Physics 2101
Section 5
Aug. 27th, Chapt. 1-4

- Who am I?
- Who are you?
- Why are you here?
- What are you suppose to learn?
- How will the grades be determined?
Announcements

Homework problem sessions: Thursday’s 4:45—5:45 PM in 108 Nicholson Hall

Supplemental Instruction

- The SI session will be:
  Sunday 4:30 - 6:00 PM
  Wednesday 4:30 – 6:00
  In 212 Coates Hall?

Tutoring: Graduate tutors in Room 102 of Nicholson Hall. Check the room for scheduled times.

Carlin Donart: Office hours 1:30—2:30 in Allen 39.
Earl Ward Plummer---Ward Plummer

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Visit my personal website for more information:
http://www.phys.lsu.edu/plummer/
Who Are You?

You are Science & Engineering Majors.

You are registered for PHYS 2101.

You want to learn PHYS 2101??

You want to have good grade!! So do I!
Spring 2013: PHYS 2101 Section 5

Class time: Tuesday & Thursday: 10:30 – 11:50 AM

Office Hours: Tuesday & Thursday: 1:00 PM – 3:30 PM

If you are not available in these time windows, please feel free to send me an e-mail for appointment

Class Website: http://www.phys.lsu.edu/classes/Fall2013/phys2101

Lecture notes: http://www.phys.lsu.edu/classes/Fall2013/phys2101-5

Pre-requisites: Basic Algebra & Calculus; Physics 1100


Class: Covers Chapters 1-6 (PHYS 1100, what you need to know); 7-16,18-20

Reading Assignments: Lecture schedule is provided

- read material before lecture!

Lectures: Concepts will be developed through the lectures, demonstrations and class discussion

Homework: Best way to learn the material: -- Quizzes & Exams mostly based on HW
Homework on WebAssign

WebAssign will handle homework

http://webassign.net/student.html

IMPORTANT: Try to log into WebAssign TODAY

✪ Click “I have a class key” then input your class key: lsu 7164 8681.
✪ If you have used WebAssign before, your old password will be in effect
✪ If you have NOT used WebAssign before, you can log on by using your LSU PAWS email address without the @lsu.edu, and setup your own password.
✪ If you have a problem to log on, please check:
  (1) username (has to be PAWS username);
  (2) if you have paid for accessing WebAssign;
  (3) if you are in my class roster. Please contact me if you cannot logon.

The first homework assignment is posted.

Web assign HW will be due Aug. 29th
Each week there will be two problems assigned as an open book, open notes, work together homework assignment. They will be available on Moodle for the class at least 1 week before they are due.

The solutions are due at the beginning of class on Tuesday. They will be graded and returned. The solutions will be posted on Moodle.

The first written homework assignment is posted and is due Sept. 3.
Course details -- see syllabus

Class Format
- Announcements
- Mixture of Power Point and Chalk Board/Overhead
- Some theory …. Some problems…
- Power Point slides are available on class website--physics and Moodle
- Please ask questions (and correct me!).

Course:
• It is assumed that everyone has credit in PHYS 1100 so the material in Chapters 1-6 (vectors, 1- and 2-D kinematics, Newton’s laws) will only be discussed in the first week of class. The objective is not to teach this material but to review what you need to know. If you do not know what is in these Chapters you need to drop before the 4th of Sept.
• After the first week the course assumes a more normal pace and will cover most of the section contained in chapters 7 – 20, with the exception of chapter 17, which will be skipped.
• The core material of the course covers concepts in mechanics, fluids, wave motion, and thermodynamics. The lecture schedule will specifically indicate sections of text that are covered on a given week. Students should read and become familiar with this material before coming to class.
• Course grades will be determined by quizzes (weekly base), Homework, three 1-hour mid-term tests, and a final (see following).
# 2101 Tentative Schedule – Fall 2013

