

**PHY 113 A General Physics I**  
**9-9:50 AM MWF Olin 101**

**Plan for Lecture 4:**

**Chapter 3 – Vectors**

- 1. Abstract notion of vectors**
- 2. Displacement vectors**
- 3. Other examples**

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Department of Physics

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Wake Forest Physics

Nationally recognized for teaching excellence.


Internationally recognized for research advances.

A department emphasis on providing primary study and research opportunities for the


News




Article by Lacra Neumann of the Solihury Group Selected for Inaugural Contribution to Protocopa from JRSO



Prof. Thonhauser receives NSF CAREER award



Carroll Group's Power Left Featured on CNN International



Prof. Cho Organizes the Wake@James Computational Thinking Workshop for Middle

Events

Wed Sep 5, 2012

Physics Research Opportunities I

4:00 PM in Olin 101

Refreshments at 3:30 in Lobby

The Sep 6, 2012

Society of Physics Students Meeting

12:00 PM in Olin Lounge

Pizza Provided - All Interested Invited!

Wed Sep 12, 2012

Physics Research Opportunities I

4:00 PM in Olin 101

Refreshments at 3:30 in Lobby

Wed Sep 19, 2012

Dr. Václav Špalek

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No.	Lecture Date	Topic	Text Sections	Problem Assignments	Assignment Due Date
1	08/29/2012	Units & measurement	1.1-1.6	1.2, 1.6.1, 1.13, 1.20	
2	08/31/2012	Motion in 1d – constant velocity	2.1, 2.3	2.1, 2.8	09/07/2012
3	09/03/2012	Motion in 1d – constant acceleration	2.4, 2.8	2.13, 2.16	09/07/2012
4	09/05/2012	Vectors	3.1, 3.4	3.3, 3.22	09/07/2012
5	09/07/2012	Motion in 2d	4.1, 4.3	4.3, 4.19	09/10/2012
6	09/10/2012	Circular motion	4.4, 4.6		09/12/2012
7	09/12/2012	Newton's laws	5.1, 5.6		09/14/2012
8	09/14/2012	Newton's laws applied	5.7, 5.8		09/17/2012
	09/17/2012	Review	1-5		
	09/19/2012	Exam	1-5		
9	09/21/2012	More applications of Newton's laws	6.1, 6.4		09/24/2012
10	09/24/2012	Work	7.1, 7.4		09/26/2012

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**iclicker question**

- A. Have you attended a tutoring session yet?  
 B. Have you attended a lab session yet?  
 C. Have you attended both tutoring and lab sessions?

Fall 2012 Schedule  
for B. A. W. Holzwart

	Monday	Tuesday	Wednesday	Thursday	Friday
8:00-9:00	Lecture Preparation/ Office Hours	Lecture Preparation/ Office Hours	Lecture Preparation/ Office Hours	Lecture Preparation/ Office Hours	Lecture Preparation/ Office Hours
9:00-10:00	General Physics JPHY113	General Physics Office Hours	General Physics JPHY113	General Physics Office Hours	General Physics JPHY113
10:00-11:00	Classical Mech PHY711	Classical Mech Office Hours	Classical Mech PHY711	Classical Mech Office Hours	Classical Mech PHY711
11:00-12:30	Office Hours	Physics Research	Office Hours	Physics Research	Office Hours
12:30-2:00	Condensed Matter Theory Journal Club	Condensed Matter Theory Journal Club	Physics Research	Physics Research	Physics Research
2:00-3:30	Physics Research	Physics Research	Physics Colloquium	Physics Research	Physics Research
3:30-5:00	Physics Research	Physics Research	Physics Colloquium	Physics Research	QELS - Renewable Energy Research

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**iclicker question**

Have you changed your webassign password yet?

- A. yes  
 B. no

Mathematics Review -- Appendix B Serway & Jewett

**iclicker question**

- A. Have you used this appendix?  
 B. Have you used the appendix, and find it helpful?  
 C. Have you used the appendix, but find it unhelpful?

