Welcome to Physics 7B!

Prof. John Conway

office: 311 Phy/Geo

office hours: Monday 9:00-10:30

phone: 754-7639 (not recommended)

email: conway@physics.ucdavis.edu

Course Organization, Etc.

- 10 lectures on Tuesdays
- quiz each week starting next week: **may be at the beginning, middle or end of lecture!**
- will use PRS starting next week
- two DL meetings per week
- final exam 19 March, 10:30 am
- main course website:

  http://www.physics.ucdavis.edu/~jconway/teaching/Physics-7B-W07/calendar.html

Vectors: Motion/Forces/Momentum

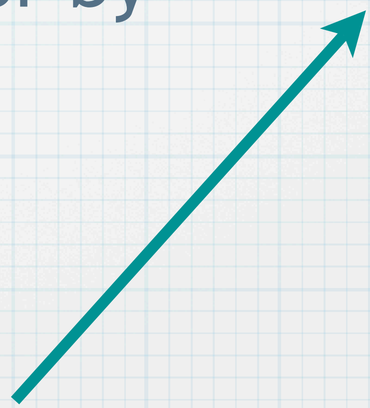
Prof. John Conway
Physics 7B - Lecture 1

Vectors Defined

A vector is a mathematical object which has

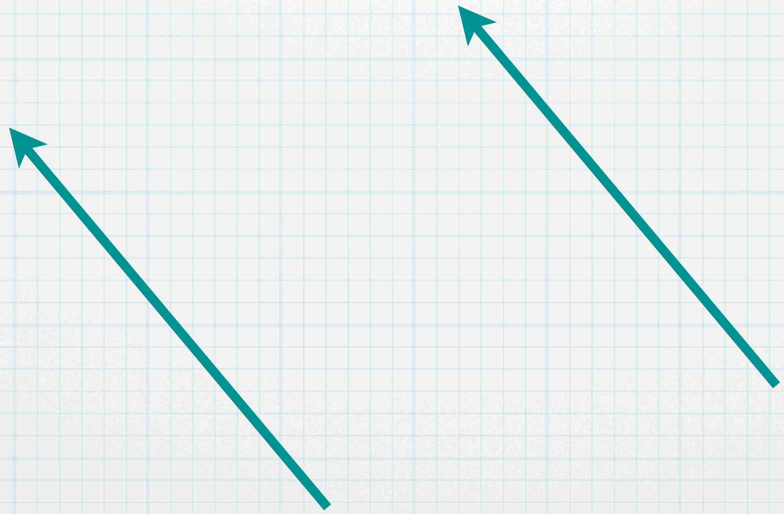
- magnitude (length)
- direction

We often represent a vector by drawing an arrow:



Vectors Defined

- A vector does not have a position in space!
- These two vectors are the same since they have the same direction and magnitude:



Vectors are Useful

We can use vectors to represent

- position in space
- velocity
- forces
- fields (electric, magnetic, ...)
- what else?

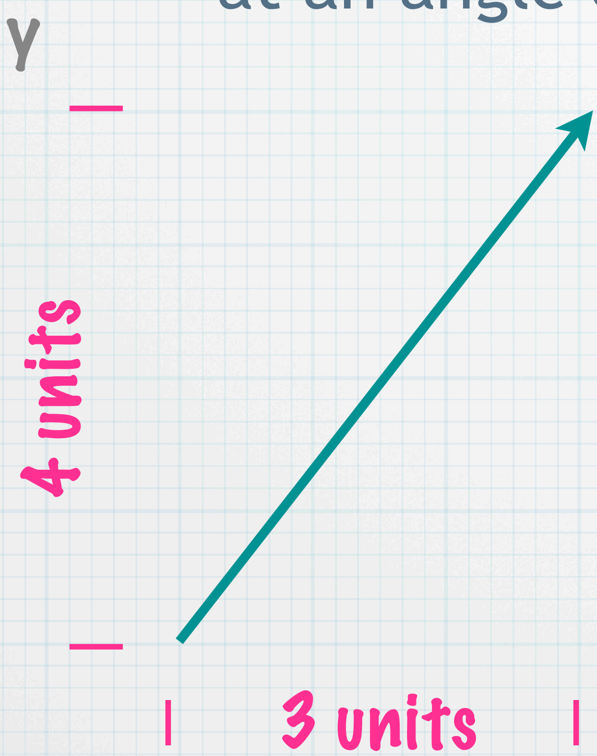
For the mathematically inclined...

