fall 2026

Wed, Nov 18

- 11:00am
  PHYS 101 A & BL: College Physics I Fall 2026

Fri, Nov 20

- 11:00am
  PHYS 101 A & BL: College Physics I Fall 2026

Mon, Nov 23

- 11:00am
  PHYS 101 A & BL: College Physics I Fall 2026

Wed, Nov 25

- 11:00am
  PHYS 101 A & BL: College Physics I Fall 2026

Fri, Nov 27

- 11:00am
  PHYS 101 A & BL: College Physics I Fall 2026

Mon, Nov 30

- 11:00am
  PHYS 101 A & BL: College Physics I Fall 2026

Wed, Dec 2

- 11:00am
  PHYS 101 A & BL: College Physics I Fall 2026

Fri, Dec 4

- 11:00am
  PHYS 101 A & BL: College Physics I Fall 2026

Mon, Dec 7

- 11:00am
  PHYS 101 A & BL: College Physics I Fall 2026

Wed, Dec 9

- 11:00am
  PHYS 101 A & BL: College Physics I Fall 2026

Fri, Dec 11

- 11:00am
  PHYS 101 A & BL: College Physics I Fall 2026

CHAPTER 8 HANDOUTS

PHYSICS 101
CHAPTER 8 EQUATION SHEET

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

$$p_x = mv_x; \quad p_y = mv_y$$

$$p_x = p_{A,x} + p_{B,x} + \cdots \qquad p_y = p_{A,y} + p_{B,y} + \cdots$$

$$\vec{p}_i = \vec{p}_f; \quad m\vec{v}_i = m\vec{v}_f$$

$$m_A(v_{A,i,x}) + m_B(v_{B,i,x}) = m_A(v_{A,f,x}) + m_B(v_{B,f,x})$$

$$m_A(v_{A,i,y}) + m_B(v_{B,i,y}) = m_A(v_{A,f,y}) + m_B(v_{B,f,y})$$

$$m_A v_{A,i,x} + m_B v_{B,i,x} = (m_A + m_B)v_{f,x}$$

$$m_A v_{A,i,y} + m_B v_{B,i,y} = (m_A + m_B)v_{f,y}$$

$$v_{A,f} = \left(\frac{m_A - m_B}{m_A + m_B}\right) v_{A,i} \qquad v_{B,f} = \left(\frac{2m_A}{m_A + m_B}\right) v_{A,i}$$

HANDOUT 8 – 1

LEARNING OUTCOMES

- Relate the momentum of a particle to its velocity and determine the momentum of a system of particles.

- Apply the law of conservation of momentum to isolated systems, including collisions and explosions in one and two dimensions.

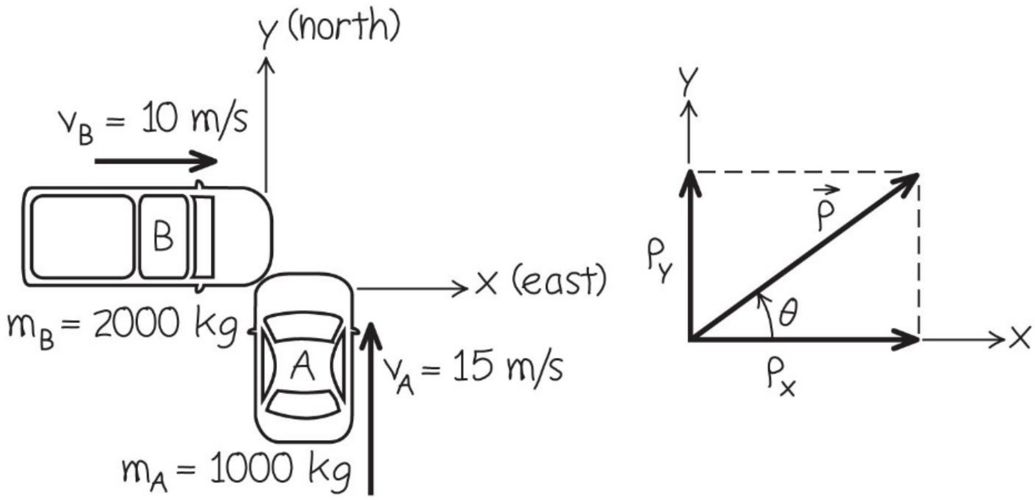
- Use energy conservation to determine whether a collision is elastic or inelastic.

HANDOUT 8 – 2

EXAMPLE – PRELIMINARY ANALYSIS OF A COLLISION

Suppose a small compact car $(\boldsymbol{A})$ with a mass of $\mathbf{1000}\ \boldsymbol{kg}$ is traveling north at speed of $\mathbf{15}\ \boldsymbol{m/s}$. At an intersection, it collides with truck $(\boldsymbol{B})$ with a mass of $\mathbf{2000}\ \boldsymbol{kg}$ that is traveling east at $\mathbf{10}\ \boldsymbol{m/s}$.

Treating each vehicle as a particle, find the total momentum (magnitude and direction) just before the collision.



Treating each vehicle as a particle, find the total momentum (magnitude and direction) just before the collision.

Calculate components of momentum of each vehicle.

$$\boldsymbol{p_{Ax} = m_A v_{Ax} = (1000)(0) = 0}$$

$$\boldsymbol{p_{Ay} = m_A v_{Ay} = (1000)(15)}$$

$$\boldsymbol{p_{Ay} = 15000\ kg\ m/s}$$

$$\boldsymbol{p_{By} = m_B v_{By} = (2000)(0) = 0}$$

$$\boldsymbol{p_{Bx} = m_B v_{Bx} = (2000)(10)}$$

$$\boldsymbol{p_{Bx} = 20000\ kg\ m/s}$$

HANDOUT 8 – 2 (CONT'D)

EXAMPLE – PRELIMINARY ANALYSIS OF A COLLISION

Component of total momentum

$$\boldsymbol{P_x = p_{Ax} + p_{Bx} = 0 + 20000 = 2.0\ x\ 10^4\ kg\ m/s}$$

$$\boldsymbol{P_y = p_{Ay} + p_{By} = 15000 + 0 = 1.5\ x\ 10^4\ kg\ m/s}$$

$$\boldsymbol{P = \sqrt{(P_x)^2 + \left(P_y\right)^2} = \sqrt{(2.0\ x\ 10^4)^2 + (1.5\ x\ 10^4)^2}}$$

$$\boldsymbol{P = 2.50\ x\ 10^4\ kg \cdot m/s}$$

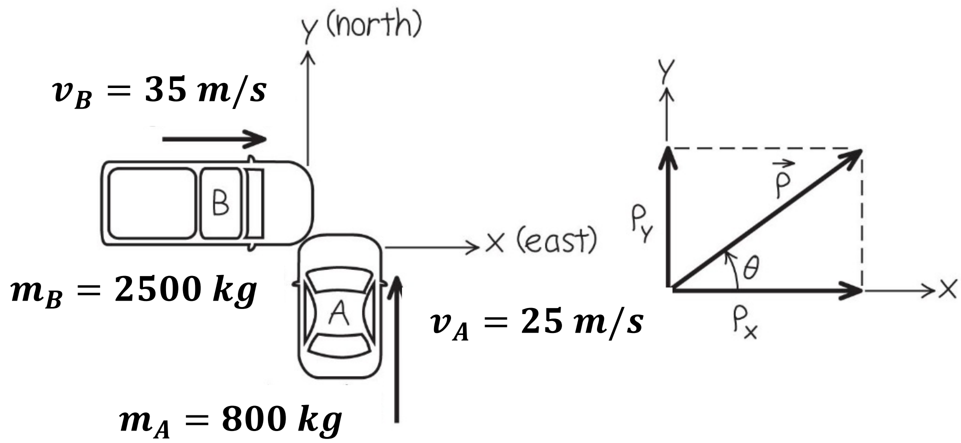
$$\boldsymbol{\theta = tan^{-1}\left(\frac{P_y}{P_x}\right) = tan^{-1}\left(\frac{1.5\ x\ 10^4}{2.0\ x\ 10^4}\right) = 36.9^0\ north\ of\ east}$$

The total momentum of the system (Car A and Truck B) before the collision is $\boldsymbol{2.5\ x\ 10^4\ kg \cdot m/s}$ at an angle of $\boldsymbol{36.9^0}$ north of east.

