

# PHYS 1441 – Section 501

## Lecture #3

*Wednesday, June 9, 2004*

*Dr. Jaehoon Yu*

- Chapter two: Motion in one dimension
  - Free Fall
- Chapter three: Motion in two dimension
  - Coordinate systems
  - Vector and Scalar
  - Two dimensional equation of motion
  - Projectile motion
- Chapter four: Newton's Laws of Motion

Today's homework is HW #2, due 6pm, next Wednesday, June 15!!



# Announcements

- E-mail distribution list: 25 of you have registered
  - Remember 3 extra credit points if done by midnight tonight
  - Next Wednesday is the last day of e-mail registration
  - -5 extra points if you don't register by next Wednesday
  - A test message will be sent out this Friday
- Homework: You are supposed to download the homework assignment, solve it offline and input the answers back online.
  - 44 registered
  - 40 submitted



# Kinematic Equations of Motion on a Straight Line Under Constant Acceleration

$$v_{xf}(t) = v_{xi} + a_x t$$

Velocity as a function of time

$$x_f - x_i = \frac{1}{2} \bar{v}_x t = \frac{1}{2} (v_{xf} + v_{xi}) t$$

Displacement as a function of velocities and time

$$x_f = x_i + v_{xi} t + \frac{1}{2} a_x t^2$$

Displacement as a function of time, velocity, and acceleration

$$v_{xf}^2 = v_{xi}^2 + 2a_x(x_f - x_i)$$

Velocity as a function of Displacement and acceleration

You may use different forms of Kinetic equations, depending on the information given to you for specific physical problems!!



# Falling Motion

- Falling motion is a motion under the influence of gravitational pull (gravity) only; Which direction is a freely falling object moving?
  - A motion under constant acceleration
  - All kinematic formula we learned can be used to solve for falling motions.
- Gravitational acceleration is inversely proportional to the distance between the object and the center of the earth
- The gravitational acceleration is  $g=9.80\text{m/s}^2$  on the surface of the earth, most of the time.
- The direction of gravitational acceleration is ALWAYS toward the center of the earth, which we normally call (-y); where up and down direction are indicated as the variable "y"
- Thus the correct denotation of gravitational acceleration on the surface of the earth is  $g=-9.80\text{m/s}^2$



# Example for Using 1D Kinematic Equations on a Falling object

Stone was thrown straight upward at  $t=0$  with  $+20.0\text{m/s}$  initial velocity on the roof of a  $50.0\text{m}$  high building,


What is the acceleration in this motion?

$$g = -9.80\text{m/s}^2$$

(a) Find the time the stone reaches at the maximum height.

What happens at the maximum height? The stone stops;  $V=0$

$$v_f = v_{yi} + a_y t = +20.0 - 9.80t = 0.00\text{m/s}$$



$$t = \frac{20.0}{9.80} = 2.04\text{s}$$

(b) Find the maximum height.

$$\begin{aligned} y_f &= y_i + v_{yi}t + \frac{1}{2}a_y t^2 = 50.0 + 20 \times 2.04 + \frac{1}{2} \times (-9.80) \times (2.04)^2 \\ &= 50.0 + 20.4 = 70.4(\text{m}) \end{aligned}$$



# Example of a Falling Object cnt'd

(c) Find the time the stone reaches back to its original height.

$$t = 2.04 \times 2 = 4.08s$$

(d) Find the velocity of the stone when it reaches its original height.

$$v_{yf} = v_{yi} + a_y t = 20.0 + (-9.80) \times 4.08 = -20.0(m / s)$$

(e) Find the velocity and position of the stone at  $t=5.00s$ .