- scalar: single number 47.3
- vector: 1-D array (34.1, -15.2, 22.1, 39.0)
- tensor: n-D array

5.1	0.5	-3.2
1.1	20.1	6.5
33.5	0.4	-0.5

Representing Vectors

- Let's start with a two-dimensional vector which is five units in magnitude, and oriented at an angle of 53.1 degrees from horizontal



$$\begin{aligned} \bar{A} &= 3\hat{x} + 4\hat{y} \\ &= 3\hat{i} + 4\hat{j} \\ &= (3, 4) \end{aligned}$$

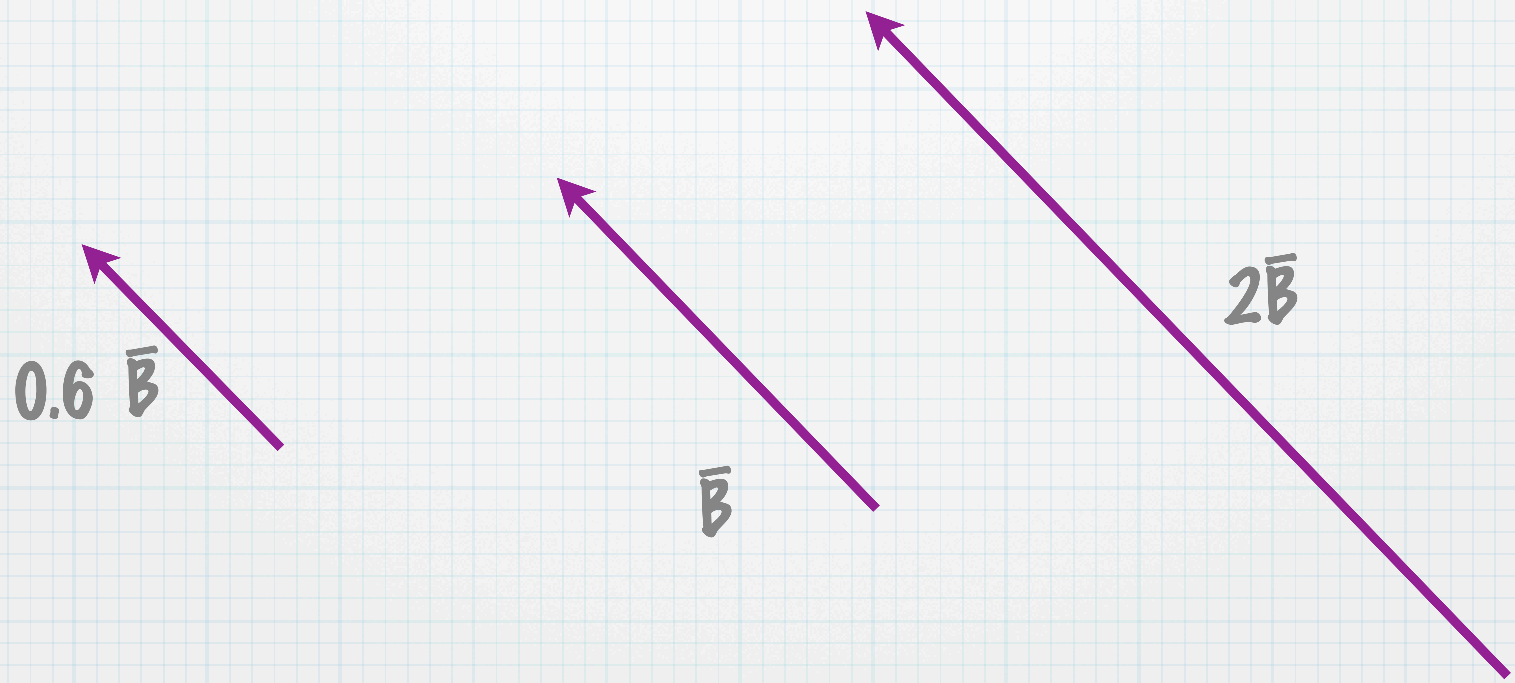
What are the funny things with hats??

Representing Vectors

- A vector is expressed in a particular coordinate system (also called “basis”)
- We often use Cartesian coordinates (x,y,z) as the basis for vectors
- Coordinate system has origin, scale, orientation, and “handedness”
- To understand how to write vectors, though, we need to first understand how to scale and add them!