HANDOUT 8 – 3

CLASS PROBLEM – PRELIMINARY ANALYSIS OF A COLLISION

Suppose a small compact car (A) with a mass of $800\ kg$ is traveling north at speed of $25\ m/s$. At an intersection, it collides with truck (B) with a mass of $2500\ kg$ that is traveling east at $35\ m/s$.



Treating each vehicle as a particle, find the total momentum (magnitude and direction) just before the collision. (Total initial momentum)

HANDOUT 8 – 4

Problem Solving Strategy – Conservation of Momentum

Momentum is a vector quantity; you *must* use vector addition to compute the total momentum of a system. Using components is usually the simplest method.

SET UP

1. Define the system you are analyzing. Choose a coordinate system, specifying the positive direction for each axis. Often, it is easiest to choose the $\boldsymbol{x}$ axis as having the direction of one of the initial velocities.

2. Treat each object as a particle. Sketch "before" and "after" diagrams, including your coordinate system. Add vectors on each diagram to represent all known velocities. Label the vectors with magnitudes, angles, components, or whatever information is given, and give each unknown magnitude, angle, or component an algebraic symbol. It's often helpful to use multiple subscripts on velocity and momentum symbols to ensure complete identification. For example, the initial value $(\boldsymbol{i})$ of the $\boldsymbol{x}$ component of velocity of object A can be written as $\boldsymbol{v_{A,i,x}}$.

SOLVE

3. Compute the $\boldsymbol{x}$ and $\boldsymbol{y}$ components of momentum of each particle, both before and after the interaction, using the relationships $\boldsymbol{p_x} = \boldsymbol{mv_x}$ and $\boldsymbol{p_y} = \boldsymbol{mv_y}$. Some of the components will be expressed in terms of symbols representing unknown quantities.

   Even when all the velocities lie along a line (such as the $\boldsymbol{x}$ axis), the components of velocity and momentum along this line can be positive or negative, so be careful with signs!

HANDOUT 8 – 4 (CONT'D)

Problem Solving Strategy – Conservation of Momentum

4. Write an expression that equates the total *initial* x component of momentum to the total *final* x component of momentum. Write another equation for the y components. These two equations express conservation of momentum in component form. In some problems, only one component of momentum is conserved. If the sum of the x components of the external forces is zero, then the x component of total momentum is conserved, and so on.

5. Solve the equations you wrote in step 4 to determine whatever quantities are asked for in the problem. In some problems, you'll have to convert from the x and y components of a velocity to its magnitude and direction, and in others, you'll need to make the opposite conversion from magnitude and direction to x and y components.

   Remember that the x and y components of velocity or momentum are *never* added together in the same equation.

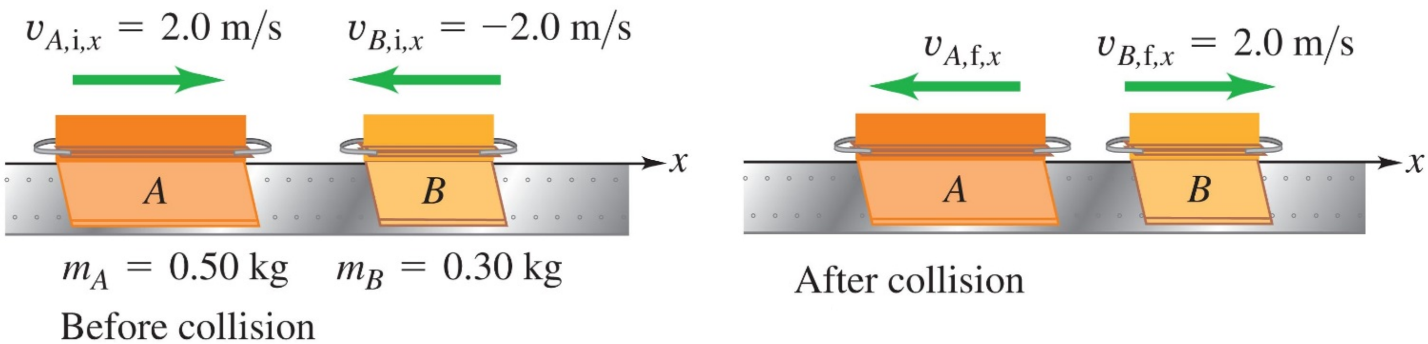
REFLECT

6. In all problem solving, especially when the results are expressed in symbols rather than numbers, try to think of particular cases in which you can predict the results of your analysis. What happens when two masses are equal? When one mass is zero? Is the result what you would expect?

HANDOUT 8 – 5

EXAMPLE – HEAD-ON COLLISION

Two gliders move toward each other along a linear frictionless track. Glider $\boldsymbol{A}$ has a mass $\mathbf{0.50}\ \boldsymbol{kg}$ and glider $\boldsymbol{B}$ has a mass of $\mathbf{0.30}\ \boldsymbol{kg}$. Both gliders move with an initial speed of $\mathbf{2.0}\ \boldsymbol{m/s}$. After they collide, glider $\boldsymbol{B}$ moves away with a final velocity whose $\boldsymbol{x}$ component is $\mathbf{+2.0}\ \boldsymbol{m/s}$. What is the final velocity of glider $\boldsymbol{A}$?



All vector quantities along $\boldsymbol{x}$ axis; no external forces; total momentum same before and after collision

$$\boldsymbol{m_A}(\boldsymbol{v_{A,i,x}}) + \boldsymbol{m_B}(\boldsymbol{v_{B,i,x}}) = \boldsymbol{m_A}(\boldsymbol{v_{A,f,x}}) + \boldsymbol{m_B}(\boldsymbol{v_{B,f,x}})$$

$$(\mathbf{0.50})(\mathbf{2.0}) + (\mathbf{0.30})(\mathbf{-2.0}) = (\mathbf{0.50})(\boldsymbol{v_{A,f,x}}) + (\mathbf{0.30})(\mathbf{2.0})$$

$$\mathbf{1.0} + (\mathbf{-0.60}) = (\mathbf{0.50})(\boldsymbol{v_{A,f,x}}) + (\mathbf{0.60})$$

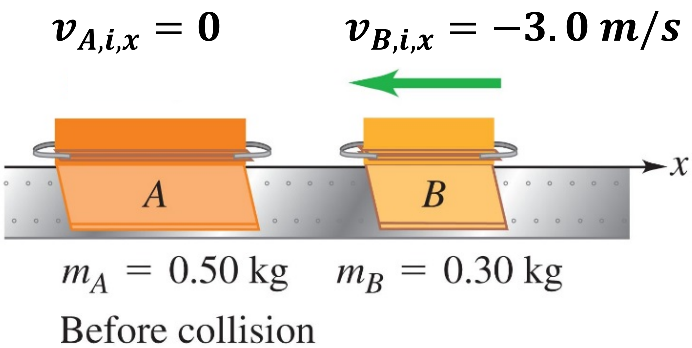
$$\boldsymbol{v_{A,f,x}} = \frac{\mathbf{0.40 - 0.60}}{\mathbf{0.50}} = \mathbf{-0.400}\ \boldsymbol{m/s}$$

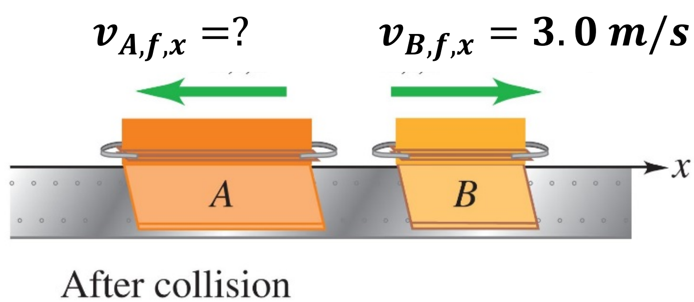
Two initial velocities are equal but two final velocities are not. Total momentum is the same before and after collision but is distributed differently.