<table>
<thead>
<tr>
<th>Week</th>
<th>Dates</th>
<th>Sections covered</th>
<th>Homework</th>
<th>Comments</th>
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<tbody>
<tr>
<td>1</td>
<td>Aug 27, 29</td>
<td>Review Ch.1-6</td>
<td>HW1 – Aug 29</td>
<td></td>
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<tr>
<td>2</td>
<td>Sep. 3, 5</td>
<td>Review and Ch. 7.1-4</td>
<td>Hw2 – Sep.5</td>
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<tr>
<td>3</td>
<td>Sep. 10, 12</td>
<td>7.5-8, 8.1-4</td>
<td>HW3 – Sep.12</td>
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<td>4</td>
<td>Sep. 17, 19</td>
<td>8.5-8, 9.1-4</td>
<td>Hw4 - Sep. 19</td>
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<tr>
<td>Sep. 23</td>
<td>TEST #1 – Cha. 1-8</td>
<td></td>
<td>6 - 7 pm</td>
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<tr>
<td>5</td>
<td>Sep. 24, 26</td>
<td>9.5-11, 10.1-4</td>
<td>Hw4 - Sep. 26</td>
<td></td>
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<tr>
<td>6</td>
<td>Oct. 1, 3</td>
<td>10.5-10, 11.1-4</td>
<td>Hw5 – Oct. 3</td>
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<tr>
<td>7</td>
<td>Oct. 10, 12</td>
<td>11.6-11</td>
<td>Hw6 – Oct. 8</td>
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<td>8</td>
<td>Oct. 15, 17</td>
<td>12.1-5, 13.1-4</td>
<td>Hw7 - Oct. 17</td>
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<td>Oct. 21</td>
<td>Test #2 – Chapt. 9-12</td>
<td></td>
<td>6 - 7 pm</td>
<td></td>
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<td>9</td>
<td>Oct. 22, 24</td>
<td>13.5-6, 14.1-7</td>
<td>Hw8 - Oct. 24</td>
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<tr>
<td>10</td>
<td>Oct. 29, 31</td>
<td>14.8-10, 15.1-6</td>
<td>Hw9 – Oct. 31</td>
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<tr>
<td>11</td>
<td>Nov. 5</td>
<td>15.7-8, 16.1-4</td>
<td>Hw10 - Nov. 5</td>
<td>Nov. 7 Fall Holiday</td>
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<td>12</td>
<td>Nov. 12, 14</td>
<td>16.5-6,9-10,12-13, 18.1-5</td>
<td>Hw11 - Nov. 14</td>
<td></td>
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<td>Nov. 18</td>
<td>Test #3 – Chapt. 13-16</td>
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<td>6 - 7 pm</td>
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<td>12</td>
<td>Nov. 19, 21</td>
<td>18.6-11, 19.1-3</td>
<td>Hw11 - Nov. 21</td>
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<td>13</td>
<td>Nov. 26</td>
<td>19.4-5, 7</td>
<td>Hw12 - Nov. 26</td>
<td>Nov. 27-29, Thanks.</td>
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<td>14</td>
<td>Dec. 3, 5</td>
<td>19.9-11, 20.1-7</td>
<td>Hw13 - Nov. 5</td>
<td></td>
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<td>Dec. 13</td>
<td>FINAL EXAM</td>
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<td>12:30 – 2:30 pm</td>
<td>(Chapt. 1-16 + Chapt. 18-20)</td>
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Exams:

• There will be three 1-hour mid term exams. Sept. 23, Oct. 21\textsuperscript{st}, Nov. 18\textsuperscript{th} from 6 –7 PM. Room to be announced.
• There will be no make-up exams: if you need to miss an exam for a university-scheduled function, make sure you obtain permission from your instructor in advance. If you miss an exam with permission your other scores will be adjusted.
• Exams will contain a combination of multiple-choice questions and conceptual problems for which you must show your work.
• A formula sheet will also be provided. Old exams will be posted.

Final Exam: on Friday, December 13\textsuperscript{th} at 12:30—2:30 PM

Comprehensive in nature, but will emphasize the material covered since Nov. 18\textsuperscript{th} exam.

