Physics 203

for syllabus & important messages see www.physics.rutgers.edu/~croft

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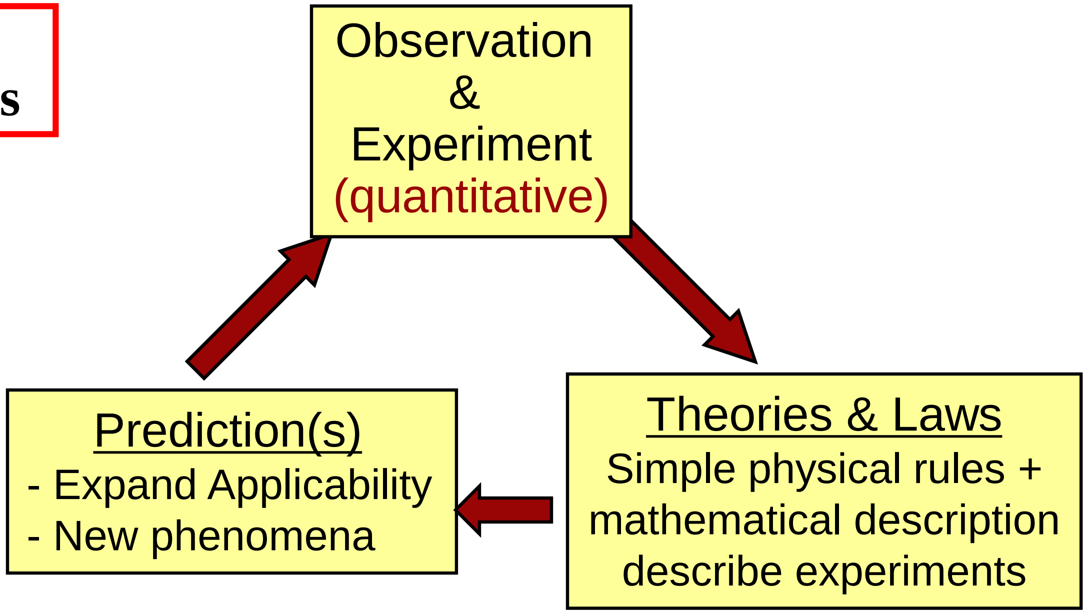
- **Physics – nature of things moving – Aristotle 350 BC**
- **Spirit of physics --e.g. Pythagorean tradition ~ 550 BC**
  - **musical tones described by mathematics (exactly!)**

    - all nature can be described by mathematics

    (approximations and limitations must be recognized)
- **careful observation of natural phenomena essential**

•Physics underlies all sciences



'Beauty is truth, truth beauty,—that is all
Ye know on earth, and all ye need to know.' (Keats)

measure: Space, Time, & Matter

Units: SI or MKS System

Distance	Mass	Time
meter	kilogram	second
m	kg	s or sec

Originally:
1 m = 1/(10 Millionth) of distance from equator to North Pole
Now:
1 m = 1,650,763.7321 wavelengths of orange light emitted from Kr.

Derived units

speed = distance/time: m/sec

later will see

Weight (force of gravity on mass) = mass distance/ time^2

Newton = N= kg m/s^2 (unit of force)

Weight (in English units) = slug ft/s^2=pound=lb

unit conversion- mole method

60 mi/hr= ? m/s

$$60\,\frac{mi}{hr}\cdot\frac{1\,hr}{60\,min}\cdot\frac{1\,min}{60\,s}\cdot\frac{5280\,ft}{1\,mi}\cdot\frac{12\,in}{1\,ft}\cdot\frac{2.54\,cm}{1\,in}\cdot\frac{1\,m}{100\,cm} = \;?\;\; m/s$$

cancel

$$\frac{60\cdot 5280\cdot 12\cdot 2.54}{60\;\;60\;\;100} = \frac{5280\,(12)\,2.54}{6000\;1000} = \frac{26822.}{1000}$$

$$60\,\frac{mi}{hr.} \approx 26.8\; m/s$$

$$\frac{1\,mi}{hr} = 0.446\; m/s$$

Note: the **units** start and finish with distance/time. All conversions are unity conversions 1 hr = 60 min e.g. 1hr / 60min = 1.

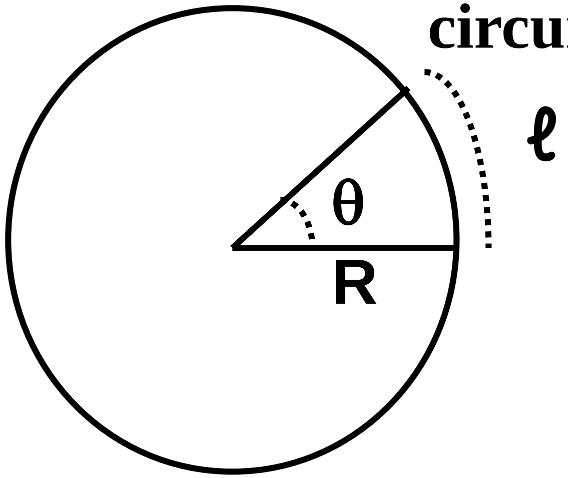
$$30\,mph \sim 13.4\; m/s$$

Problem Solving

1. Read problem carefully, reread
2. Draw a diagram and label
3. Write question in symbols
4. Find (better derive) relevant mathematical relation
5. Solve Equation
6. Plug in numbers
7. Check whether answer is reasonable
   (Numbers & Units) (Should it be + OR - ?)
8. Talk to someone about the problem and its solution