HANDOUT 8 – 6

CLASS PROBLEM – HEAD-ON COLLISION

In the previous example, suppose glider $\boldsymbol{B}$ is initially moving to the left at $\mathbf{3.0}\ \boldsymbol{m/s}$ when it runs into glider $\boldsymbol{A}$, which is initially at rest. At what speed does glider $\boldsymbol{A}$ move away from the collision if glider $\boldsymbol{B}$ bounces back with a speed of $\mathbf{3.0}\ \boldsymbol{m/s}$?





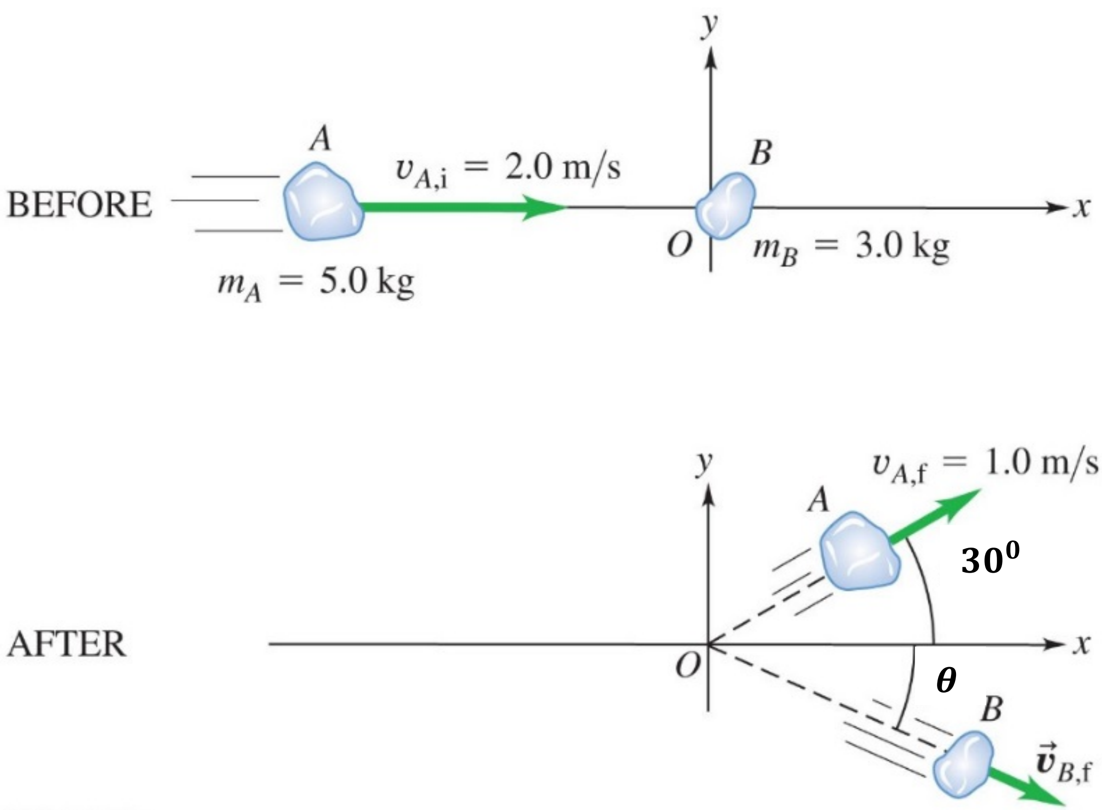
HANDOUT 8 – 7

EXAMPLE – COLLISION IN A HORIZONTAL PLANE

This is a two-dimensional problem so you will have to keep track of both the $\boldsymbol{x}$ and $\boldsymbol{y}$ components of momentum for each object in the system.

Two chucks of ice are sliding toward each other on the surface of a frictionless frozen pond. Chunk $\boldsymbol{A}$ with mass $\boldsymbol{m_A = 5.0\ kg}$, moves with an initial velocity of $\boldsymbol{2.0\ m/s}$ parallel to $\boldsymbol{x}$ axis. It collides with chunk $\boldsymbol{B}$, which has a mass $\boldsymbol{m_B = 3.0\ kg}$ and is initially at rest. After the collision, the velocity of chunk $\boldsymbol{A}$ is found to be $\boldsymbol{v_{A,f} = 1.0\ m/s}$ in a direction with an angle $\boldsymbol{30^0}$ with the initial direction.

What is final velocity of Chunk $\boldsymbol{B}$ (magnitude and direction)?



HANDOUT 8 – 7 (CONT'D)

EXAMPLE – COLLISION IN A HORIZONTAL PLANE

Consider both $\boldsymbol{x}$ and $\boldsymbol{y}$ directions.