• Students having three or more final examinations in a 24 hour period may request permission to take no more than two examinations on the day concerned. These requests must be requested by the student and approved by the instructor before Friday April 9\textsuperscript{th}. 
# Grades

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<tr>
<th></th>
<th>100 points each</th>
<th>300 points Total</th>
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<tr>
<td>Exams</td>
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<tr>
<td>Final Exam</td>
<td>200 points</td>
<td>200 points</td>
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<tr>
<td>WebAssign HW</td>
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<td>50 points</td>
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<tr>
<td>Written HW</td>
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<td>50 points</td>
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<tr>
<td>Quizzes</td>
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<td>50 points total</td>
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<table>
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<tr>
<th></th>
<th></th>
<th>650 points</th>
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<tbody>
<tr>
<td>Total</td>
<td></td>
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</table>

Each Exam will be curved to obtain an average of 70%. Please note that nothing else is curved!!

**Grades:** In terms of % of 650 points

<table>
<thead>
<tr>
<th>Grade</th>
<th>Percentage</th>
<th>Grade</th>
<th>Percentage</th>
</tr>
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<tbody>
<tr>
<td>A</td>
<td>90—100 %</td>
<td>B</td>
<td>80—90 %</td>
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<tr>
<td>C</td>
<td>60—80 %</td>
<td>D</td>
<td>50—60 %</td>
</tr>
<tr>
<td>F</td>
<td>&lt;50 %</td>
<td></td>
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</tr>
</tbody>
</table>

90 is a A
80 is a B

We will hold firm on this grading scheme!

Any question...?
Chapter 1: Measurement

Chapter 2: Motion along a Straight Line (1D)

Chapter 3: Vectors

Chapter 4: Motion in 2 and 3 dimensions

Chapter 5: Force and Motion -- I

Chapter 6: Force and Motion -- II
Chapter 1: Measurement

Basic concepts:

1. Measurement of a physical parameter
2. Units, systems of units (example: SI)
3. Basic units in mechanics
4. Changing units
5. Significant figures
SI Base Units – seven
1) meter (m)  distance
2) kilogram (kg) mass
3) second (s)  time
4) ampere (A) electric current
5) kelvin (K)  temperature
6) mole (mol) amount of stuff
7) candela (cd) intensity of light

Derived Unit | Measures | Derivation | Formal Def.
--- | --- | --- | ---
hertz (Hz) | frequency | /s | s^{-1}
newton (N) | force | kg·(m/s^2) | kg·m·s^{-2}
pascal (Pa) | pressure | N/m^2 | kg·m^{-1}·s^{-2}
joule (J) | energy or work | N·m | kg·m^2·s^{-2}

prefix | Symbol | Factor
--- | --- | ---
Giga | G | 10^9
Mega | M | 10^6
Kilo | k | 10^3
Centi | c | 10^{-2}
Milli | m | 10^{-3}
Micro | µ | 10^{-6}
Nano | n | 10^{-9}

See Appendix A: International System of Units
See Appendix D: Conversion Factors
Significant figures…

Use units to help you!!
Be sure that numerical answers appear with appropriate SI units. Points will be deducted for missing, incorrect, or “silly” units.

If the final answer is in fact a dimensionless quantity, please write the numerical result followed by the word “dimensionless”
Basic Concepts:

Displacement: \( \Delta x = x_2 - x_1 \)  
(SI Unit: m)

Average velocity: \( v_{avg} = \frac{x_2 - x_1}{t_2 - t_1} = \frac{\Delta x}{\Delta t} \)  
(SI Unit: m/s)

Instantaneous velocity: \( v = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t} = \frac{dx}{dt} \)

Average acceleration: \( a_{avg} = \frac{v_2 - v_1}{t_2 - t_1} = \frac{\Delta v}{\Delta t} \)  
(SI Unit: m/s²)

Instantaneous acceleration \( a = \lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t} = \frac{dv}{dt}, \quad a = \frac{dv}{dt} = \frac{d}{dt}\left(\frac{dx}{dt}\right) = \frac{d^2 x}{dt^2} \)  

We are dealing with Kinematics
Special Case: Motion with Constant Acceleration

\[ a = \frac{dv}{dt} \rightarrow dv = at. \]  If we integrate both sides of the equation we get:

\[ \int dv = \int at \, dt \rightarrow v = at + C. \]  Here \( C \) is the integration constant.