Velocity

$$v_{yf} = v_{yi} + a_y t = 20.0 + (-9.80) \times 5.00 = -29.0(m / s)$$

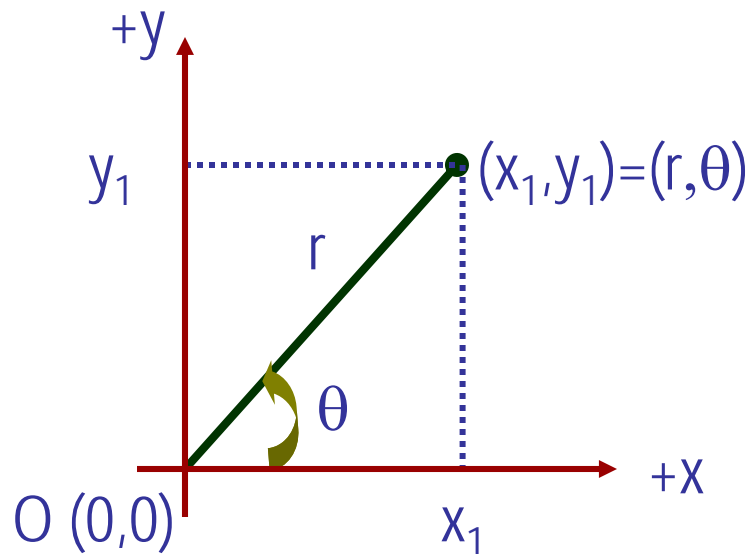
Position

$$\begin{aligned} y_f &= y_i + v_{yi} t + \frac{1}{2} a_y t^2 \\ &= 50.0 + 20.0 \times 5.00 + \frac{1}{2} \times (-9.80) \times (5.00)^2 = +27.5(m) \end{aligned}$$



# Coordinate Systems

- Makes it easy to express locations or positions
- Two commonly used systems, depending on convenience
  - Cartesian (Rectangular) Coordinate System
    - Coordinates are expressed in  $(x,y)$
  - Polar Coordinate System
    - Coordinates are expressed in  $(r,\theta)$
- Vectors become a lot easier to express and compute



How are Cartesian and Polar coordinates related?

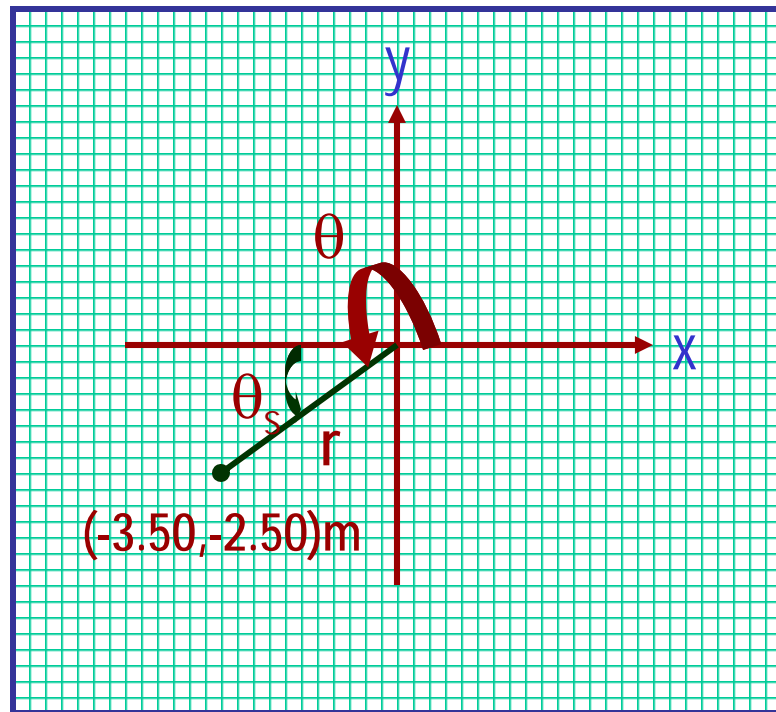
$$x_1 = r \cos \theta \quad r = \sqrt{(x_1^2 + y_1^2)}$$

$$y_1 = r \sin \theta \quad \tan \theta = \frac{y_1}{x_1}$$



# Example

Cartesian Coordinate of a point in the x-y plane are  $(x,y) = (-3.50, -2.50)\text{m}$ . Find the polar coordinates of this point.



$$\begin{aligned} r &= \sqrt{(x^2 + y^2)} \\ &= \sqrt{((-3.50)^2 + (-2.50)^2)} \\ &= \sqrt{18.5} = 4.30(m) \end{aligned}$$

$$\theta = 180 + \theta_s$$

$$\tan \theta_s = \frac{-2.50}{-3.50} = \frac{5}{7}$$

$$\theta_s = \tan^{-1}\left(\frac{5}{7}\right) = 35.5^\circ$$

$$\therefore \theta = 180 + \theta_s = 180^\circ + 35.5^\circ = 216^\circ$$



# Vector and Scalar

Vector quantities have both magnitude (size) and direction

*Force, gravitational acceleration, momentum*

Normally denoted in **BOLD** letters,  $\mathbf{F}$ , or a letter with arrow on top  $\vec{F}$