$$v_{A,i,x} = 2.0\ m/s; \quad v_{A,i,y} = 0$$

$$v_{A,f,x} = v_{A,f}\ cos\ 30^0 = 1.0\ cos\ 30^0 = 0.866\ m/s$$

$$v_{A,f,y} = v_{A,f}\ \ sin\ 30^0 = 1.0\ \ sin\ 30^0 = 0.50\ m/s$$

$$v_{B,i,x} = 0; \quad v_{B,i,y} = 0$$

$$m_A(v_{A,i,x}) + m_B(v_{B,i,x}) = m_A(v_{A,f,x}) + m_B(v_{B,f,x})$$

$$(5.0)(2.0) + (3.0)(0) = (5.0)(0.866) + (3.0)(v_{B,f,x})$$

$$10.0 = 4.33 + (3.0)(v_{B,f,x}); \quad v_{B,f,x} = \frac{10.0 - 4.33}{3.0}$$

$$v_{B,f,x} = 1.89\ m/s$$

$$m_A(v_{A,i,y}) + m_B(v_{B,i,y}) = m_A(v_{A,f,y}) + m_B(v_{B,f,y})$$

$$(5.0)(0) + (3.0)(0) = (5.0)(0.50) + (3.0)(v_{B,f,y})$$

$$0 = 2.5 + (3.0)(v_{B,f,y}); \ \ v_{B,f,y} = \frac{-2.5}{3.0} = -0.83\ m/s$$

$$v_{B,f} = \sqrt{(1.89)^2 + (-0.83)^2} = 2.1\ m/s$$

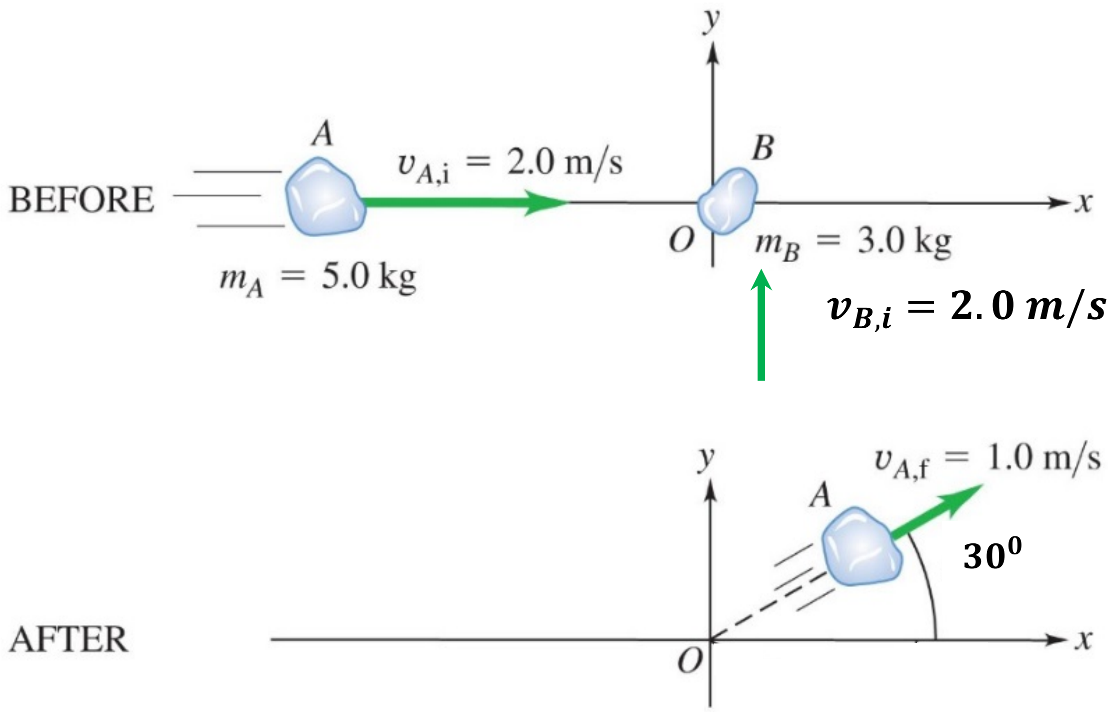
$$\theta = tan^{-1}\left(\frac{v_{B,f,y}}{v_{B,f,x}}\right) = tan^{-1}\left(\frac{-0.83}{1.89}\right) = -23.7^0$$

Direction is $\mathbf{23.7^0}$ below the positive $\boldsymbol{x}$ axis.

HANDOUT 8 – 8

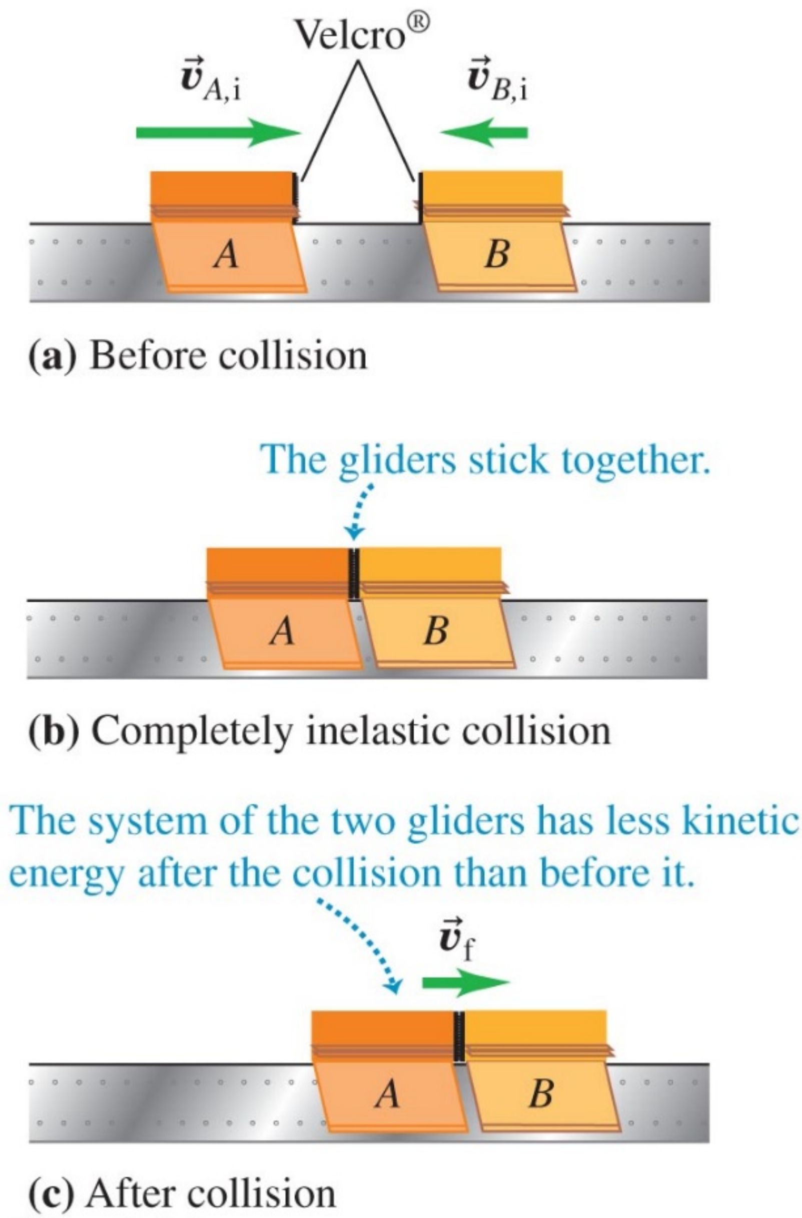
CLASS PROBLEM – COLLISION IN A HORIZONTAL PLANE

In the previous example, if chunk $\boldsymbol{B}$ has an initial velocity of magnitude $\mathbf{2.0\ m/s}$ in the $+\boldsymbol{y}$ direction instead of being initially at rest, find its final velocity (magnitude and direction).



HANDOUT 8 – 9

COMPLETELY INELASTIC COLLISIONS

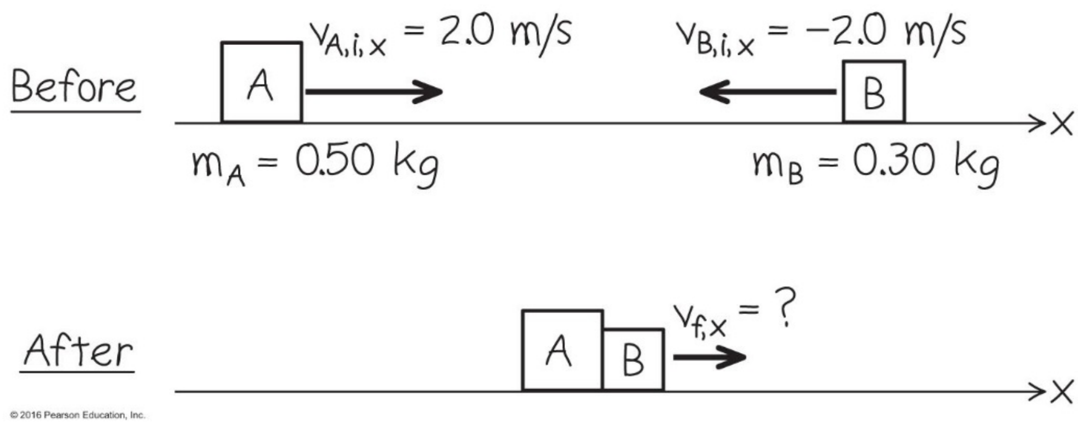


HANDOUT 8 – 10

EXAMPLE – INELASTIC COLLISION ON AIR TRACK

Glider $\boldsymbol{A}$ and glider $\boldsymbol{B}$ are both equipped with Velcro®. Glider $\boldsymbol{A}$ has mass of $\mathbf{0.50}\ \boldsymbol{kg}$ and glider $\boldsymbol{B}$ has mass of $\mathbf{0.30}\ \boldsymbol{kg}$; both move toward each other with initial speeds of $\mathbf{2.0}\ \boldsymbol{m/s}$.

Find the final velocity of the joined gliders.



No external forces: total momentum conserved; Movement only along $\boldsymbol{x}$ axis.