\( C \) can be determined if we know the velocity \( v_0 = v(0) \) at \( t = 0 \):

\[ v(0) = v_0 = (a)(0) + C \rightarrow C = v_0 \rightarrow v = v_0 + at \]  (eq. 1)

\[ v = \frac{dx}{dt} \rightarrow dx = vdt = (v_0 + at) \, dt = v_0 \, dt + at \, dt \]  If we integrate both sides we get:

\[ \int dx = \int v_0 \, dt + \int at \, dt \rightarrow x = v_0 \, t + \frac{at^2}{2} + C'. \]  Here \( C' \) is the integration constant.

\( C' \) can be determined if we know the position \( x_o = x(0) \) at \( t = 0 \):

\[ x(0) = x_o = (v_0)(0) + \frac{a}{2}(0) + C' \rightarrow C' = x_o \]

\[ x(t) = x_o + v_0 \, t + \frac{at^2}{2} \]  (eq. 2)

If we eliminate the time \( t \) between equation 1 and equation 2 we get:

\[ v^2 - v_0^2 = 2a(x - x_o) \]  (eq. 3)

Below we plot the position \( x(t) \), the velocity \( v(t) \), and the acceleration \( a \) versus time \( t \):
Motion with Constant Acceleration

The acceleration $a$ is a constant.

The $v(t)$ versus $t$ plot is a straight line with slope $= a$ and intercept $= v_0$.

The $x(t)$ versus $t$ plot is a parabola that intercepts the vertical axis at $x = x_0$.

The acceleration $a$ is a constant.

Could you plot these on a Quiz?
Special Case: free-falling body motion

Close to the surface of the Earth all objects move toward the center of the Earth with an acceleration whose magnitude is constant and equal to 9.8 m/s\(^2\). We use the symbol \( g \) to indicate the acceleration of an object in free fall.

\[
a = -g
\]

\[
v = v_0 - gt \quad \text{(eq. 1)}
\]

\[
x = x_o + v_0 t - \frac{gt^2}{2} \quad \text{(eq. 2)}
\]

\[
v^2 - v_0^2 = -2g \left( x - x_o \right) \quad \text{(eq. 3)}
\]
**Kinematics:** Taking Advantage of Symmetry

\[ v = v_0 - gt \]
\[ y = v_0 t - \frac{1}{2} gt^2 \]
\[ v^2 = v_0^2 - 2gy \]
\[ y = \frac{1}{2} (v + v_0) t \]
A person standing at the edge of a cliff throws one ball straight up and another ball straight down at the same initial speed. Neglecting air resistance, the ball to hit the ground below the cliff with the greater speed is the one initially thrown

1. upward.
2. downward.
3. neither—they both hit at the same speed.
A person standing at the edge of a cliff throws one ball straight up and another ball straight down at the same initial speed. Neglecting air resistance, which ball hits the ground first?

1. upward.
2. downward.
3. neither—they both hit at the same speed.
Graphical Integration in Motion Analysis (nonconstant acceleration)

When the acceleration of a moving object is not constant we must use integration to determine the velocity $v(t)$ and the position $x(t)$ of the object.