Scaling Vectors

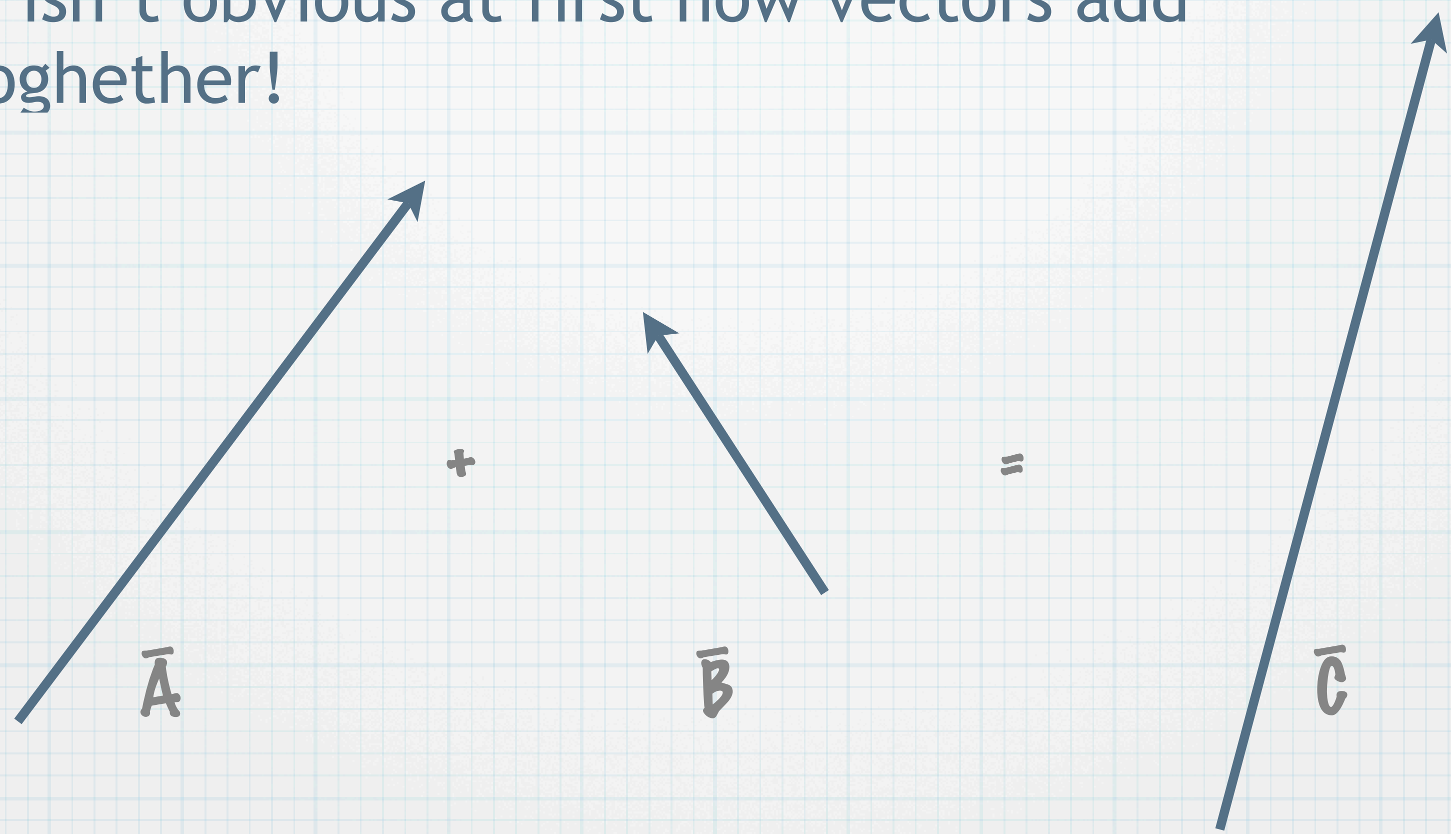
- Scaling a vector (multiplying it by a scalar number) makes it either longer or shorter:



Scaling a vector does not change its direction!