Measuring Angles

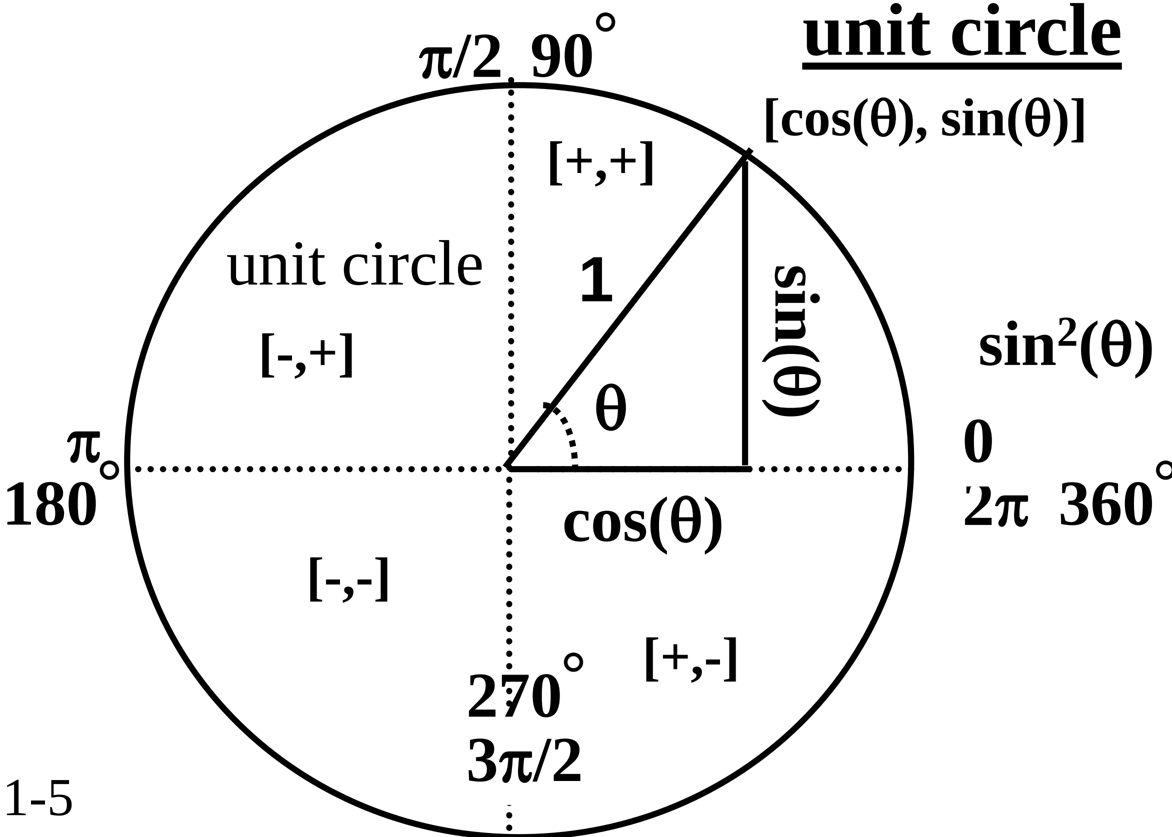
circumference = $2\pi R$



$$\theta(\text{radians}) = \frac{\ell}{R}$$

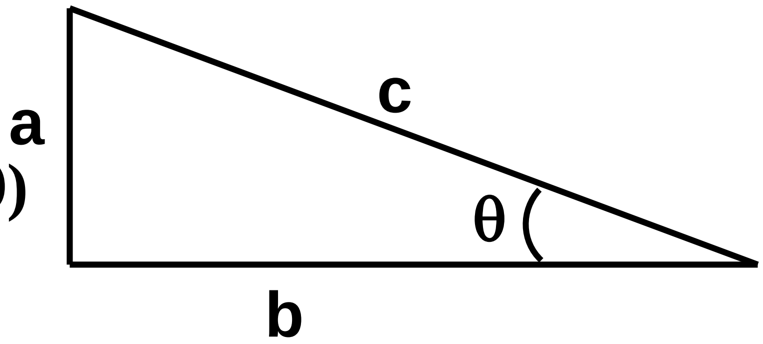
$$\theta(\text{degrees}) = \theta(\text{radians}) \; \frac{\ell}{2\pi R} \; 360$$

unit circle



$$\sin^2(\theta) + \cos^2(\theta) = 1$$

$$a^2+b^2=c^2$$



$$a = c\sin(\theta)$$

$$b = c\cos(\theta)$$

$$\sin(\theta) = \frac{a}{c} \qquad \theta = \sin^{-1}\left(\frac{a}{c}\right)$$

$$\cos(\theta) = \frac{b}{c} \qquad \theta = \cos^{-1}\left(\frac{b}{c}\right)$$

$$\tan(\theta) = \frac{a}{b} \qquad \theta = \tan^{-1}\left(\frac{a}{b}\right)$$

See link below for demo on Pythagorean theorem

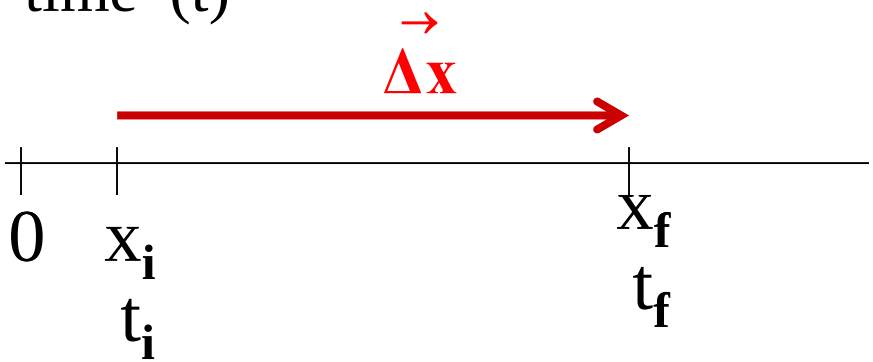
http://i.imgur.com/W8VJp.gif

vector in 1D - magnitude (length) - direction

one dimension motion

position   coordinate (x) – measure of position

time (t)