The integration can be done either using the analytic or the graphical approach:

$$a = \frac{dv}{dt} \rightarrow dv = adt \rightarrow \int_{t_0}^{t_1} dv = \int_{t_0}^{t_1} adt \rightarrow v - v_0 = \int_{t_0}^{t_1} adt \rightarrow v = v_0 + \int_{t_0}^{t_1} adt$$

$$\int_{t_0}^{t_1} adt = \text{[Area under the } a \text{ versus } t \text{ curve between } t_0 \text{ and } t_1 \text{]}$$

$$v = \frac{dx}{dt} \rightarrow dx = vdt \rightarrow \int_{t_0}^{t_1} dx = \int_{t_0}^{t_1} vdt \rightarrow$$

$$x_1 - x_0 = \int_{t_0}^{t_1} vdt \rightarrow x_1 = x_0 + \int_{t_0}^{t_1} vdt$$

$$\int_{t_0}^{t_1} vdt = \text{[Area under the } v \text{ versus } t \text{ curve between } t_0 \text{ and } t_1 \text{]}$$

Being able to graph or understand a graph is important!
A dog is initially walking due east. He stops, noticing a cat behind him. He runs due west and stops when the cat disappears into some bushes. He starts walking due east again. Then, a motorcycle passes him and he runs due east after it. The dog gets tired and stops running. Which of the following graphs correctly represent the position versus time of the dog?
Which of the following velocity vs. time graphs represents an object with a negative constant acceleration?

What does $x$ vs. $t$ look like?
Consider the graph of position versus time shown. Which curve on the graph best represents a constantly accelerating car?

a) A  

b) B  

c) C  

d) D  

e) None of the curves represent a constantly accelerating car.

What do the other curves represent?
In physics we have parameters that can be completely described by a number and are known as **scalars**. Temperature and mass are such parameters.

Other physical parameters require additional information about direction and are known as **vectors**. Examples of vectors are displacement, velocity, and acceleration.

In this chapter we learn the basic mathematical language to describe vectors. In particular we will learn the following:

- Geometric vector addition and subtraction
- Resolving a vector into its components
- The notion of a unit vector
- Addition and subtraction vectors by components
- Multiplication of a vector by a scalar
- The scalar (dot) product of two vectors
- The vector (cross) product of two vectors
An example of a vector is the displacement vector, which describes the change in position of an object as it moves from point $A$ to point $B$. This is represented by an arrow that points from point $A$ to point $B$. The length of the arrow is proportional to the displacement magnitude. The direction of the arrow indicated the displacement direction.

The three arrows from $A$ to $B$, from $A'$ to $B'$, and from $A''$ to $B''$, have the same magnitude and direction. A vector can be shifted without changing its value if its length and direction are not changed.

In text books vectors are written in two ways:

Method 1: $\vec{a}$ (using an arrow above)

Method 2: $\mathbf{a}$ (using boldface print)

The magnitude of the vector is indicated by italic print: $a$. 
Geometric Vector Addition

\[ \vec{s} = \vec{a} + \vec{b} \]

Sketch vector \( \vec{a} \) using an appropriate scale.
Sketch vector \( \vec{b} \) using the same scale.
Place the tail of \( \vec{b} \) at the tip of \( \vec{a} \).
The vector \( \vec{s} \) starts from the tail of \( \vec{a} \)
and terminates at the tip of \( \vec{b} \).
Vector addition is commutative:
\[ \vec{a} + \vec{b} = \vec{b} + \vec{a} \]

Negative \( -\vec{b} \) of a given vector \( \vec{b} \)
has the same magnitude as \( \vec{b} \)
but opposite direction.
Geometric Vector Subtraction

\[ \vec{d} = \vec{a} - \vec{b} \]

We write: \[ \vec{d} = \vec{a} - \vec{b} = \vec{a} + (\vec{-b}) \]

From vector \( \vec{b} \) we find \( -\vec{b} \).

Then we add \( (\vec{-b}) \) to vector \( \vec{a} \).

We thus reduce vector subtraction to vector addition, which we know how to do.

Note: We can add and subtract vectors using the method of components. For many applications this is a more convenient method.
Resolving a vector into its components

A component of a vector along an axis is the projection of the vector on this axis. For example $a_x$ is the projection of $\vec{a}$ along the $x$-axis. The component $a_x$ is defined by drawing straight lines from the tail and tip of the vector $\vec{a}$ that are perpendicular to the $x$-axis.