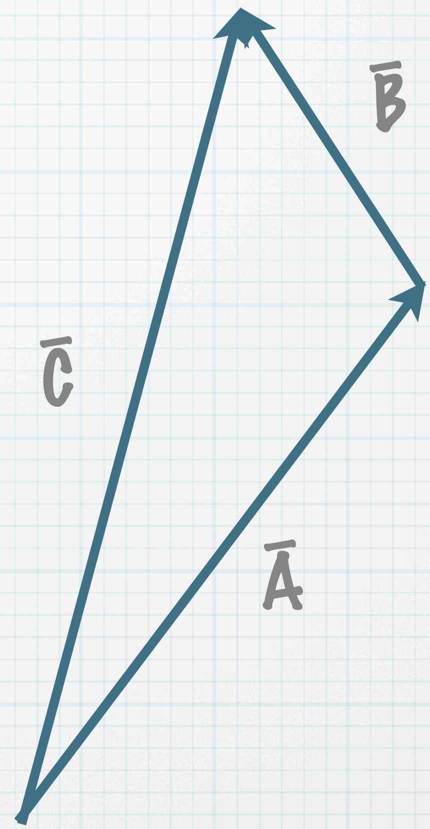
Adding Vectors

It isn’t obvious at first how vectors add toghether!



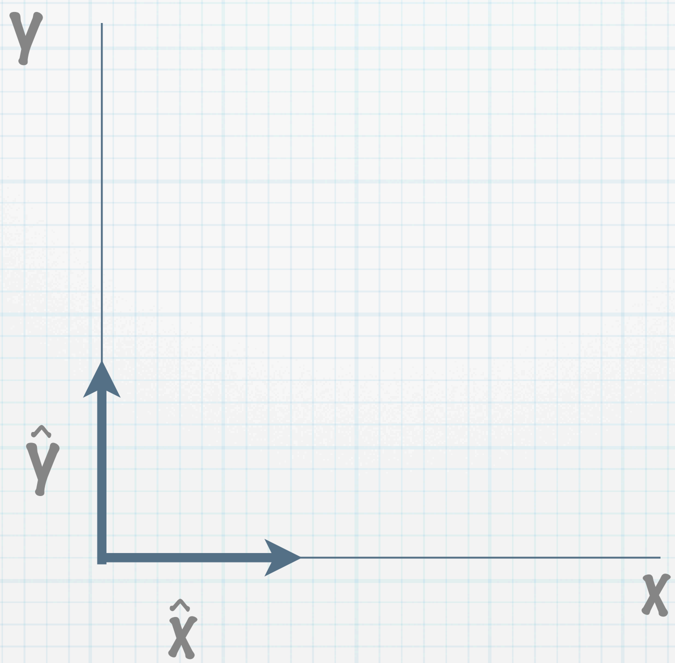
Adding Vectors

You simply put them head to tail to get the sum:



The sum of two vectors is another vector!

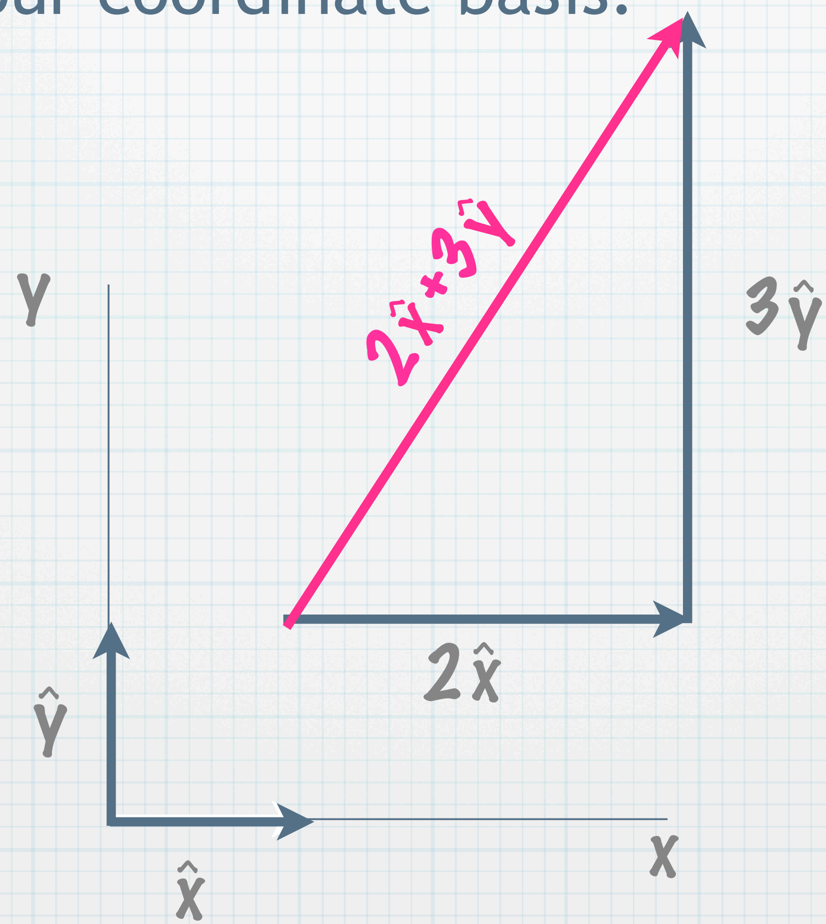
Unit Vectors



The funny things with hats are **unit vectors** which lie along the coordinate axes and have length 1 (unit length).