$\rightarrow$ define

+ direction

initial position time

final position time

displacement $\Delta x = x_f - x_i$

- how far
- what direction + or -

magnitude

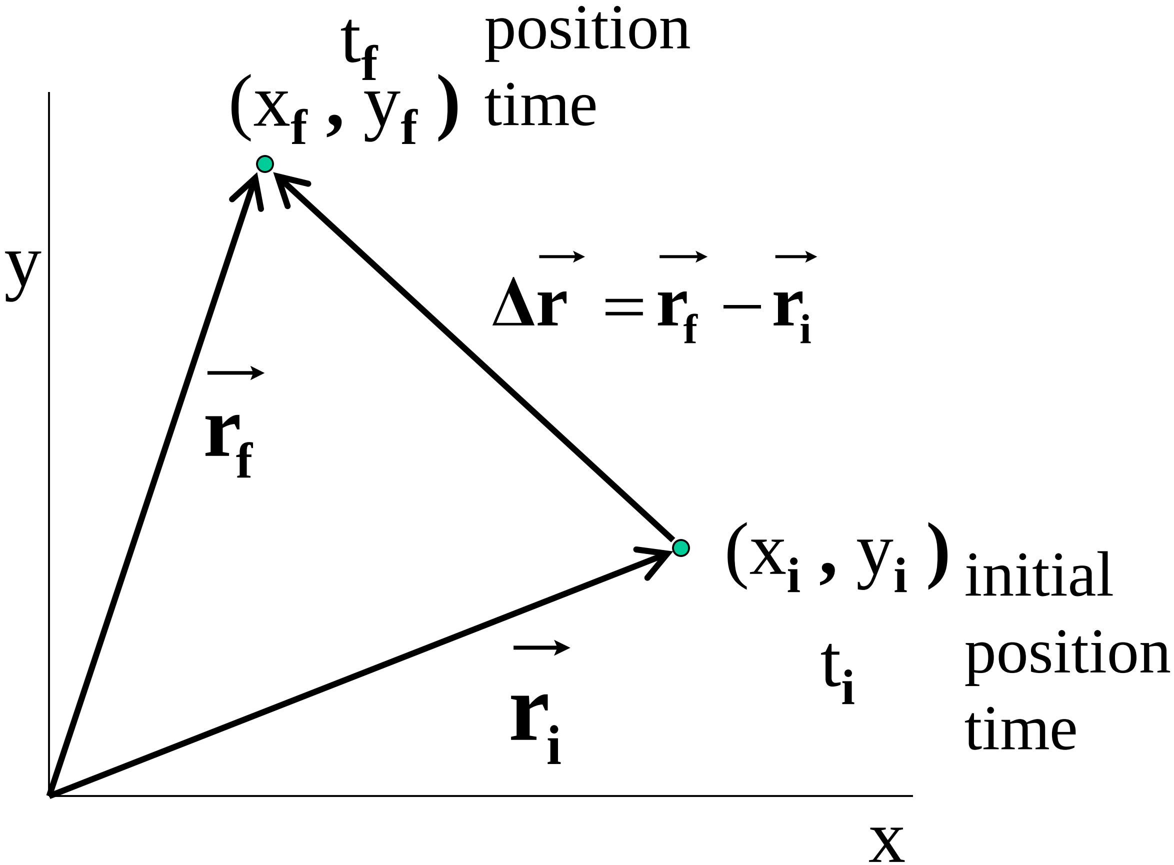
direction

average velocity $\bar{v} = \frac{\Delta x}{\Delta t} = \frac{x_f - x_i}{t_f - t_i}$

- how fast
- what direction + or -

vector (position and displacement)

- magnitude (length)
- direction



Note: unit vector notation discussed at end of lecture

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

http://phet.colorado.edu/sims/vector-addition/vector-addition_en.html two dimensions

vector position label $\vec{r}$

2 ways to represent position

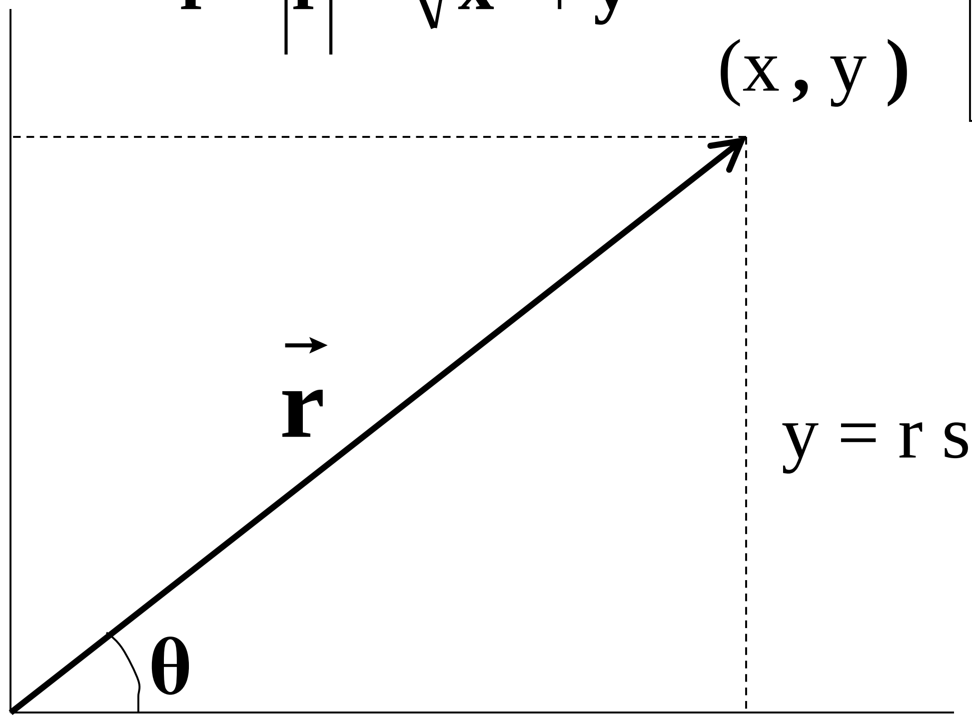
x component
y component

r magnitude
θ direction

y-dir

$$\mathbf{r} = |\vec{\mathbf{r}}| = \sqrt{\mathbf{x}^2 + \mathbf{y}^2}$$

(x , y)



y = r sin(θ)

x = r cos(θ)

