# PHYS 1443 – Section 003
# Lecture #4

*Monday, Sept. 8, 2003*
*Dr. Jaehoon Yu*

## Motion in Two Dimensions

- Vector Properties and Operations
- Motion under constant acceleration
- Projectile Motion

# Announcements

- Homework: 34 of you have signed up (out of 37)
  - Very good!!!
- e-mail distribution list:16 of you have subscribed so far.
  - This is the primary communication tool. So subscribe to it ASAP.
  - A test message has been sent last Wednesday for verification purpose
  - There will be negative extra credit from this week
    - -1 point if not done by 5pm, Friday, Sept. 12
    - -3 points if not done by 5pm, Friday, Sept. 19
    - -5 points if not done by 5pm, Friday, Sept. 26
- Quiz #1:
  - Average score of the class: 3.2
  - Quizzes are 15% of the final grades

# Displacement, Velocity and Speed

Displacement

$$\Delta x \equiv x_f - x_i$$

Average velocity

$$v_x \equiv \frac{x_f - x_i}{t_f - t_i} = \frac{\Delta x}{\Delta t}$$

Average speed

$$v \equiv \frac{\text{Total Distance Traveled}}{\text{Total Time Spent}}$$

Instantaneous velocity

$$v_x \equiv \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t} = \frac{dx}{dt}$$

Instantaneous speed

$$\left|v_x\right| \equiv \lim_{\Delta t \to 0} \left|\frac{\Delta x}{\Delta t}\right| = \left|\frac{dx}{dt}\right|$$

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

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

Velocity as a function of time

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

Displacement as a function of velocity 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

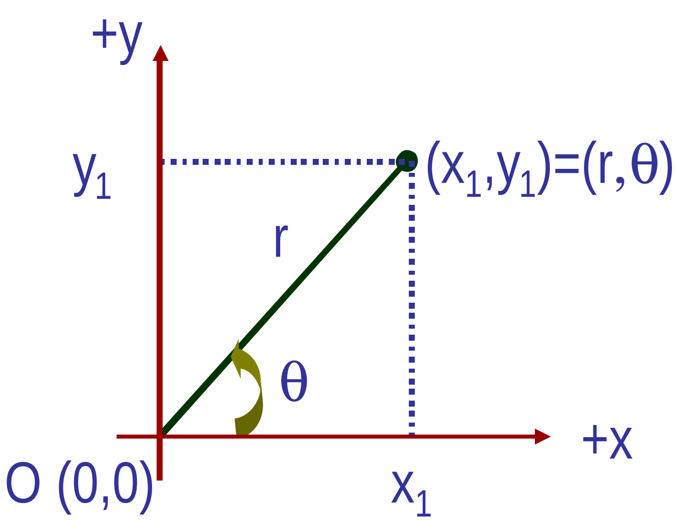
$$v_{xf}^2 = v_{xi}^2 + 2a_x\left(x_f - x_i\right)$$

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!!

# 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,θ)
- Vectors become a lot easier to express and compute



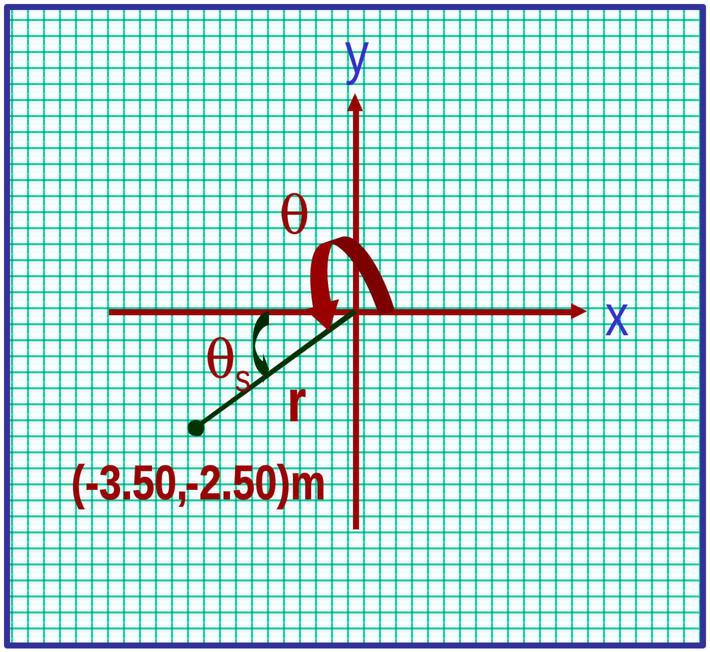

How are Cartesian and Polar coordinates related?

$$x = r\cos q$$
$$y = r\sin q$$

$$r = \sqrt{\left(x_1^2 + y_1^2\right)}$$
$$\tan q = \frac{y_1}{x_1}$$

# Example

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




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

$$q = 180 + q_s$$

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

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

$$\therefore q = 180 + q_s = 180^{o} + 35.5^{o} = 216^{o}$$

# Vector and Scalar

Vector quantities have both magnitude (size) and direction

*Force, gravitational pull, momentum*

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

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

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Scalar quantities have magnitude only