Building a Vector

- To build a vector we scale and add the unit vectors in our coordinate basis:



Adding Vectors

- It is trivial to add vectors: just add them component by component

$$\begin{aligned}\bar{A} &= 3\hat{x} + 4\hat{y} \\ \bar{B} &= -2\hat{x} + \hat{y} \\ \bar{C} &= \bar{A} + \bar{B} \\ &= \hat{x} + 5\hat{y}\end{aligned}$$

Just remember to keep the x components distinct from the y components! No mixing!

Subtracting Vectors

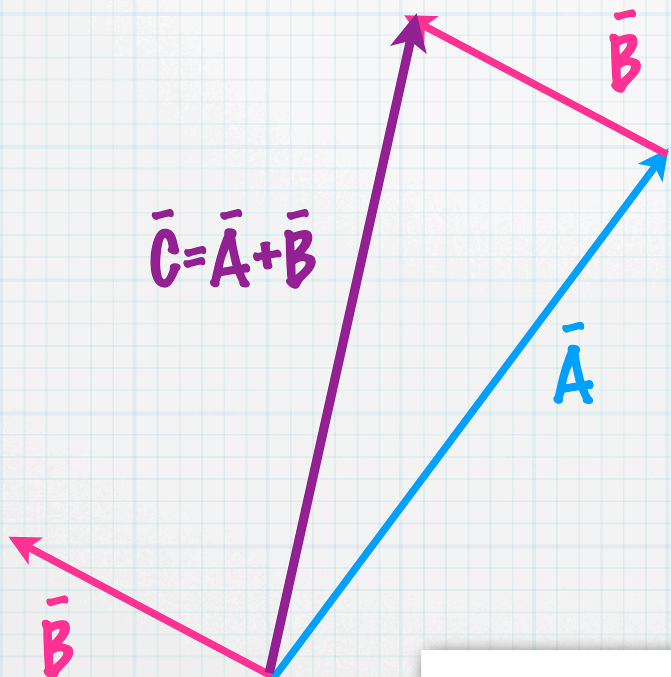
- It is trivial to substract vectors: just add the opposite component by component

$$\begin{aligned} \bar{A} &= 3\hat{x} + 4\hat{y} \\ \bar{B} &= -2\hat{x} + \hat{y} \\ \bar{C} &= \bar{A} - \bar{B} \\ &= 5\hat{x} + 3\hat{y} \end{aligned}$$

Just remember to keep the x components distinct from the y components! No mixing!

Adding/Subtracting Graphically

- head to tail? tail to head??