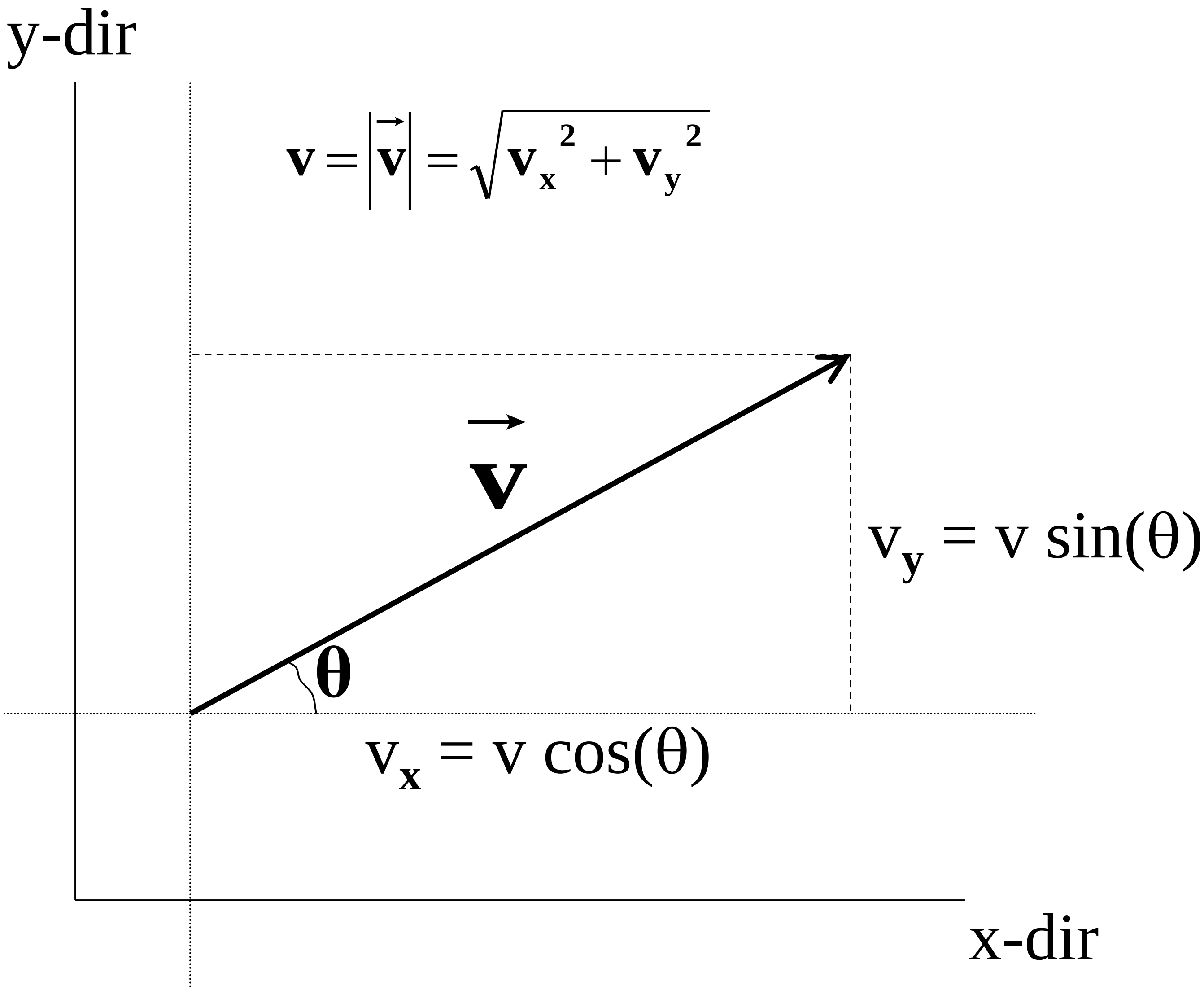
x-dir

$\sin(\theta) = \frac{y}{r}$	$\theta = \sin^{-1}(\frac{y}{r})$
$\cos(\theta) = \frac{x}{r}$	$\theta = \cos^{-1}(\frac{x}{r})$
$\tan(\theta) = \frac{y}{x}$	$\theta = \tan^{-1}(\frac{y}{x})$

position vector
- magnitude (length)
- direction

general vector not tied to particular origin

$$\mathbf{v} = \left|\vec{\mathbf{v}}\right| = \sqrt{\mathbf{v_x}^2 + \mathbf{v_y}^2}$$