Their sizes or magnitudes are denoted with normal letters,  $F$ , or absolute values:  $|\vec{F}|$  or  $|F|$

Scalar quantities have magnitude only

Can be completely specified with a value and its unit

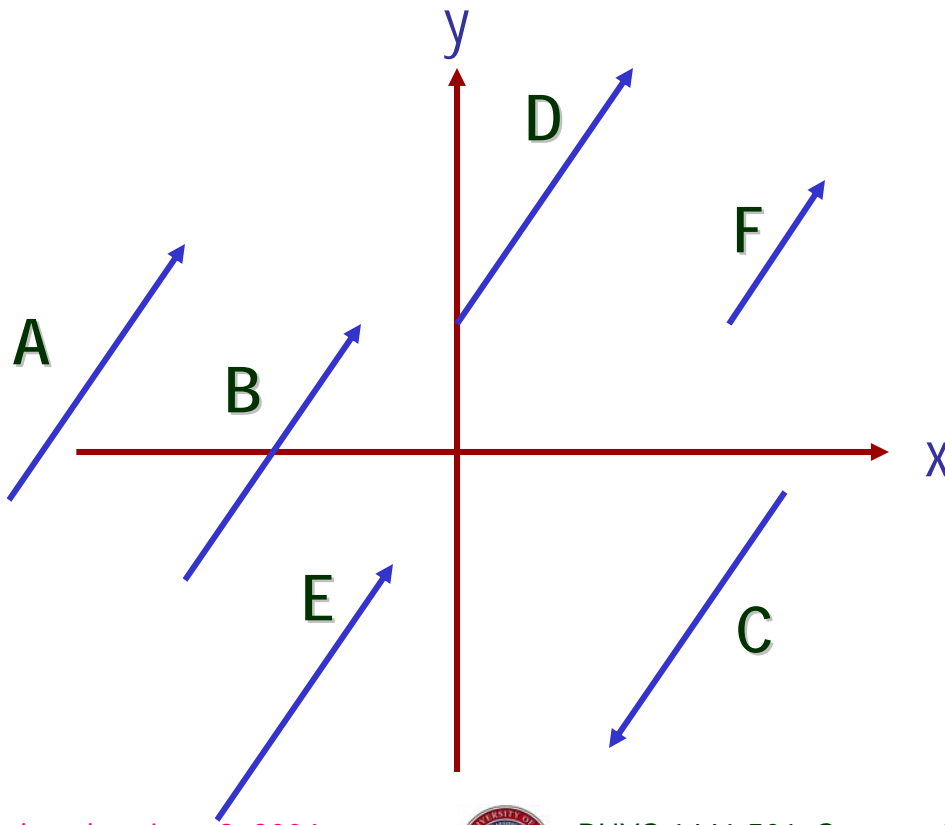
Normally denoted in normal letters,  $E$

*Energy, heat, mass, weight*

Both have units!!!

# Properties of Vectors

- Two vectors are the same if their sizes and the directions are the same, no matter where they are on a coordinate system.



Which ones are the same vectors?

**$A=B=E=D$**

Why aren't the others?

**C:** The same magnitude but opposite direction:  
 **$C=-A$ :** A negative vector

**F:** The same direction but different magnitude

Wednesday, June 9, 2004

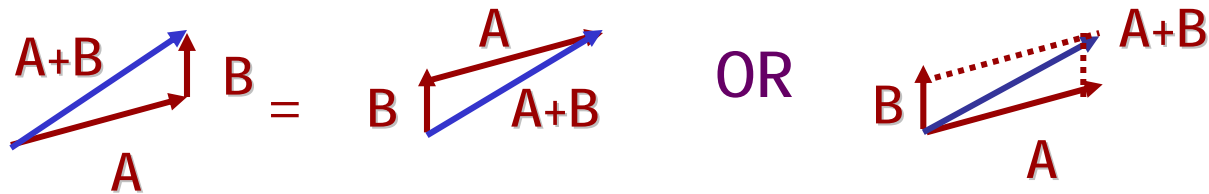


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# Vector Operations

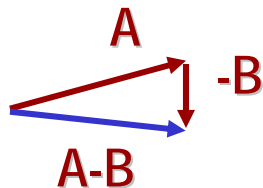
- Addition:

- Triangular Method: One can add vectors by connecting the head of one vector to the tail of the other (head-to-tail)
- Parallelogram method: Connect the tails of the two vectors and extend
- Addition is commutative: Changing order of operation does not affect the results  
 $A+B=B+A$ ,  $A+B+C+D+E=E+C+A+B+D$



- Subtraction:

- The same as adding a negative vector:  $A - B = A + (-B)$



Since subtraction is the equivalent to adding a negative vector, subtraction is also commutative!!!