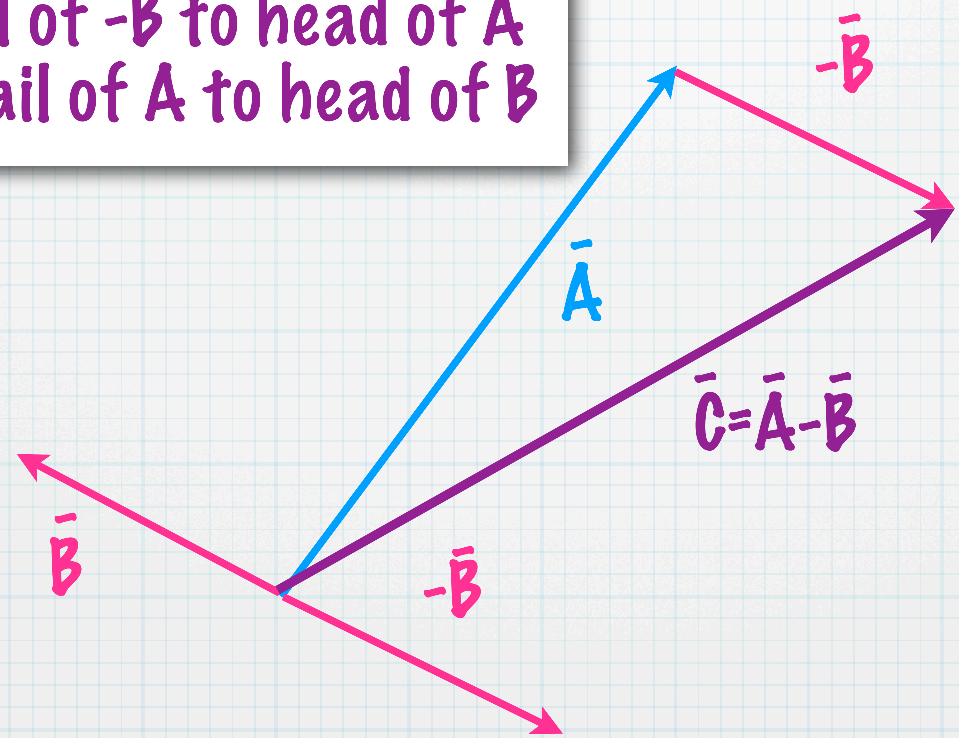


To add vector B to A:
1. "move" tail of B to head of A
2. connect tail of A to head of B

Adding/Subtracting Graphically

- head to tail? tail to head??

To subtract vector B from A:
1. "move" tail of -B to head of A
2. connect tail of A to head of B



Vector Magnitude

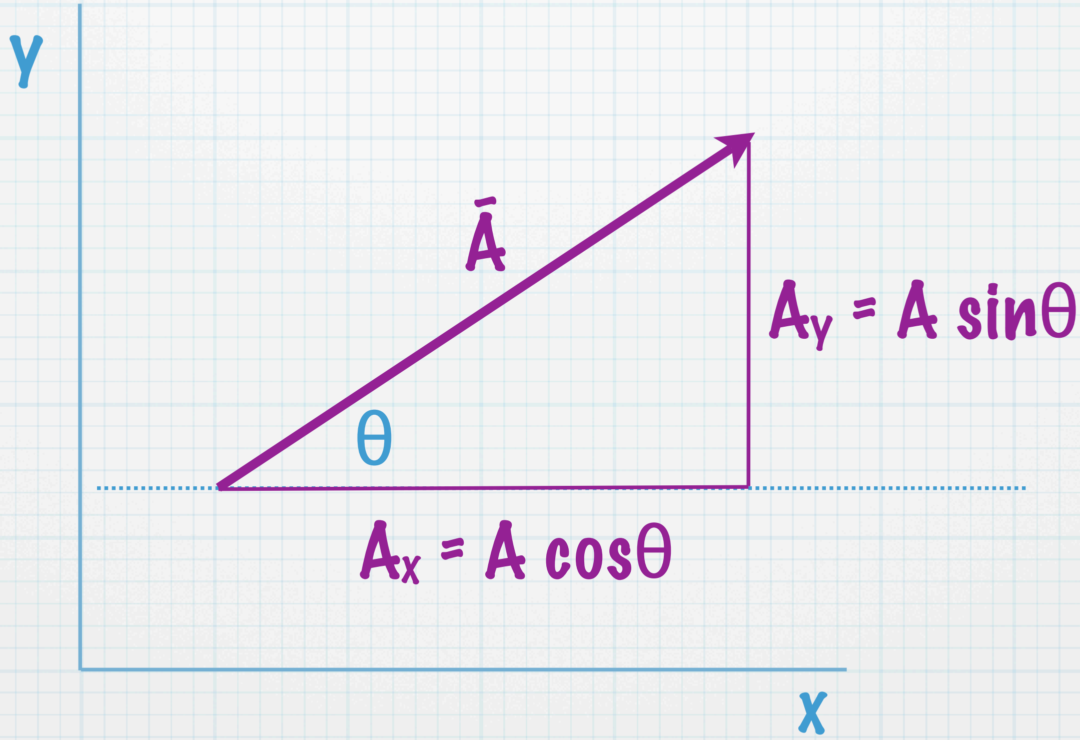
- To find the magnitude (length) of a vector, you simply take the sum of the squares of its components, and then take the square root of that (Pythagoras):

$$
\begin{aligned}
\bar{A} &= 3\hat{x} + 4\hat{y} \\
|\bar{A}| \equiv A &= \sqrt{3^2 + 4^2} = \sqrt{25} = 5
\end{aligned}
$$

Note that the magnitude of a vector is **not** a vector: it's a scalar (a single number) > 0