From triangle $ABC$ the $x$- and $y$-components of vector $\vec{a}$ are given by the equations

$$a_x = a \cos \theta \quad \text{and} \quad a_y = a \sin \theta.$$ 

If we know $a_x$ and $a_y$ we can determine $a$ and $\theta$. From triangle $ABC$ we have:

$$a = \sqrt{a_x^2 + a_y^2} \quad \text{and} \quad \tan \theta = \frac{a_y}{a_x}.$$
We are given two vectors $\vec{a} = a_x \hat{i} + a_y \hat{j}$ and $\vec{b} = b_x \hat{i} + b_y \hat{j}$.

We want to calculate the vector difference

$$\vec{d} = \vec{a} - \vec{b} = d_x \hat{i} + d_y \hat{j}.$$ 

The components $d_x$ and $d_y$ of $\vec{d}$ are given by the equations

$$d_x = a_x - b_x \quad \text{and} \quad d_y = a_y - b_y.$$
A unit vector is defined as a vector that has magnitude equal to 1 and points in a particular direction. Unit vectors lack units and their sole purpose is to point in a particular direction. The unit vectors along the $x$, $y$, and $z$ axes are labeled $\hat{i}$, $\hat{j}$, and $\hat{k}$, respectively.

Unit vectors are used to express other vectors. For example, vector $\vec{a}$ can be written as

$$\vec{a} = a_x \hat{i} + a_y \hat{j}.$$  

The quantities $a_x \hat{i}$ and $a_y \hat{j}$ are called the vector components of vector $\vec{a}$. 
We are given two vectors $\vec{a} = a_x \hat{i} + a_y \hat{j}$ and $\vec{b} = b_x \hat{i} + b_y \hat{j}$.

We want to calculate the vector sum $\vec{r} = r_x \hat{i} + r_y \hat{j}$.

The components $r_x$ and $r_y$ are given by the equations

$$r_x = a_x + b_x \quad \text{and} \quad r_y = a_y + b_y.$$
We are given two vectors \( \vec{a} = a_x \hat{i} + a_y \hat{j} \) and \( \vec{b} = b_x \hat{i} + b_y \hat{j} \).

We want to calculate the vector difference
\[
\vec{d} = \vec{a} - \vec{b} = d_x \hat{i} + d_y \hat{j}.
\]

The components \( d_x \) and \( d_y \) of \( \vec{d} \) are given by the equations
\[
d_x = a_x - b_x \quad \text{and} \quad d_y = a_y - b_y.
\]
Multiplying a Vector by a Scalar

Multiplication of a vector $\vec{a}$ by a scalar $s$ results in a new vector $\vec{b} = s\vec{a}$. The magnitude $b$ of the new vector is given by $b = |s|a$.

If $s > 0$, vector $\vec{b}$ has the same direction as vector $\vec{a}$.

If $s < 0$, vector $\vec{b}$ has a direction opposite to that of vector $\vec{a}$.

The Scalar Product of Two Vectors

The scalar product $\vec{a} \cdot \vec{b}$ of two vectors $\vec{a}$ and $\vec{b}$ is given by $\vec{a} \cdot \vec{b} = ab \cos \phi$. The scalar product of two vectors is also known as the "dot" product. The scalar product in terms of vector components is given by the equation $\vec{a} \cdot \vec{b} = a_x b_x + a_y b_y + a_z b_z$. 
What is the scalar product, $\vec{A} \cdot \vec{B}$, if
\[ \vec{A} = 1.1\hat{i} + 2.0\hat{j} \text{ and } \vec{B} = 1.0\hat{i} - 1.0\hat{j} \]
The Vector Product of Two Vectors

The vector product \( \vec{c} = \vec{a} \times \vec{b} \) of the vectors \( \vec{a} \) and \( \vec{b} \) is a vector \( \vec{c} \).