Find the final velocity of the joined gliders.

$$\boldsymbol{m_A v_{A,i,x} + m_B v_{B,i,x} = (m_A + m_B) V_{f,x}}$$

$$(\mathbf{0.50})(\mathbf{2.0}) + (\mathbf{0.30})(-\mathbf{2.0}) = (\mathbf{0.80})\boldsymbol{V_{f,x}}$$

$$\mathbf{1.0} - \mathbf{0.60} = (\mathbf{0.80})\boldsymbol{V_{f,x}};\quad \boldsymbol{V_{f,x}} = \frac{\mathbf{0.40}}{\mathbf{0.80}} = \mathbf{0.500}\ \boldsymbol{m/s}$$

Final velocity is positive; Gliders move together to the right.

Compare the initial and final kinetic energies.

$$\boldsymbol{K_{A,i}} = \frac{\mathbf{1}}{\mathbf{2}}\boldsymbol{m_A}\left(\boldsymbol{v_{A,i}}\right)^2 = \frac{\mathbf{1}}{\mathbf{2}}(\mathbf{0.50})(\mathbf{2.0})^2$$

HANDOUT 8 – 10 (CONT'D)

EXAMPLE – INELASTIC COLLISION ON AIR TRACK

$$\boldsymbol{K_{A,i} = 1.00\,J}$$

$$\boldsymbol{K_{B,i} = \frac{1}{2} m_B \left(v_{B,i}\right)^2 = \frac{1}{2}(0.30)(-2.0)^2}$$

$$\boldsymbol{K_{B,i} = 0.600\,J}$$

$$\boldsymbol{K_i = K_{A,i} + K_{B,i} = 1.0 + 0.60 = 1.60\,J}$$

Final kinetic energy

$$\boldsymbol{K_{A+B,f} = \frac{1}{2}(m_A + m_b)\left(V_f\right)^2 = \frac{1}{2}(0.50 + 0.30)(0.5)^2}$$

$$\boldsymbol{K_f = K_{A+B,f} = 0.100\,J}$$

Final kinetic energy is only one-sixteenth of original; rest of initial kinetic energy converted to other forms of energy.

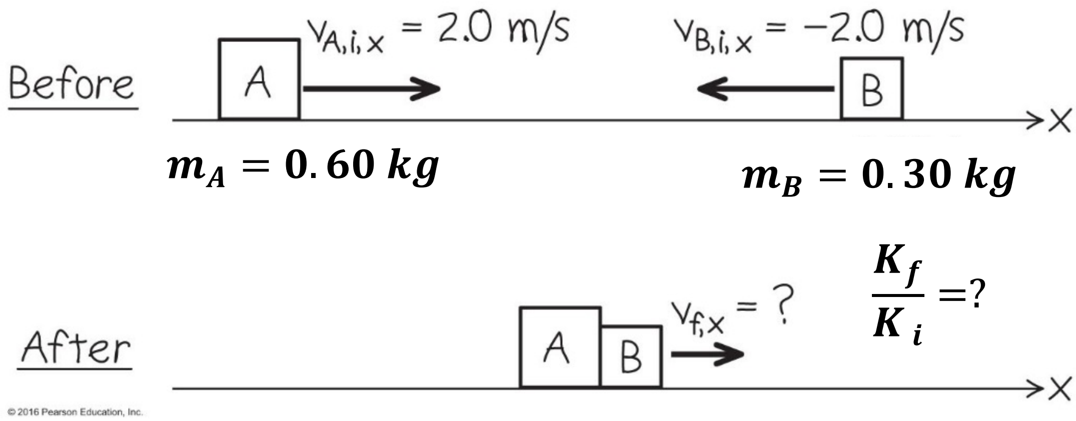
Total energy is conserved although kinetic energy is not**. In an isolated system, momentum is always conserved.**

HANDOUT 8 – 11

CLASS PROBLEM – INELASTIC COLLISION ON AIR TRACK

Glider $\boldsymbol{A}$ and glider $\boldsymbol{B}$ are both equipped with Velcro®. If glider $\boldsymbol{A}$ has twice the mass of glider $\boldsymbol{B}$, determine the ratio of final to initial kinetic energy.

Glider $\boldsymbol{A}$ has mass of $\mathbf{0.60\ kg}$ and glider $\boldsymbol{B}$ has mass of $\mathbf{0.30\ kg}$; both move toward each other with initial speeds of $\mathbf{2.0\ m/s}$.



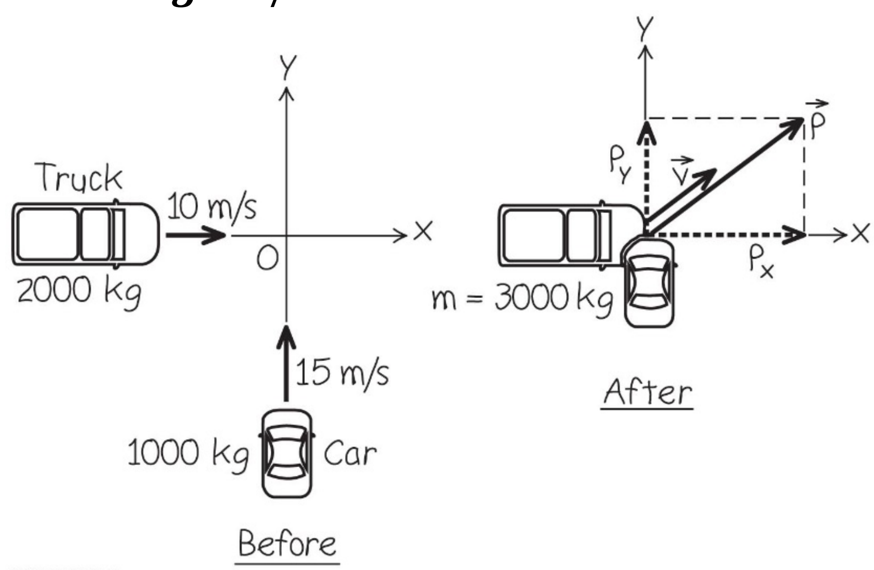
HANDOUT 8 – 12

EXAMPLE – TOTALLY INELASTIC COLLISION

Let's revisit the previous example of impending collision of a small car with larger truck. It is now $\mathbf{2}$ seconds later, and the collision has occurred. The two vehicles became entangled and moved away from the point of impact as one mass. Find the velocity of the wreckage just after impact.

The total momentum of the system just before the collision was previously calculated as:

$$\boldsymbol{P_i = 2.5\ x\ 10^4\ kg \cdot m/s}$$



The total momentum of the system just before the collision was previously calculated as:

$$\boldsymbol{P_i = 2.50\ x\ 10^4\ kg \cdot m/s}$$

By conservation of momentum, total momentum after collision is the same as just before collision.

$$\boldsymbol{P_i = P_f = 2.50\ x\ 10^4\ kg \cdot m/s}$$

HANDOUT 8 – 12 (CONT'D)

EXAMPLE – TOTALLY INELASTIC COLLISION

If the two vehicles stuck together after the collision, then.

$$\boldsymbol{P_f = (m_A + m_B)V_f}$$

$$\boldsymbol{V_f = velocity\ of\ both}$$

Find velocity just after impact.