$$\theta = \tan^{-1}\left(\frac{\mathbf{v_y}}{\mathbf{v_x}}\right)$$

$$\theta = \cos^{-1}\left(\frac{\mathbf{v_x}}{\mathbf{v}}\right)$$

$$\theta = \sin^{-1}\left(\frac{\mathbf{v_y}}{\mathbf{v}}\right)$$

vector components can be found using different angles

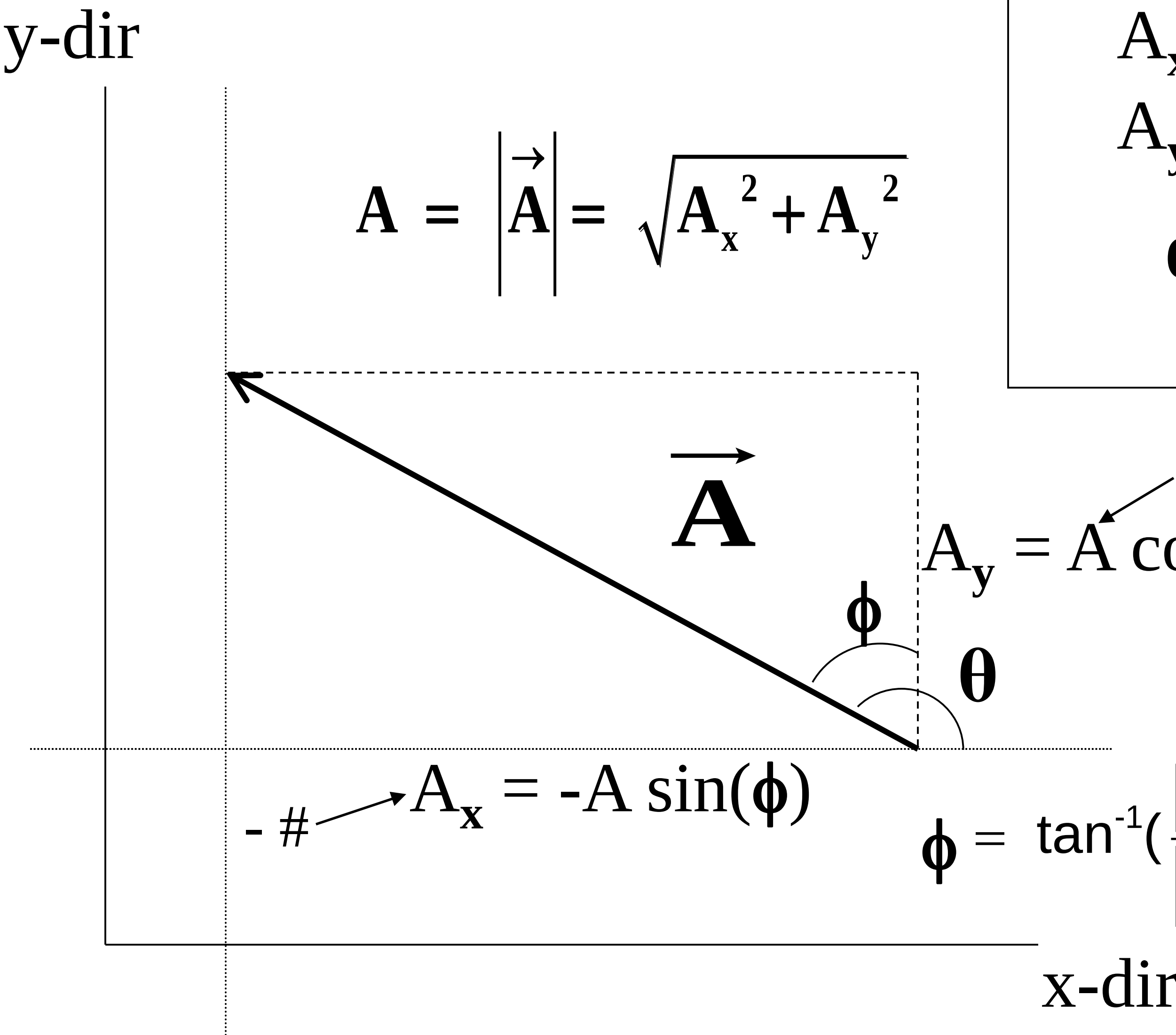
or

$$A_x = A\cos(\theta) \quad \text{(- \#)}$$

$$A_y = A\sin(\theta) \quad \text{(+ \#)}$$

$$\theta = \tan^{-1}\left(\frac{A_y}{A_x}\right)$$

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



+ #

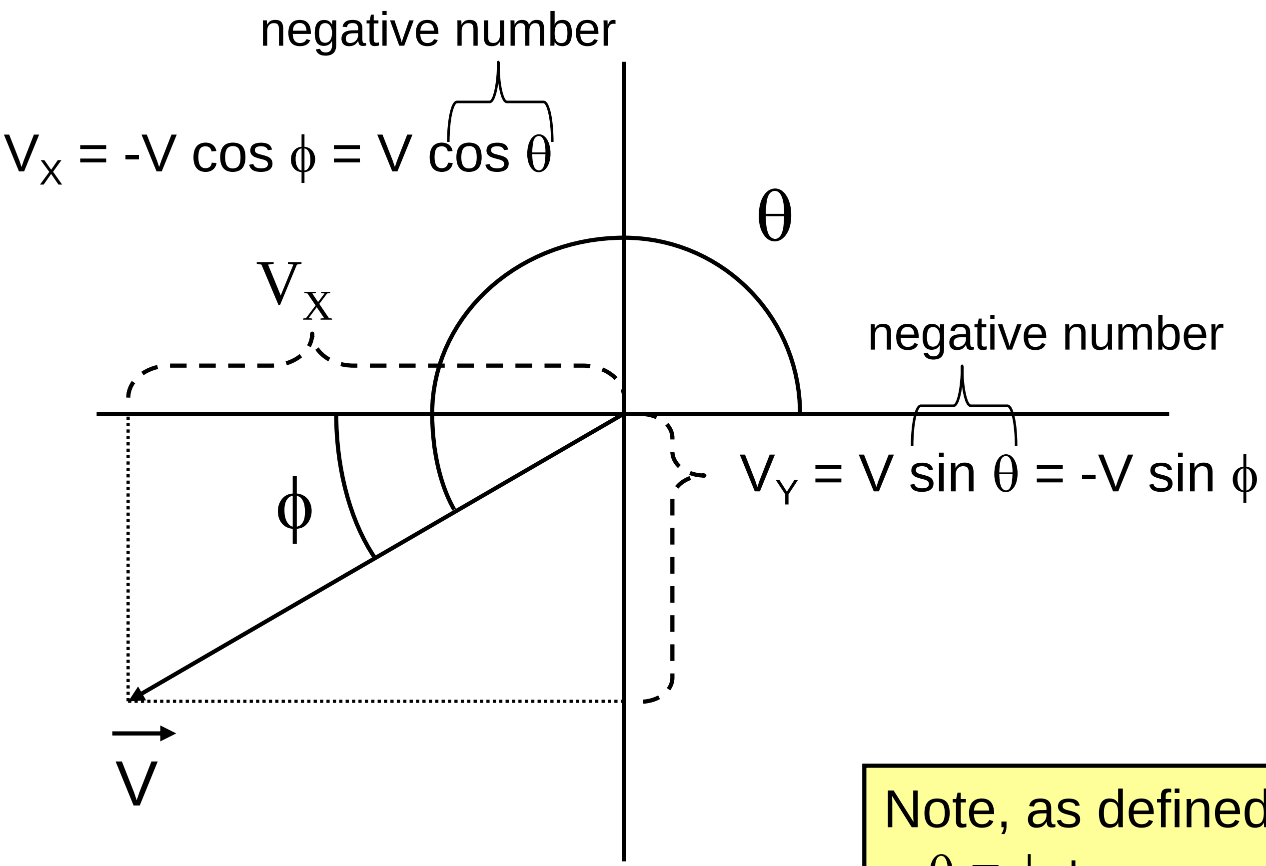
$$A_y = A\cos(\phi)$$

- #

$$A_x = -A\sin(\phi)$$

$$\phi = \tan^{-1}\left(\frac{|A_x|}{|A_y|}\right)$$

vector components can be found using different angles (angle bigger than 90º example)



Note, as defined above:

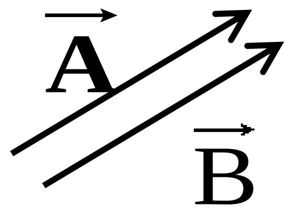
$\theta = \phi + \pi$

$\theta = \phi + 180^{O}$

$\sin\theta = \sin(\theta + 2\pi)$

Vector equality

$$\vec{A} = \vec{B}$$



$\Updownarrow$

$A_x = B_x$

$A_y = B_y$

$\Leftrightarrow$

$$|\vec{A}| = |\vec{B}|$$

$$\theta_A = \theta_B$$

Scalar Multiplication

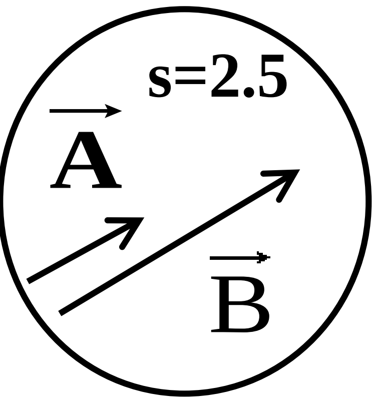
s = #

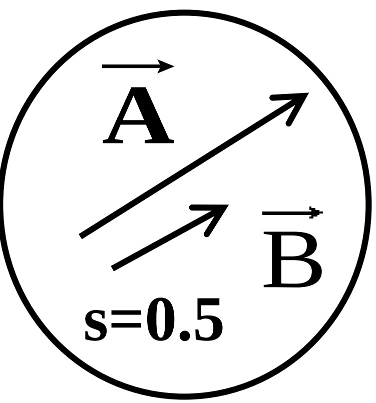
$$\vec{B} = s\vec{A} \Rightarrow \begin{cases} B_x = s\,A_x \\ B_y = s\,A_y \end{cases}$$