The magnitude of \( \vec{c} \) is given by the equation
\[
c = ab \sin \phi.
\]
The direction of \( \vec{c} \) is perpendicular to the plane \( P \) defined by the vectors \( \vec{a} \) and \( \vec{b} \).

The sense of the vector \( \vec{c} \) is given by the right-hand rule:

a. Place the vectors \( \vec{a} \) and \( \vec{b} \) tail to tail.

b. Rotate \( \vec{a} \) in the plane \( P \) along the shortest angle so that it coincides with \( \vec{b} \).

c. Rotate the fingers of the right hand in the same direction.

d. The thumb of the right hand gives the sense of \( \vec{c} \).

The vector product of two vectors is also known as the "cross" product.
Question

Consider the various vectors given in the choices below. The cross product of which pair of vectors is equal to zero?
The Vector Product \( \vec{c} = \vec{a} \times \vec{b} \) in Terms of Vector Components

\[
\vec{a} = a_x \hat{i} + a_y \hat{j} + a_z \hat{k}, \quad \vec{b} = b_x \hat{i} + b_y \hat{j} + b_z \hat{k}, \quad \vec{c} = c_x \hat{i} + c_y \hat{j} + c_z \hat{k}
\]

The vector components of vector \( \vec{c} \) are given by the equations

\[
c_x = a_y b_z - a_z b_y, \quad c_y = a_z b_x - a_x b_z, \quad c_z = a_x b_y - a_y b_x.
\]

Note: Those familiar with the use of determinants can use the expression

\[
\vec{a} \times \vec{b} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ a_x & a_y & a_z \\ b_x & b_y & b_z \end{vmatrix}
\]

Note: The order of the two vectors in the cross product is important:

\[
\vec{b} \times \vec{a} = - \left( \vec{a} \times \vec{b} \right)
\]
Which of the following are right-handed coordinate systems?
What is the vector product, $\vec{A} \times \vec{B}$, if

$\vec{A} = 2.2\hat{i} + 3.4\hat{j}$ and $\vec{B} = 4.4\hat{i} + 2.0\hat{j}$?
Chapter 4: Motion in 2 and 3 Dimensions

1-D vectors \(\rightarrow\) 2- and 3-D vectors

for position, velocity, and acceleration

\[
\vec{r} = r_x \hat{i} + r_y \hat{j} + r_z \hat{k}
\]

\[
\vec{v} = \frac{d\vec{r}}{dt} = v_x \hat{i} + v_y \hat{j} + v_z \hat{k}
\]

\[
\vec{a} = \frac{d\vec{v}}{dt} = a_x \hat{i} + a_y \hat{j} + a_z \hat{k}
\]

Decouple motion into components

Graphing is very important!
2-D with CONSTANT ACCELERATION
(a_x=C, and a_y=C')

The $x$ and $y$ motions are **decoupled**: this means that we can consider both directions of motion independently.

<table>
<thead>
<tr>
<th>$x$–direction motion</th>
<th>$y$–direction motion</th>
</tr>
</thead>
<tbody>
<tr>
<td>$v_x = v_{ox} + a_x t$</td>
<td>$v_y = v_{oy} + a_y t$</td>
</tr>
<tr>
<td>$x = \frac{1}{2}(v_x + v_{ox})t$</td>
<td>$y = \frac{1}{2}(v_y + v_{oy})t$</td>
</tr>
<tr>
<td>$x = v_{ox}t + \frac{1}{2}a_xt^2$</td>
<td>$y = v_{oy}t + \frac{1}{2}a_yt^2$</td>
</tr>
<tr>
<td>$v_x^2 = v_{ox}^2 + 2a_xx$</td>
<td>$v_y^2 = v_{oy}^2 + 2a_yy$</td>
</tr>
</tbody>
</table>

Assuming $x_o = 0 : y_0 = 0$

$\Delta \vec{r} = \Delta \hat{x} + \Delta \hat{y}$

$\vec{v} = v_x \hat{i} + v_y \hat{j}$

$\vec{a} = a_x \hat{i} + a_y \hat{j}$

Can you derive these two equations?
Projectile Motion

Toss something in the air:

\[ a_x = 0 \text{ and } a_y = -g \]