$$\boldsymbol{(m_A + m_B) = 3000\ kg;\quad V_f = \frac{P}{(m_A + m_B)} = \frac{2.50\ x\ 10^4}{3000} = 8.33\ m/s}$$

$$\boldsymbol{K_i = \frac{1}{2}m_c v_c^2 + \frac{1}{2}m_t v_t^2}$$

$$\boldsymbol{K_i = \frac{1}{2}(1000)(15)^2 + \frac{1}{2}(2000)(10)^2 = 2.13\ x\ 10^5\ J}$$

$$\boldsymbol{K_f = \frac{1}{2}(m_A + m_B)V_f^2}$$

$$\boldsymbol{K_f = \frac{1}{2}(3000)(8.33)^2 = 1.04\ x\ 10^5\ J}$$

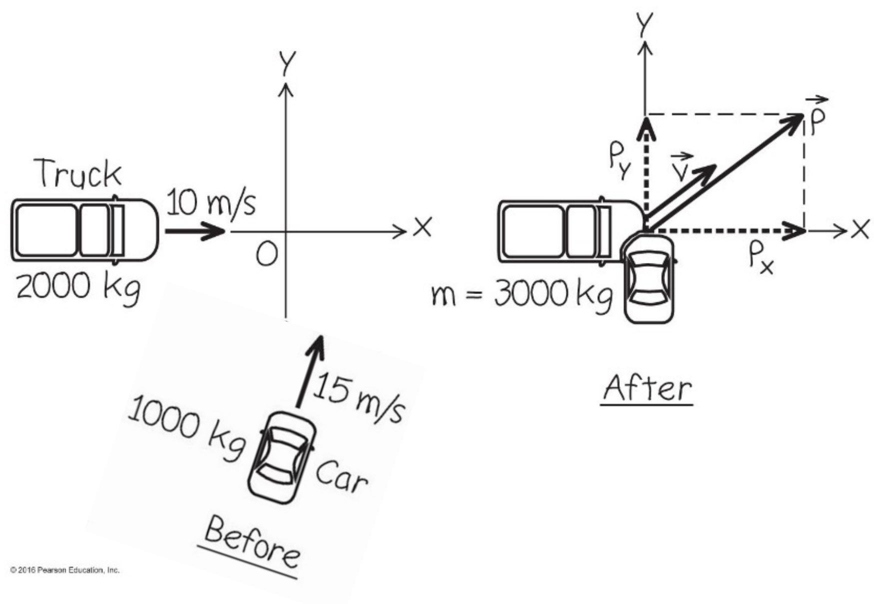
The initial kinetic energy was $\boldsymbol{2.13\ x\ 10^5\ J}$ and the final kinetic energy is $\boldsymbol{1.04\ x\ 10^5\ J}$. More than half of the initial kinetic energy is converted to some other form of energy.

HANDOUT 8 – 13

CLASS PROBLEM – TOTALLY INELASTIC COLLISION

Suppose that just before the collision, the driver of the car swerves, so that the car $(\boldsymbol{A})$ with a mass of $\mathbf{1000}\ \boldsymbol{kg}$ is still traveling at a speed of $\mathbf{15}\ \boldsymbol{m/s}$, but in the direction of $\mathbf{15^0}$ east of north when the car collides with the truck $(\boldsymbol{B})$ with a mass of $\mathbf{2000}\ \boldsymbol{kg}$ that is traveling east at $\mathbf{10}\ \boldsymbol{m/s}$.

If the two vehicles stick together after the collision, find the velocity (magnitude and direction) of the wreckage.

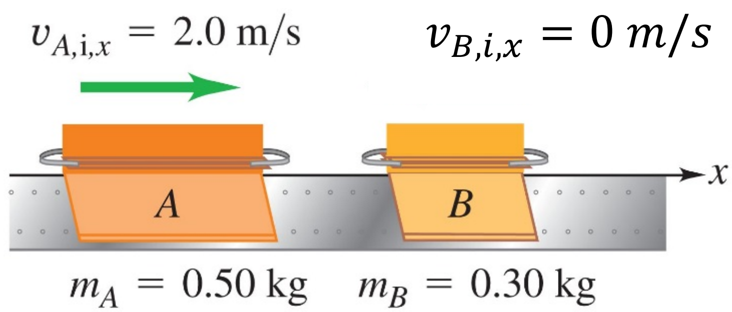


HANDOUT 8 – 14

EXAMPLE – ELASTIC COLLISION (ONE OBJECT STATIONARY)

A $\mathbf{0.50\ kg}$ object moving to the right on frictionless, horizontal air track with speed of $\mathbf{2.0\ m/s}$ makes head on collision with stationary $\mathbf{0.30\ kg}$ object.

Find magnitude and direction of the final velocities of each object and find the total initial kinetic energy and the total final kinetic energy and compare.



$$v_{A,f} = \frac{m_A - m_B}{m_A + m_B}\, v_{A,i} = \left(\frac{0.50 - 0.30}{0.50 + 0.30}\right) 2.0 = 0.500\ m/s$$

$$v_{B,f} = \frac{2m_A}{m_A + m_B}\, v_{A,i} = \left(\frac{2(0.50)}{0.50 + 0.30}\right) 2.0 = 2.50\ m/s$$

Find total initial kinetic energy and the total final kinetic energy and compare.

Total initial kinetic energy

$$K_i = \frac{1}{2} m_A \left(v_{A,i,x}\right)^2 + \frac{1}{2} m_B \left(v_{B,i,x}\right)^2 = \frac{1}{2} 0.50(2.0)^2 + \frac{1}{2} 0.30(0)^2 = 1.00\ J$$

Total final kinetic energy

$$K_f = \frac{1}{2} m_A \left(v_{A,f,x}\right)^2 + \frac{1}{2} m_B \left(v_{Bf,x}\right)^2 = \frac{1}{2} 0.50(0.50)^2 + \frac{1}{2} 0.30(2.5)^2 = 1.00\ J$$

Conservation of kinetic energy as expected in an elastic collision.

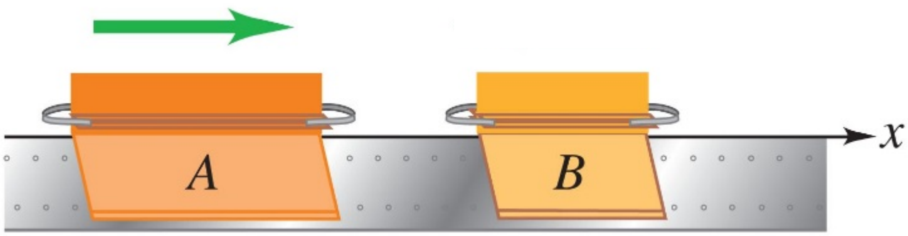
HANDOUT 8 – 15

CLASS PROBLEM – ELASTIC COLLISION (ONE OBJECT STATIONARY)

A $\mathbf{4.00}\ \boldsymbol{kg}$ cart is moving to the right on a frictionless, horizontal track with a speed of $\mathbf{7.0}\ \boldsymbol{m/s}$ when it makes a head-on elastic collision with a stationary $\mathbf{2.00}\ \boldsymbol{kg}$ cart.

Find the velocities of the carts after the collision and find the total initial kinetic energy and the total final kinetic energy and compare.

$\boldsymbol{v_{A.i.x} = 7.0\ m/s}$ $\boldsymbol{v_{B,i,x} = 0\ m/s}$



$\boldsymbol{m_A = 4.00\ kg}$ $\boldsymbol{m_B = 2.00\ kg}$

CHAPTER 8 PROBLEMS

1. On a frictionless air track, a $\mathbf{0.150\ kg}$ glider moving at $\mathbf{1.20\ m/s}$ to the right collides with and sticks to a stationary $\mathbf{0.250\ kg}$ glider.

   a. What is the net momentum of this two glider system before the collision?

   b. What must be the net momentum of this system after the collision?

   c. Use the answers in a. and b. to find the final speed of the gliders after the collision.

2. A $\mathbf{4.25\ g}$ bullet travelling horizontally with a velocity of magnitude $\mathbf{375\ m/s}$ is fired into a wooden block with mass $\mathbf{1.12\ kg}$, initially at rest on a level frictionless surface. The bullet passes through the block and emerges with its speed reduced to $\mathbf{122\ m/s}$. How fast is the block moving just after the bullet emerges from it?