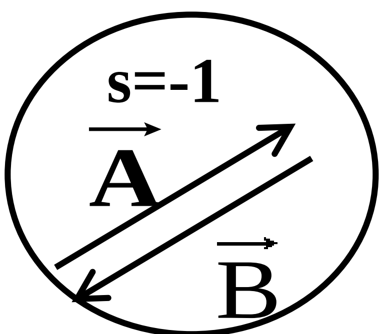
or

same direction
s times longer

$$\begin{cases} \theta_A = \theta_B \\ |\vec{B}| = s\,|\vec{A}| \end{cases}$$

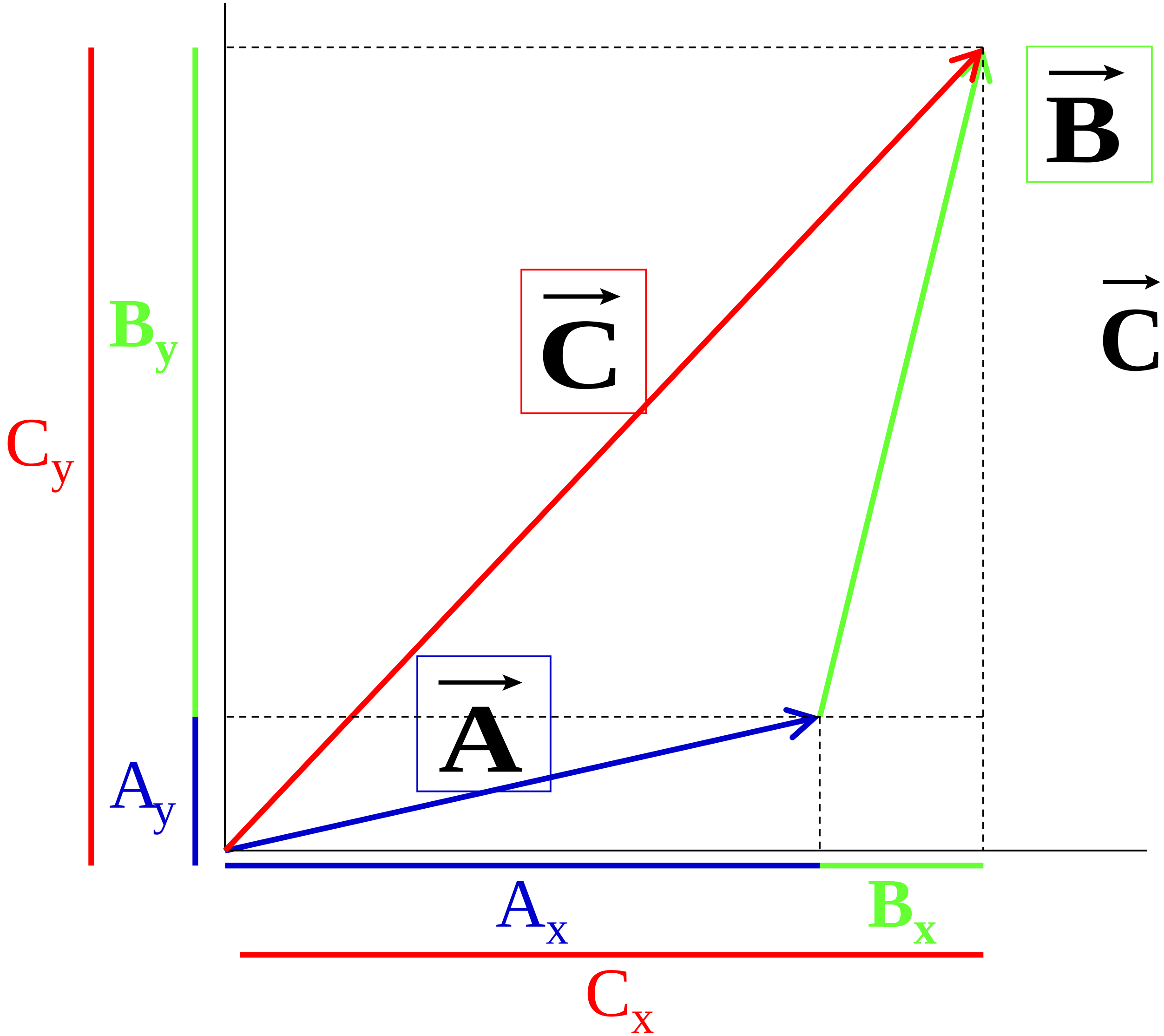






note: if s<0 then reverse vector direction

vector addition

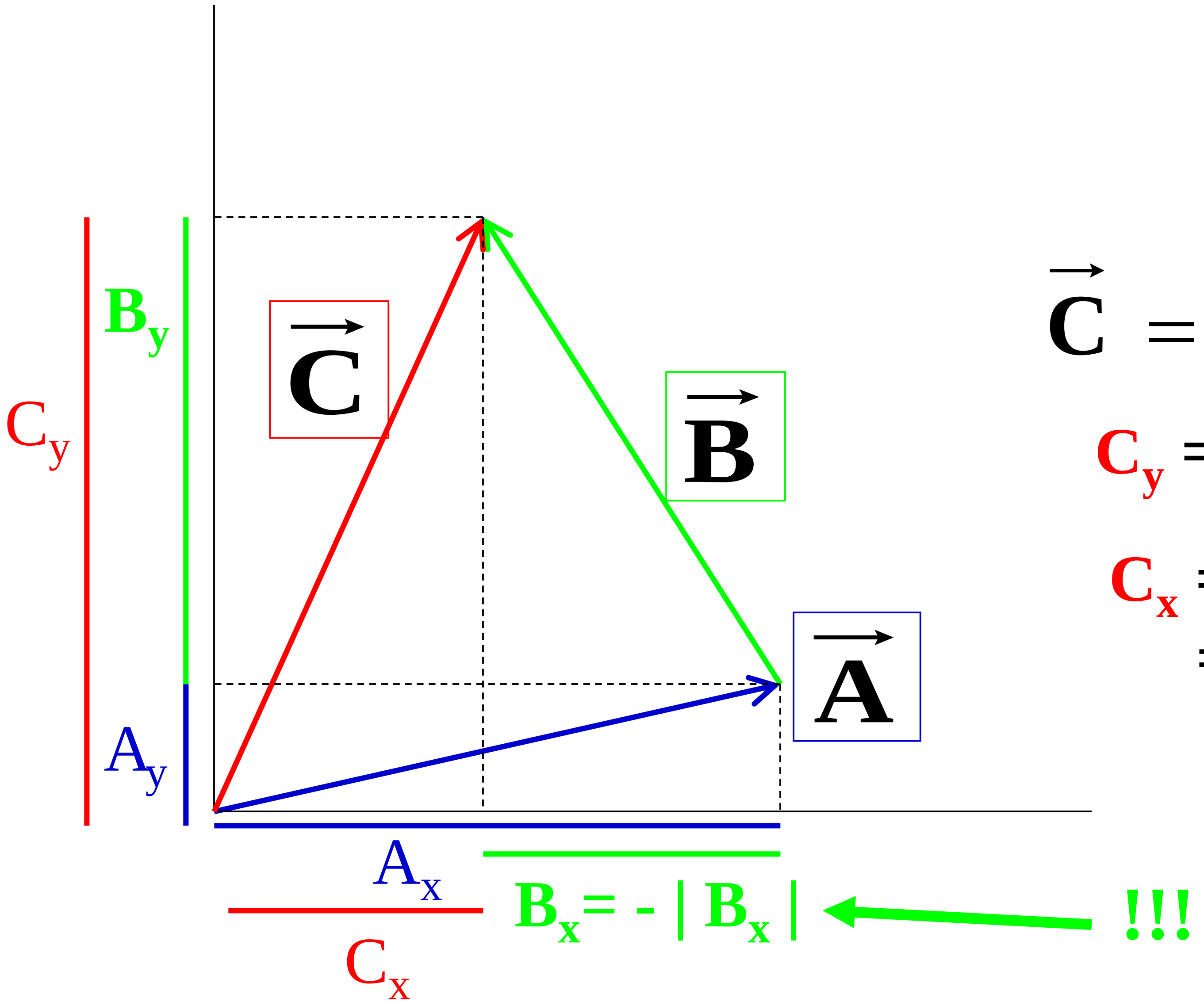


$$\vec{\mathbf{C}} = \vec{\mathbf{A}} + \vec{\mathbf{B}}$$

$$C_x = A_x + B_x$$

$$C_y = A_y + B_y$$

vector addition

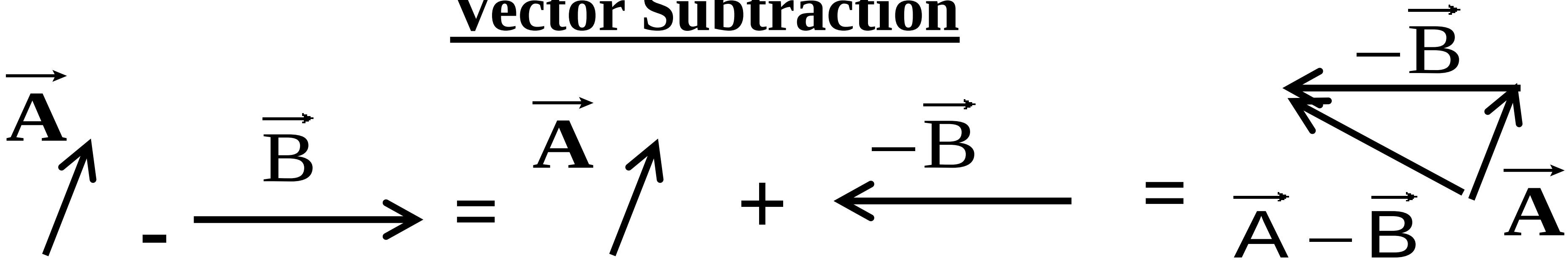


$$\vec{C} = \vec{A} + \vec{B}$$

$$C_y = A_y + B_y$$

$$C_x = A_x + B_x$$
$$= A_x - |B_x|$$

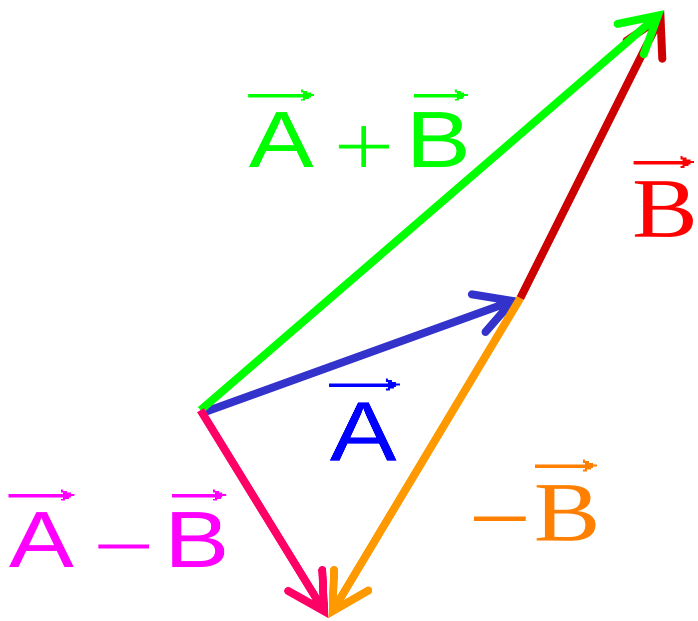