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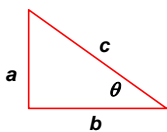
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Mathematics Review -- Appendix B Serway & Jewett

Quadratic equation :

$$ax^2 + bx + c = 0$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$



Trigonometry :

$$\cos \theta = \frac{b}{c}$$

$$\sin \theta = \frac{a}{c}$$

$$\tan \theta = \frac{a}{b}$$

Differential calculus :

$$\frac{d}{dt} at^n = ant^{n-1}$$

$$\frac{d}{dt} e^{at} = ae^{at}$$

$$\frac{d}{dt} \sin(\beta t) = \beta \cos(\beta t)$$

Integral calculus :

$$\int at^n dt = \frac{at^{n+1}}{n+1}$$

$$\int e^{at} dt = \frac{1}{a} e^{at}$$

$$\int \sin(\beta t) dt = -\frac{1}{\beta} \cos(\beta t)$$

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### Definition of a vector

1. A vector is defined by its **length** and **direction**.



2. Addition, subtraction, and two forms of multiplication can be defined
3. In practice, we can use trigonometry or component analysis for quantitative work involving vectors.
4. Abstract vectors are useful in physics and mathematics.

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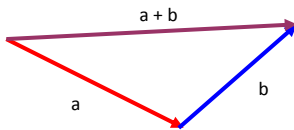
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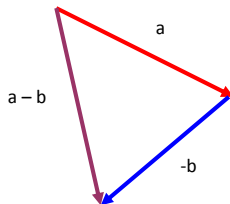
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### Vector addition:



### Vector subtraction:



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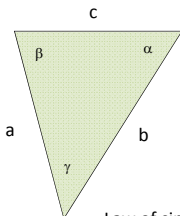
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### Some useful trigonometric relations

(see Appendix B of your text)



#### Law of cosines:

$$a^2 = b^2 + c^2 - 2bc \cos \alpha$$

$$b^2 = c^2 + a^2 - 2ca \cos \beta$$

$$c^2 = a^2 + b^2 - 2ab \cos \gamma$$

#### Law of sines:

$$\frac{a}{\sin \alpha} = \frac{b}{\sin \beta} = \frac{c}{\sin \gamma}$$

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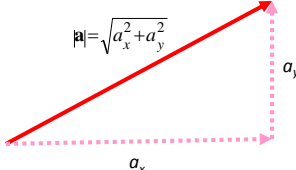
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Vector components:  $\mathbf{a} = a_x \hat{\mathbf{x}} + a_y \hat{\mathbf{y}} = a_x \hat{\mathbf{i}} + a_y \hat{\mathbf{j}}$



$|\mathbf{a}| = \sqrt{a_x^2 + a_y^2}$

For  $\mathbf{a} = a_x \hat{\mathbf{x}} + a_y \hat{\mathbf{y}}$  and  $\mathbf{b} = b_x \hat{\mathbf{x}} + b_y \hat{\mathbf{y}}$

$\mathbf{a} + \mathbf{b} = (a_x + b_x) \hat{\mathbf{x}} + (a_y + b_y) \hat{\mathbf{y}}$

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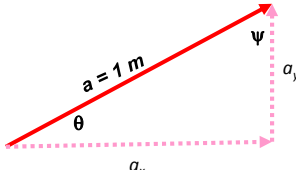
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Suppose you are given the length of the vector  $\mathbf{a}$  as shown. How can you find the components?



$a = 1 \text{ m}$

$\theta$

$\psi$

$a_x$

$a_y$

A.  $a_x = a \cos \theta$ ,  $a_y = a \sin \theta$   
 B.  $a_x = a \sin \psi$ ,  $a_y = a \cos \psi$   
 C. Neither of these  
 D. Both of these

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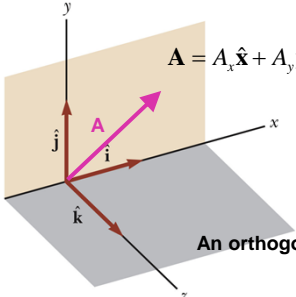
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Vector components; using trigonometry