Assuming \( x_o = 0 : y_0 = 0 \)

**x–direction motion**

\[ v_x = v_{ox} + a_x t \]

\[ x = \frac{1}{2} (v_x + v_{ox}) t \]

\[ x = v_\theta x \, t + \frac{1}{2} a_x t^2 \]

\[ v_x^2 = v_{θx}^2 + 2a_x x \]

**y–direction motion**

\[ v_y = v_{oy} + g t \]

\[ y = \frac{1}{2} (v_y + v_{oy}) t \]

\[ y = v_{oy} t + \frac{1}{2} g t^2 \]

\[ v_y^2 = v_{oy}^2 + 2gy \]
At the top of a cliff a projectile is fired horizontally with some initial velocity, $v_{ox}$. At the exact same time, an identical projectile is dropped from rest straight down to the same height. Which projectile hits the ground first?

1. The one fired horizontally
2. The one that is dropped
3. Both hit at the same time
4. It depends on $v_{ox}$
Example: A Falling Care Package to Haiti

The airplane is moving horizontally with a constant velocity of +115 m/s at an altitude of 1050 m. It drops a box. What is the box's speed at impact?

**How do you find final speed?**

\[
v_f = \sqrt{v_{fx}^2 + v_{fy}^2}
\]

**What is \(v_{fx}\)?**

Because \(a_x = 0\),

\[
v_{0x} = v_{fx} = 115 \text{ m/s}
\]

**What is \(v_{fy}\)?**

Because \(a_y = -g\) and \(v_{oy} = 0\)

\[
v_{fy}^2 = 0 - 2(9.8 \text{ m/s}^2)(-1050 \text{ m})
\]

\[
v_{fy} = 143 \text{ m/s}
\]

**Final Speed**

\[
v_f = \sqrt{(115 \text{ m/s})^2 + (143 \text{ m/s})^2}
\]

\[
= 184 \text{ m/s} \quad \text{FINAL SPEED}
\]
The figure shows three paths for a football kicked from ground level. Ignoring the effects of air on the flight, rank the paths according to initial vertical velocity ($v_{oy}$) component.

1. $1 < 2 < 3$
2. $1 = 2 = 3$
3. $1 > 2 > 3$
The figure shows three paths for a football kicked from ground level. Ignoring the effects of air on the flight, rank the paths according to the flight time.

1. \( 1 < 2 < 3 \)
2. \( 1 = 2 = 3 \)
3. \( 1 > 2 > 3 \)

\[
\begin{align*}
v_x &= v_{0x} \\
x &= v_{0x}t \\
v_x^2 &= v_{0x}^2 \\
x &= \frac{1}{2}(v_x + v_{0x})t \\
v_y &= v_{0y} - gt \\
y &= v_{0y}t - \frac{1}{2}gt^2 \\
v_y^2 &= v_{0y}^2 - 2gy \\
y &= \frac{1}{2}(v_y + v_{0y})t
\end{align*}
\]
The figure shows three paths for a football kicked from ground level. Ignoring the effects of air on the flight, rank the paths according to initial horizontal velocity ($v_{0x}$) component.

1. $1 < 2 < 3$
2. $1 = 2 = 3$
3. $1 > 2 > 3$

Question

$v_x = v_{0x}$
$x = v_{0x}t$
$v_x^2 = v_{0x}^2$
$x = \frac{1}{2}(v_x + v_{0x})t$

$v_y = v_{0y} - gt$
$y = v_{0y}t - \frac{1}{2}gt^2$
$v_y^2 = v_{0y}^2 - 2gy$
$y = \frac{1}{2}(v_y + v_{0y})t$
A battleship simultaneously fires two shells at enemy ships (same $v_0$). If the shells follow the parabolic trajectories shown, which ship gets hit first?

1. A
2. Both at the same time
3. B
4. Need more information