- Multiplication by a scalar is increasing the magnitude  $A$ ,  $B=2A$



Wednesday

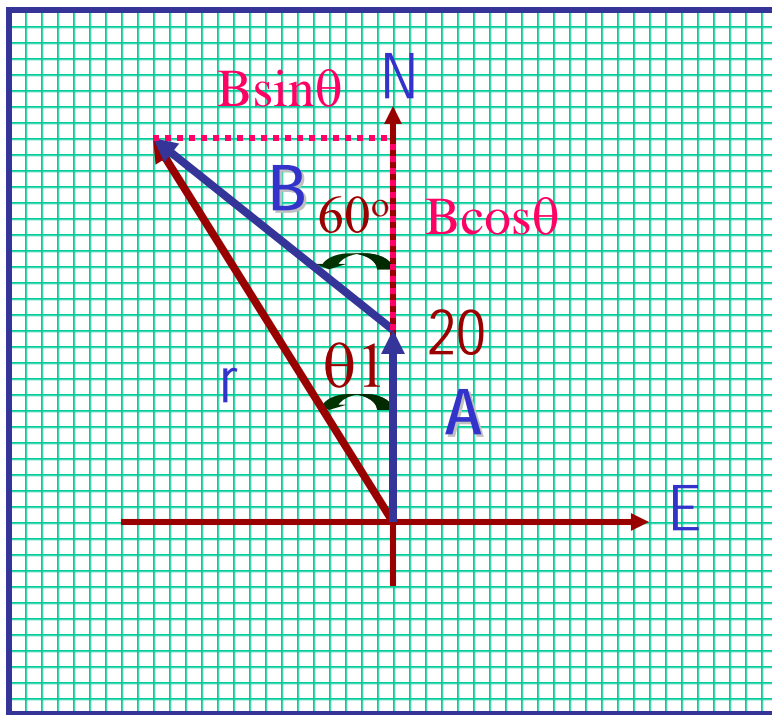
$$|B| = 2|A|$$



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# Example of Vector Addition

A car travels 20.0km due north followed by 35.0km in a direction 60.0° west of north. Find the magnitude and direction of resultant displacement.



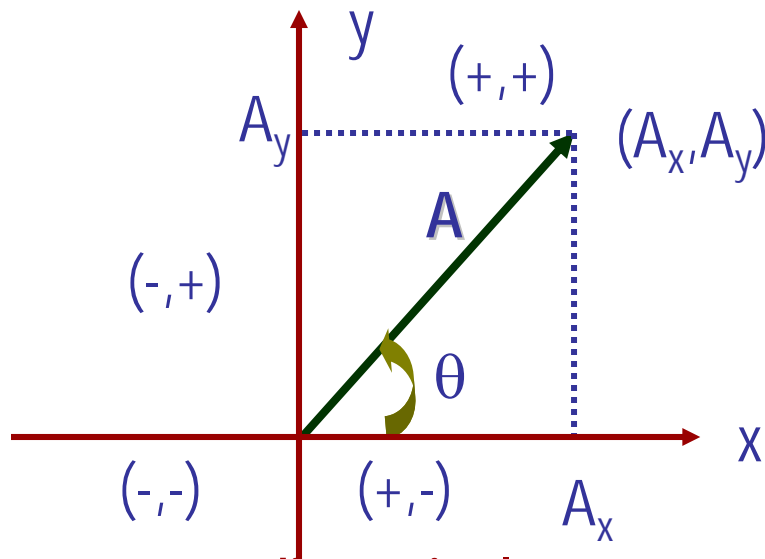
$$\begin{aligned}
 r &= \sqrt{(A + B \cos \theta)^2 + (B \sin \theta)^2} \\
 &= \sqrt{A^2 + B^2 (\cos^2 \theta + \sin^2 \theta) + 2AB \cos \theta} \\
 &= \sqrt{A^2 + B^2 + 2AB \cos \theta} \\
 &= \sqrt{(20.0)^2 + (35.0)^2 + 2 \times 20.0 \times 35.0 \cos 60} \\
 &= \sqrt{2325} = 48.2(\text{km})
 \end{aligned}$$