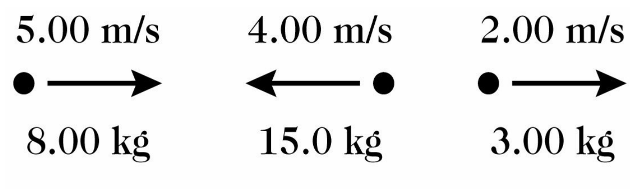
3. A ball with mass of $\mathbf{0.600\ kg}$ is initially at rest. It is struck by as second ball having a mass of $\mathbf{0.400\ kg}$, initially moving with a velocity of $\mathbf{0.250\ m/s}$ toward the right along the $\boldsymbol{x}$ axis. After the collision, the $\mathbf{0.400\ kg}$ ball has a velocity of $\mathbf{0.200\ m/s}$ at an angle of $\mathbf{36.9^0}$ above the $\boldsymbol{x}$ axis. Both balls move on a frictionless, horizontal surface.

   a. What are the magnitude and direction of the velocity of the $\mathbf{0.600\ kg}$ ball after the collision?

   b. What is the change in the total kinetic energy of the two balls as a result of the collision?

CHAPTER 8 PRACTICE PROBLEM

1. Three objects are moving along a straight line as shown in the figure below. Taking the positive direction to be to the right, what is the total momentum of this system?

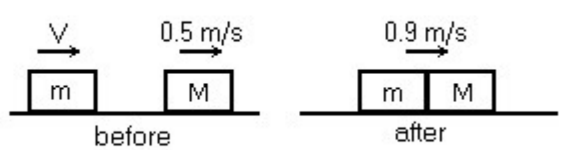


2. A $\boldsymbol{1200\ kg}$ car moving at $\boldsymbol{15.6\ m/s}$ collides with a stationary car of mass $\boldsymbol{1500\ kg}$. If the two vehicles lock together, what is their combined velocity immediately after the collision?

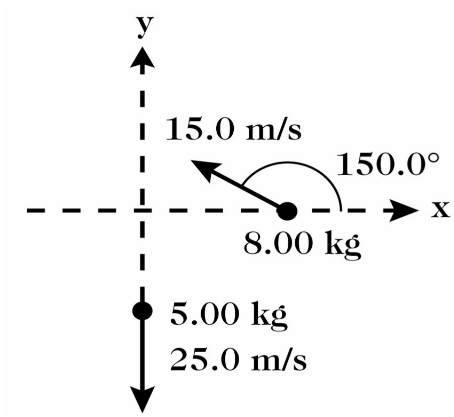
3. A $\boldsymbol{1200\ kg}$ cannon fires a $\boldsymbol{100\ kg}$ cannonball at $\boldsymbol{35\ m/s}$. What is the recoil velocity of the cannon? Assume that frictional forces are negligible and the cannon is fired horizontally.

4. A car heading north collides at an intersection with a truck heading east. If they lock together and travel at $\boldsymbol{28\ m/s}$ at $\boldsymbol{15}°$ north of east just after the collision, how fast was the car initially traveling? Assume that the two vehicles have the same mass.

5. A block of mass $\boldsymbol{m = 9\ kg}$ has a speed $\boldsymbol{V}$ and is behind a block of mass $\boldsymbol{M\ =\ 27\ kg}$ that has a speed of $\boldsymbol{0.5\ m/s}$. The surface is frictionless. The blocks collide and couple. After the collision, the blocks have a common speed of $\boldsymbol{0.9\ m/s}$. Using the figure below, calculate the loss of kinetic energy of the blocks due to the collision.



6. Find the magnitude and direction of the net momentum of the system shown in the figure below. Express the direction by giving the angle the net momentum makes with the $+\boldsymbol{x}$-axis.



7. A $\mathbf{2646}\ \boldsymbol{lb}$ car is moving on the freeway at $\mathbf{68}\ \boldsymbol{mph}$.

a. Find the magnitude of its momentum and its kinetic energy in SI units.

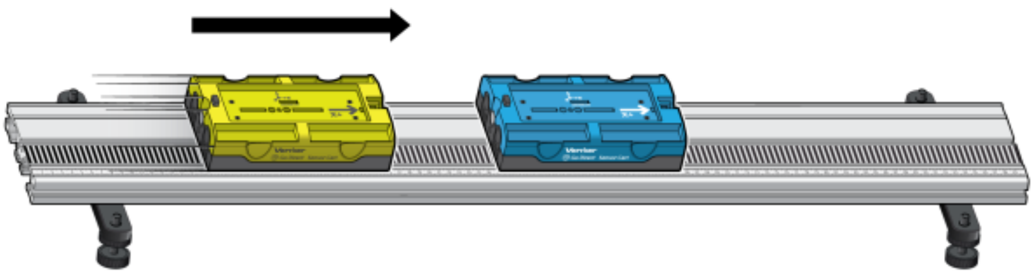
b. At what speed, in $\boldsymbol{m/s}$, will the car's momentum be half of what it is in part (a)? $[\mathbf{1}\ \boldsymbol{kg} = \mathbf{2.205}\ \boldsymbol{lb}]$

LINEAR MOMENTUM

1.0 INTRODUCTION

The collision of two carts on a track can be described in terms of momentum conservation and, in some cases, energy conservation. If there is no net external force experienced by the system of two carts, then we expect the total momentum of the system to be conserved. This is true regardless of the force acting between the carts. In contrast, energy is only conserved when certain types of forces are exerted between the carts.

Collisions are classified as *elastic* (kinetic energy is conserved), *inelastic* (kinetic energy is lost) or *completely inelastic* (the objects stick together after collision). In this experiment, you can observe elastic and inelastic collisions and test for the conservation of momentum and energy.



2.0 OBJECTIVES

- Observe collisions between two carts, testing for the conservation of momentum.
- Measure energy changes during different types of collisions.
- Classify collisions as elastic, inelastic, or completely inelastic.

3.0 EQUIPMENT

- Sensor Carts (2) – One Green and One Yellow
- Vernier Dynamics Track
- Velcro (hook & pile) pads (4) – 2 for each cart
- Magnets (4) – 2 for each cart
- Torpedo Level

- Laptop computer or smart phone with Graphical Analysis software

4.0 SETUP

4.1 Insert the hook-and-pile (Velcro) pads so they will be facing each other when both **+x** arrows are pointing to the right and that they will attach when the carts meet each other.

4.2 Measure the masses of the carts and record the values to four decimal places in Table 1.

4.3 The yellow cart will be cart 1 and the green cart will be cart 2.

4.4 Set up the Dynamics Track so that it is horizontal. Use a torpedo level to check in multiple locations (both front to back and side to side) and adjust, as necessary. Test this by releasing a cart on the track from rest. The cart should not move.

4.5 Connect the carts to USB port of the computer or use the Bluetooth connection to the computer or smart phone as described in Attachment 1.

4.6 Practice creating a gentle collision: Position cart 2 (green) at rest in the middle of the track. Release cart 1 (yellow) so it rolls toward cart 2 (green) with the hook-and-pile pads toward one another. The carts should collide, stick together, and roll together.

4.7 Click or tap Collect to start data collection. Repeat the collision you practiced and use the position graphs to verify that the carts are recording throughout the entire range of motion.

5.0 PROCEDURE

5.1 Velcro (Hook-and-Pile) Bumpers

5.1.1 Place the two carts at rest in the middle of the track, with their hook-and-pile bumpers toward one another and in contact. Zero both sensors by clicking or tapping each Position meter and choosing zero. This procedure will establish the same coordinate system for both sensors.

5.1.2 Verify that the zeroing was successful by starting data collection and allowing the still-linked carts to roll slowly along the track. The graphs for each cart should be nearly the same. If not, repeat the zeroing process.

5.1.3 Position cart 2 (green) at rest in the middle of the track. Position cart 1 (yellow) about 40 – 60 cm behind cart 2 (green). Zero both sensors by clicking or tapping each Position meter and choosing zero. Click or tap Collect to begin taking data. Release cart 1 (yellow) so it rolls toward cart 2 (green) with the hook-and-pile pads toward one another. The carts should collide, stick together, and roll together.

Note: There are two graphs shown. The top graph is a position graph and the bottom graph is a velocity graph.

5.1.4 From the velocity graphs, you can determine a mean velocity before and after the collision for each cart. To measure the mean velocity during a time interval, select the data in the interval. Click or tap Graph Tools, , and choose View Statistics.