$\mathbf{A} = A_x \hat{\mathbf{x}} + A_y \hat{\mathbf{y}} + A_z \hat{\mathbf{z}} = A_x \hat{\mathbf{i}} + A_y \hat{\mathbf{j}} + A_z \hat{\mathbf{k}}$

An orthogonal coordinate system

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Vector components:

$\mathbf{a} = a_x \hat{\mathbf{x}} + a_y \hat{\mathbf{y}}$

$\mathbf{b} = b_x \hat{\mathbf{x}} + b_y \hat{\mathbf{y}}$

$\mathbf{a} + \mathbf{b} = (a_x + b_x) \hat{\mathbf{x}} + (a_y + b_y) \hat{\mathbf{y}}$

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Examples

Vectors	Scalars
Position $\mathbf{r}$	Time $t$
Velocity $\mathbf{v}$	Mass $m$
Acceleration $\mathbf{a}$	Volume $V$
Force $\mathbf{F}$	Density $m/V$
Momentum $\mathbf{p}$	Vector components

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**Vector components**

$\mathbf{R}_1 = x_1 \hat{\mathbf{x}} + y_1 \hat{\mathbf{y}} + z_1 \hat{\mathbf{z}}$

$\mathbf{R}_2 = x_2 \hat{\mathbf{x}} + y_2 \hat{\mathbf{y}} + z_2 \hat{\mathbf{z}}$

$\mathbf{R}_1 + \mathbf{R}_2 = (x_1 + x_2) \hat{\mathbf{x}} + (y_1 + y_2) \hat{\mathbf{y}} + (z_1 + z_2) \hat{\mathbf{z}}$

**Vector multiplication**

“Dot” product  $\mathbf{A} \cdot \mathbf{B} \equiv AB \cos \theta_{AB}; \quad \hat{\mathbf{x}} \cdot \hat{\mathbf{x}} = 1$

“Cross” product  $|\mathbf{A} \times \mathbf{B}| \equiv AB \sin \theta_{AB}; \quad \hat{\mathbf{x}} \times \hat{\mathbf{y}} = \hat{\mathbf{z}}$

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Example of vector addition:



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$$\gamma = 90^\circ + 5^\circ - 21^\circ = 74^\circ$$

$$|\mathbf{a} + \mathbf{b}| = 788 \text{ mi}$$

Distance between Chicago and Dallas :

$$|\mathbf{a} + \mathbf{b}| = \sqrt{|\mathbf{a}|^2 + |\mathbf{b}|^2 - 2|\mathbf{a}||\mathbf{b}|\cos \gamma}$$

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Webassign version:

A map suggests that Atlanta is  $d_1 = 729$  mi in a direction of  $\theta_1 = 5.10^\circ$  north of east from Dallas. The same map shows that Chicago is  $d_2 = 558$  miles in a direction of  $\theta_2 = 20.8^\circ$  west of north from Atlanta. Modeling the Earth as flat, use this information to find the displacement from Dallas to Chicago.

magnitude  miles  
direction  ° northeast of Dallas



Note: In this case the angle  $\theta$  is actually measured as north of east.

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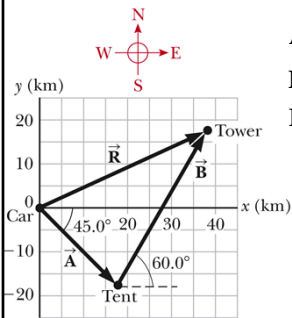
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Another example:



Position vectors in km units :

$$\mathbf{A} = 17.7\hat{\mathbf{i}} - 17.7\hat{\mathbf{j}}$$

$$\mathbf{B} = 20.0\hat{\mathbf{i}} + 34.6\hat{\mathbf{j}}$$

$$\begin{aligned}\mathbf{R} &= \mathbf{A} + \mathbf{B} \\ &= 37.7\hat{\mathbf{i}} + 16.9\hat{\mathbf{j}}\end{aligned}$$

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