$$\begin{aligned}
 \theta_1 &= \tan^{-1} \frac{|\vec{B}| \sin 60}{|\vec{A}| + |\vec{B}| \cos 60} \\
 &= \tan^{-1} \frac{35.0 \sin 60}{20.0 + 35.0 \cos 60} \\
 &= \tan^{-1} \frac{30.3}{37.5} = 38.9^\circ \text{ to W wrt N}
 \end{aligned}$$

Find other ways to solve this problem...

# Components and Unit Vectors

Coordinate systems are useful in expressing vectors in their components



$$\left. \begin{aligned} A_x &= |\vec{A}| \cos \theta \\ A_y &= |\vec{A}| \sin \theta \end{aligned} \right\} \text{Components}$$

$$\left. |\vec{A}| = \sqrt{A_x^2 + A_y^2} \right\} \text{Magnitude}$$

$$\begin{aligned} |\vec{A}| &= \sqrt{\left(|\vec{A}| \cos \theta\right)^2 + \left(|\vec{A}| \sin \theta\right)^2} \\ &= \sqrt{|\vec{A}|^2 (\cos^2 \theta + \sin^2 \theta)} = |\vec{A}| \end{aligned}$$

- Unit vectors are dimensionless vectors whose magnitudes are exactly 1
  - Unit vectors are usually expressed in  $\mathbf{i}, \mathbf{j}, \mathbf{k}$  or  $\vec{i}, \vec{j}, \vec{k}$
  - Vectors can be expressed using components and unit vectors

So the above vector **A** can be written as

$$\vec{A} = A_x \vec{i} + A_y \vec{j} = |\vec{A}| \cos \theta \vec{i} + |\vec{A}| \sin \theta \vec{j}$$

# Examples of Vector Operations

Find the resultant vector which is the sum of  $\mathbf{A}=(2.0\mathbf{i}+2.0\mathbf{j})$  and  $\mathbf{B}=(2.0\mathbf{i}-4.0\mathbf{j})$

$$\begin{aligned}\vec{C} &= \vec{A} + \vec{B} = (2.0\vec{i} + 2.0\vec{j}) + (2.0\vec{i} - 4.0\vec{j}) \\ &= (2.0 + 2.0)\vec{i} + (2.0 - 4.0)\vec{j} = 4.0\vec{i} - 2.0\vec{j} (m)\end{aligned}$$

$$\begin{aligned}|\vec{C}| &= \sqrt{(4.0)^2 + (-2.0)^2} \\ &= \sqrt{16 + 4.0} = \sqrt{20} = 4.5(m)\end{aligned}\quad \theta = \tan^{-1} \frac{C_y}{C_x} = \tan^{-1} \frac{-2.0}{4.0} = -27^\circ$$

Find the resultant displacement of three consecutive displacements:  
 $\mathbf{d}_1=(15\mathbf{i}+30\mathbf{j}+12\mathbf{k})\text{cm}$ ,  $\mathbf{d}_2=(23\mathbf{i}+14\mathbf{j}-5.0\mathbf{k})\text{cm}$ , and  $\mathbf{d}_3=(-13\mathbf{i}+15\mathbf{j})\text{cm}$

$$\begin{aligned}\vec{D} &= \vec{d}_1 + \vec{d}_2 + \vec{d}_3 = (15\vec{i} + 30\vec{j} + 12\vec{k}) + (23\vec{i} + 14\vec{j} - 5.0\vec{k}) + (-13\vec{i} + 15\vec{j}) \\ &= (15 + 23 - 13)\vec{i} + (30 + 14 + 15)\vec{j} + (12 - 5.0)\vec{k} = 25\vec{i} + 59\vec{j} + 7.0\vec{k} (cm)\end{aligned}$$

Magnitude

$$|\vec{D}| = \sqrt{(25)^2 + (59)^2 + (7.0)^2} = 65(cm)$$