Note: The statistic box is color coded. You may need to use the slider on the right to access both sets of statistics.

5.1.5 Record the mean velocity to three decimal points for each cart, before and after collision, and enter the four values in Table 2. Then dismiss the Statistics box.

5.1.6 Repeat Steps 3–5 to collect a second run with the hook-and-pile bumpers. The previous data set is automatically stored.

5.2 Velcro (Hook-and-Pile) Bumper to Empty Bumper

5.2.1 Remove the hook-and-pile inserts from one cart. Measure the mass of this cart and record it to four decimal points in Table 1. The other cart's mass will stay the same.

5.2.2 Face the hook-and-pile bumper on one cart to the empty bumper on the other. Practice this collision, again starting with cart 2 (green) at rest. The carts will not stick, but they will not smoothly bounce apart either.

5.2.3 Position cart 2 (green) at rest in the middle of the track. Position cart 1 (yellow) about 40 – 60 cm behind cart 2 (green). Zero both sensors by clicking or tapping each Position meter and choosing zero. Click or tap Collect to start data collection and repeat the new collision.

Note: There are two graphs shown. The top graph is a position graph and the bottom graph is a velocity graph.

5.2.4 From the velocity graphs, you can determine a mean velocity before and after the collision for each cart. To measure the mean velocity during a time interval, select the data in the interval. Click or tap Graph Tools, , and choose View Statistics.

Note: The statistic box is color coded. You may need to use the slider on the right to access both sets of statistics.

5.2.5 Record the mean velocity to three decimal points for each cart, before and after collision, and enter the four values in Table 2. Then dismiss the Statistics box.

5.2.6 Repeat Steps 3–5 to collect a second run with the one hook-and-pile bumper and one empty bumper. The previous data set is automatically stored.

5.3 Magnetic Bumpers

5.3.1 Remove the Velcro bumper and insert magnets into both carts, set so the carts will repel. Measure the masses of the carts and record them to four decimal places in Table 1.

5.3.2 Place the carts on the track with the magnetic bumpers facing each other. Practice making this new gentle collision, again starting with cart 2 (green) at rest. The carts should smoothly repel each other without physically touching.

5.3.3 Position cart 2 (green) at rest in the middle of the track. Position cart 1 (yellow) about 40 – 60 cm behind cart 2 (green). Zero both sensors by clicking or tapping each Position meter and choosing zero. Click or tap Collect to start data collection and repeat the new collision.

Note: There are two graphs shown. The top graph is a position graph and the bottom graph is a velocity graph.

5.3.4 From the velocity graphs, you can determine a mean velocity before and after the collision for each cart. To measure the mean velocity during a time interval, select the data in the interval. Click or tap Graph Tools, , and choose View Statistics.

Note: The statistic box is color coded. You may need to use the slider on the right to access both sets of statistics.

Note: Extremely small values of velocity like e^{-4} should be recorded as zero.

5.3.5 Record the mean velocity to three decimal places for each cart, before and after collision, and enter the four values in Table 2. Then dismiss the Statistics box.

5.3.6 Repeat Steps 3–5 to collect a second run with the magnetic bumpers. The previous data set is automatically stored.

5.3.7 When finished with data collection, remove the Sensor Cart in accordance with the instructions in Attachment 1.

DATA TABLES

Table 1		
Section	Mass of cart 1 (yellow) (kg)	Mass of cart 2 (green) (kg)
5.1		
5.2		
5.3		

Table 2							
Bumper type		Run number	Velocity of cart 1 (yellow) before collision (m/s)	Velocity of cart 2 (green) before collision (m/s)	Velocity of cart 1 (yellow) after collision (m/s)	Velocity of cart 2 (green) after collision (m/s)
5.1	Hook-and-pile	1		0		
	Hook-and-pile	2		0		
5.2	Mixed	3		0		
	Mixed	4		0		
5.3	Magnetic	5		0		
	Magnetic	6		0		

Table 3							
Run number	Momentum of cart 1 (yellow) before collision (kg•m/s)	Momentum of cart 2 (green) before collision (kg•m/s)	Momentum of cart 1 (yellow) after collision (kg•m/s)	Momentum of cart 2 (green) after collision (kg•m/s)	Total momentum before collision (kg•m/s)	Total momentum after collision (kg•m/s)	Ratio of total momentum after/before
1		0					
2		0					
3		0					
4		0					
5		0					
6		0					

Table 4							
Run number	KE of cart 1 (yellow) before collision (J)	KE of cart 2 (green) before collision (J)	KE of cart 1 (yellow) after collision (J)	KE of cart 2 (green) after collision (J)	Total KE before collision (J)	Total KE after collision (J)	Ratio of total KE after/before
1		0					
2		0					
3		0					
4		0					
5		0					
6		0					

6.0 ANALYSIS

6.1 For each run, determine the momentum (*mv*) of each cart to four decimal places before the collision, after the collision, and the total momentum before and after the collision. Calculate the ratio to three decimal places of the total momentum after the collision to the total momentum before the collision. Enter the values in Table 3. Perform your calculations on a separate sheet of paper, marked with the step number, run number, and attach to the lab sheet.

6.2 For each run, determine the kinetic energy to four decimal places ($\boldsymbol{KE = ½mv^2}$) for each cart before and after the collision. Calculate the ratio to three decimal places of the total kinetic energy after the collision to the total kinetic energy before the collision. Enter the values in Table 4. Perform your calculations on a separate sheet of paper, marked with the step number and run number and attach to the lab sheet.

7.0 QUESTIONS

7.1 If the total momentum for a system is the same before and after the collision, we say that momentum is *conserved*. If momentum were conserved, what would be the ratio of the total momentum after the collision to the total momentum before the collision?

7.2 If the total kinetic energy for a system is the same before and after the collision, we say that kinetic energy is *conserved*. If kinetic energy were conserved, what would be the ratio of the total kinetic energy after the collision to the total kinetic energy before the collision?

7.3 Inspect the momentum ratios in Table 3. Even if momentum is conserved for a given collision, the measured values may not be exactly the same before and after due to measurement uncertainty. The ratio should be close to one, however. Is momentum conserved in your collisions?

7.4 Repeat the preceding question for the case of kinetic energy, using the kinetic energy ratios in Table 4. Is kinetic energy conserved in the magnetic bumper collisions? How about the hook-and-pile collisions? Is kinetic energy conserved in the third type of collision (mixed bumpers)? Classify the three collision types as elastic, inelastic, or completely inelastic.

7.5 Discuss any measurement errors that may have affected your results. Remember personal errors are not really errors, instead, they are merely mistakes made by the experimenter. If possible, give an estimate of the measurement errors. If available, use the manufacturer's specification for any device used in making a measurement. If accuracy is not listed, use repeatability. List any assumptions made in conducting this experiment.

Attachment 1

Go Direct Sensor Connection Instructions

<u>If using Bluetooth connection:</u>

Press and hold the power button until red sensor light flashes.

Launch Graphical Analysis 4

Tap “Sensor Data Collection”

Verify sensor ID number appears on the screen.

Tap “Connect”

When sensor is connected, tap “Done.”

Verify appropriate graph appears on your screen.

In the upper right of the screen is on icon for view options (1 or 2 graphs, data table)

In the lower left, are icons for zooming the data and for graph options.

When all data collection is finished, press and hold the sensor power button until the red light stops flashing.

<u>If using computer USB port:</u>

Use the USB port to connect the sensor to the computer.

Connecting the USB cable will automatically turn on the sensor.

Launch Graphical Analysis 4

The appropriate sensor graph will appear on your screen.

In the upper right of the screen is on icon for view options (1 or 2 graphs, data table)

In the lower left, are icons for zooming the data and for graph options.

When all data collection is finished, disconnect the USB cable from the sensor and the computer.

Press and hold the sensor power button until the red light stops flashing.