*Energy, heat, mass, speed*

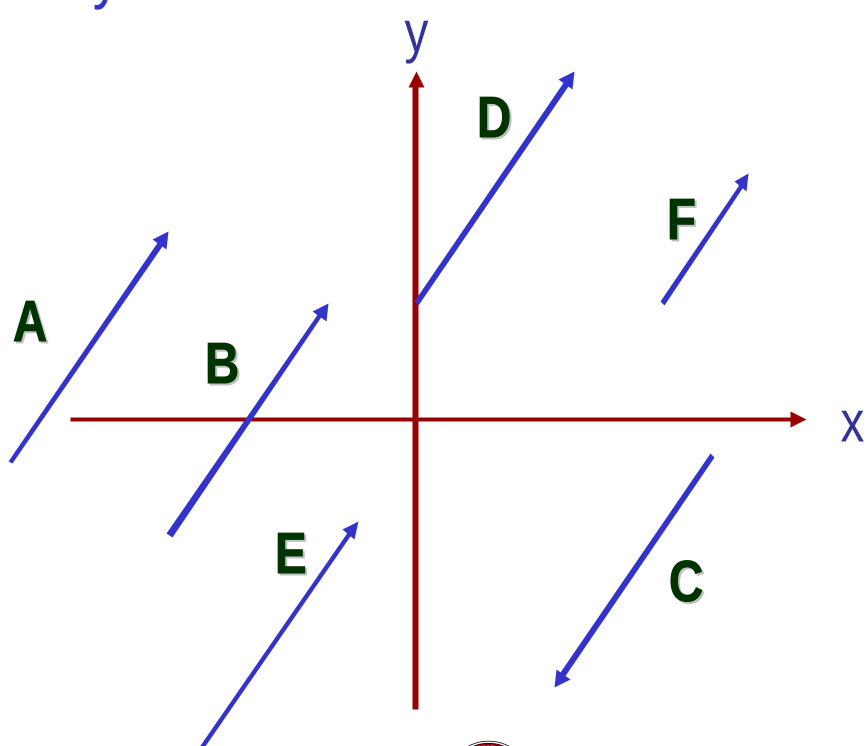
Can be completely specified with a value and its unit

Normally denoted in normal letters, *E*

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**

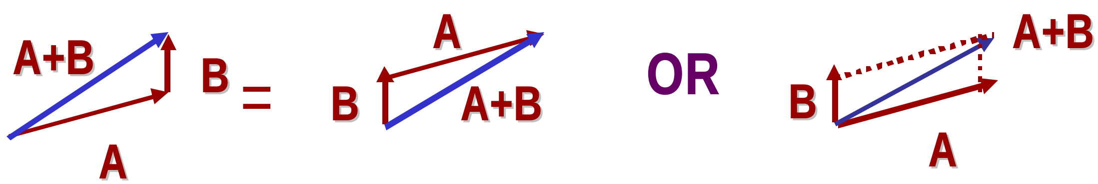
Why aren't the others?

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

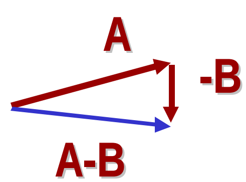
**F:** The same direction but different magnitude

# 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**)



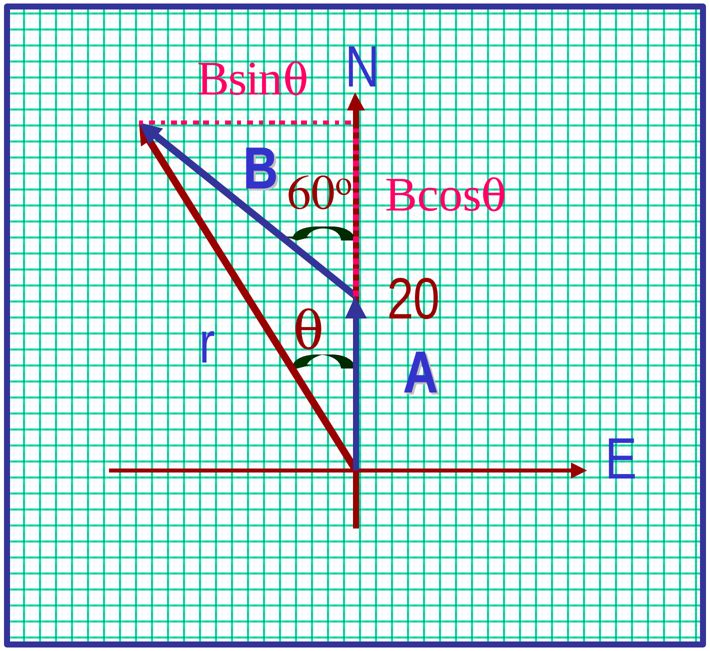

Since subtraction is the equivalent to adding a negative vector, subtraction is also commutative!!!

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

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

# Example

A car travels 20.0km due north followed by 35.0km in a direction 60.0$^{o}$ west of north. Find the magnitude and direction of resultant displacement.




$$r = \sqrt{(A + B\cos q)^2 + (B\sin q)^2}$$

$$= \sqrt{A^2 + B^2(\cos^2 q + \sin^2 q) + 2AB\cos q}$$

$$= \sqrt{A^2 + B^2 + 2AB\cos q}$$

$$= \sqrt{(20.0)^2 + (35.0)^2 + 2\times 20.0\times 35.0\cos 60}$$

$$= \sqrt{2325} = 48.2(km)$$

$$q = \tan^{-1}\frac{|\vec{B}|\sin 60}{|\vec{A}| + |\vec{B}|\cos 60}$$

$$= \tan^{-1}\frac{35.0\sin 60}{20.0 + 35.0\cos 60}$$

$$= \tan^{-1}\frac{30.3}{37.5} = 38.9^{o} \text{ to W wrt N}$$

Find other ways to solve this problem…