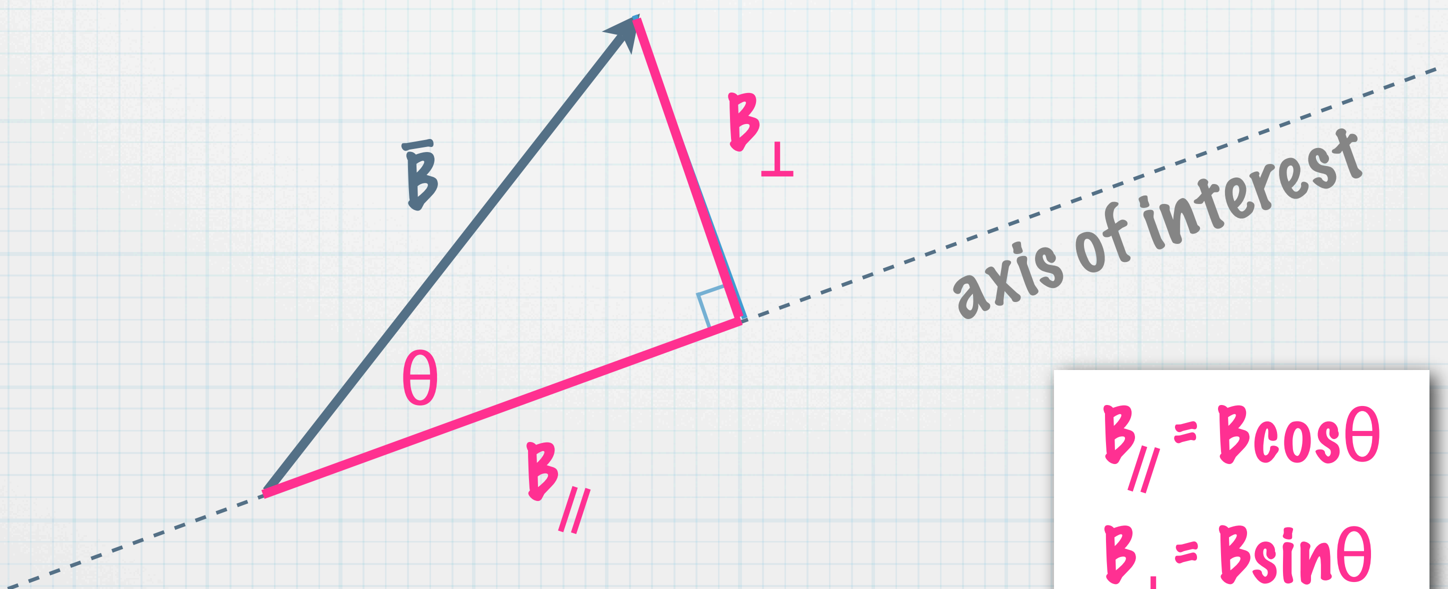
Vector Components

- yes, we have to use sines and cosines!



Vector Projections

- Often in physics we just want to know the <u>projection</u> of a vector parallel or perpendicular to some axis
- To do this you simply use the appropriate right triangle and noodle it out:

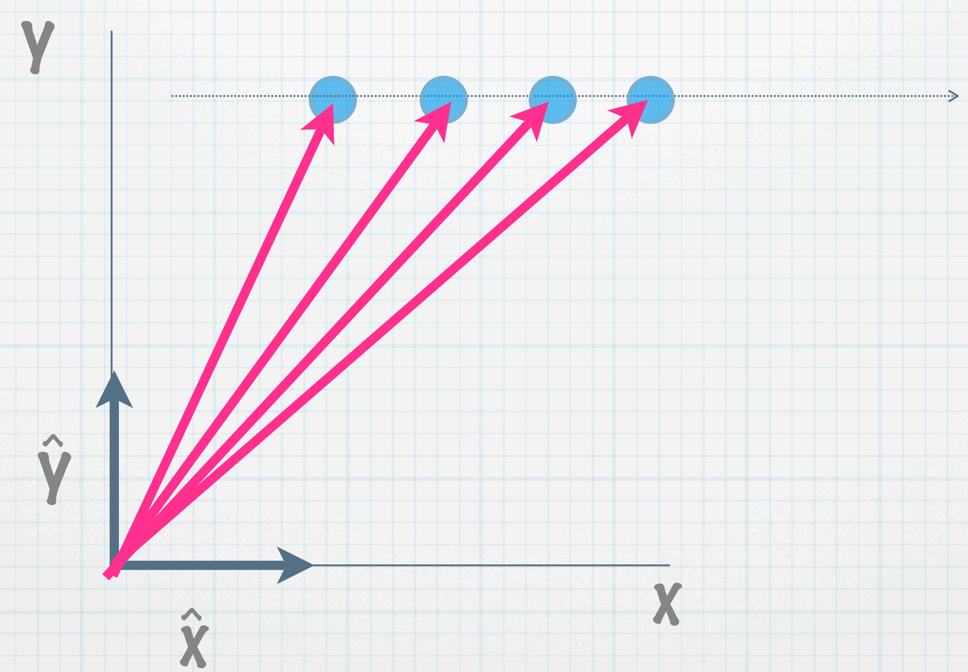


$$B_{//} = B\cos\theta$$

$$B_{\perp} = B\sin\theta$$

Position Vectors

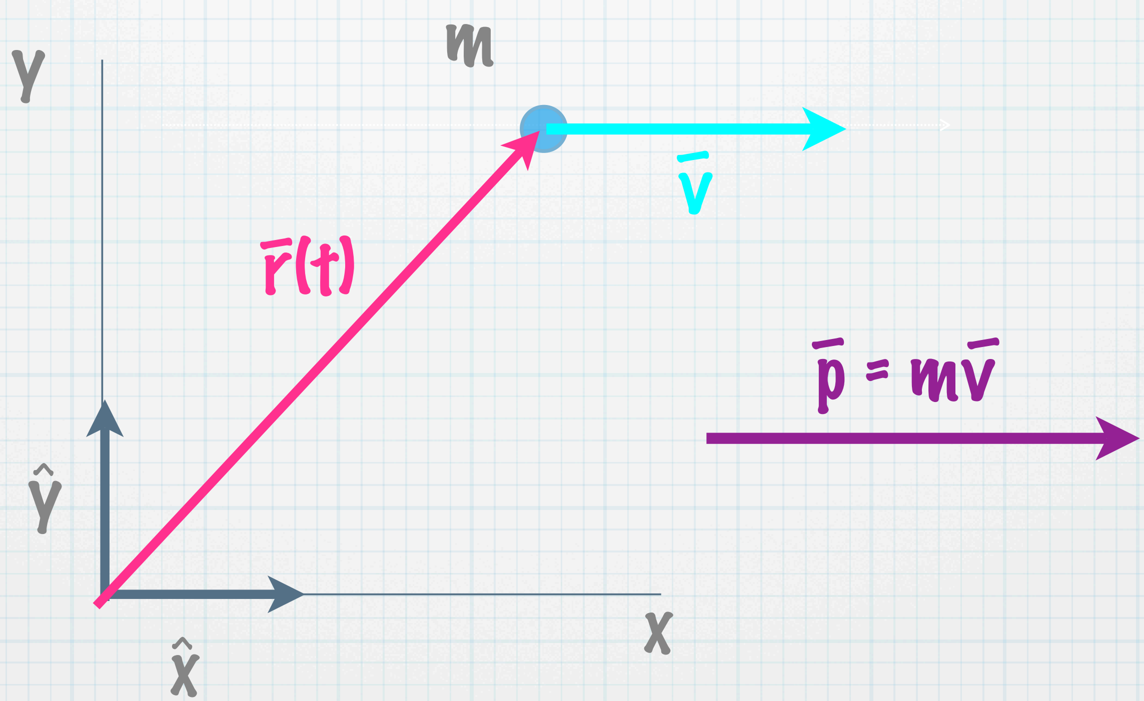
- We use a vector with one end at the origin to indicate a position in space:



In fact the position vector may be a function of time!

Momentum

- The product of the mass of an object and its velocity is its momentum



Clearly since velocity is a vector, momentum is also a vector!

Conservation of Momentum

- The total momentum of a closed system is always conserved (constant)

$$\sum \bar{F}_{ext} = \frac{d\bar{p}}{dt}$$

- This is true even if energy is not conserved! (example: inelastic collision)
- For various physical systems (cars, planets...) must consider conservation of both energy and momentum
- "Closed" system: no external forces

Demo: carts on track

Impulse

- For a non-closed system (subject to an external force) the change in momentum is equal to the force times the time it acts:

$$\Delta p = F\Delta t = \text{impulse}$$

- Review question: what happens to a body subject to a force acting through a certain distance?

Equilibrium

- For a body to be in equilibrium, one of the conditions is that the net external force on the object is zero:

$$\sum \bar{F}_{ext} = 0$$

- "Equilibrium" does not necessarily mean that an object is not moving! It just means it has constant momentum

- Next week: rotation and angular momentum