Vector Subtraction



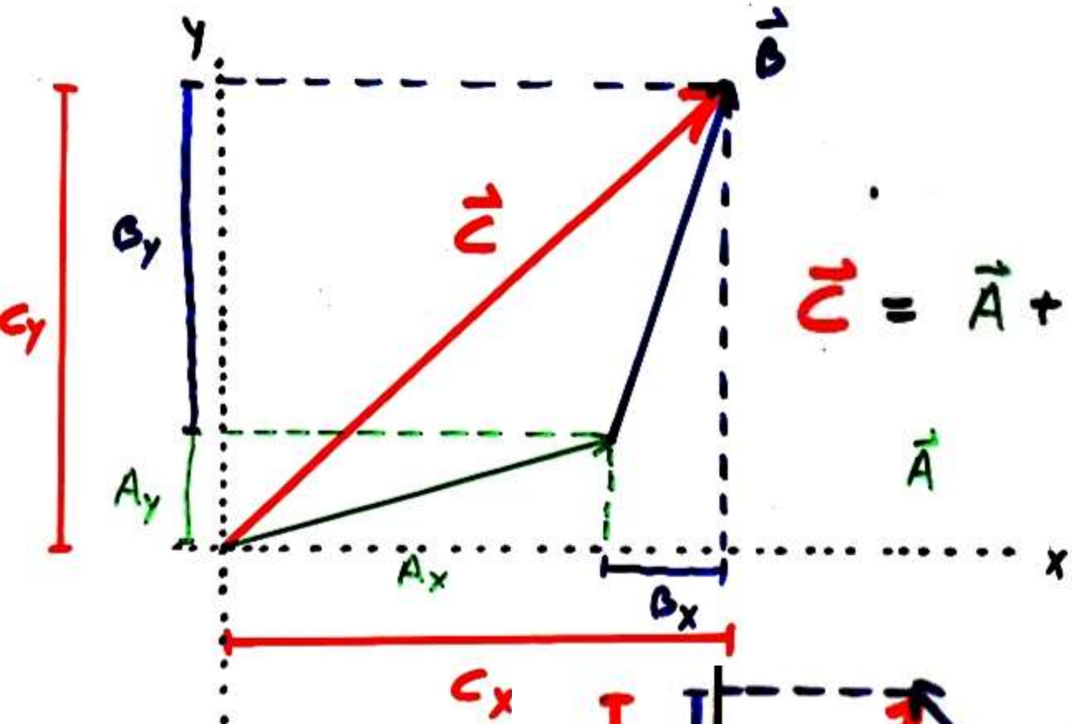
$$\vec{A}-\vec{B}=\vec{A}+\left\{-\vec{B}\right\}$$

{follows from vector addition + -1 vector reversal}

Comparison
vector
addition
subtraction



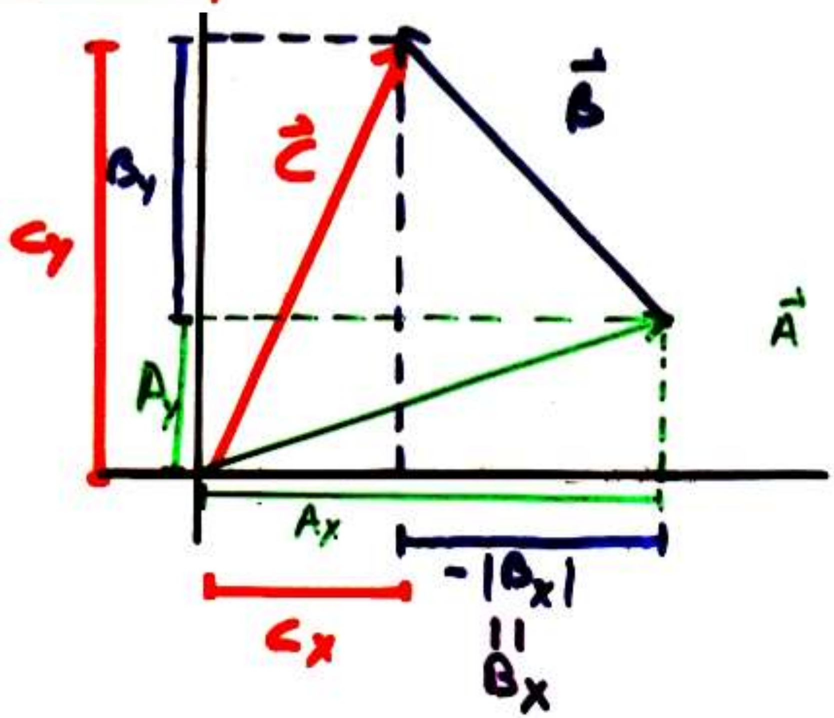
Vector Addition



$$\vec{C} = \vec{A} + \vec{B}$$

$$C_x = A_x + B_x$$

$$C_y = A_y + B_y$$



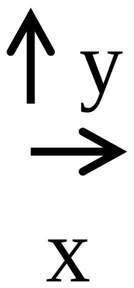
$$C_y = A_y + B_y$$

$$C_x = A_x + B_x$$

$$= A_x + (-)|B_x|$$

1-17 (other views)

Unit vectors their uses (book sometimes uses)



$$|\hat{y}|^2 = |\hat{x}|^2 = 1$$

Unit vectors along x and y directions
On length "1"

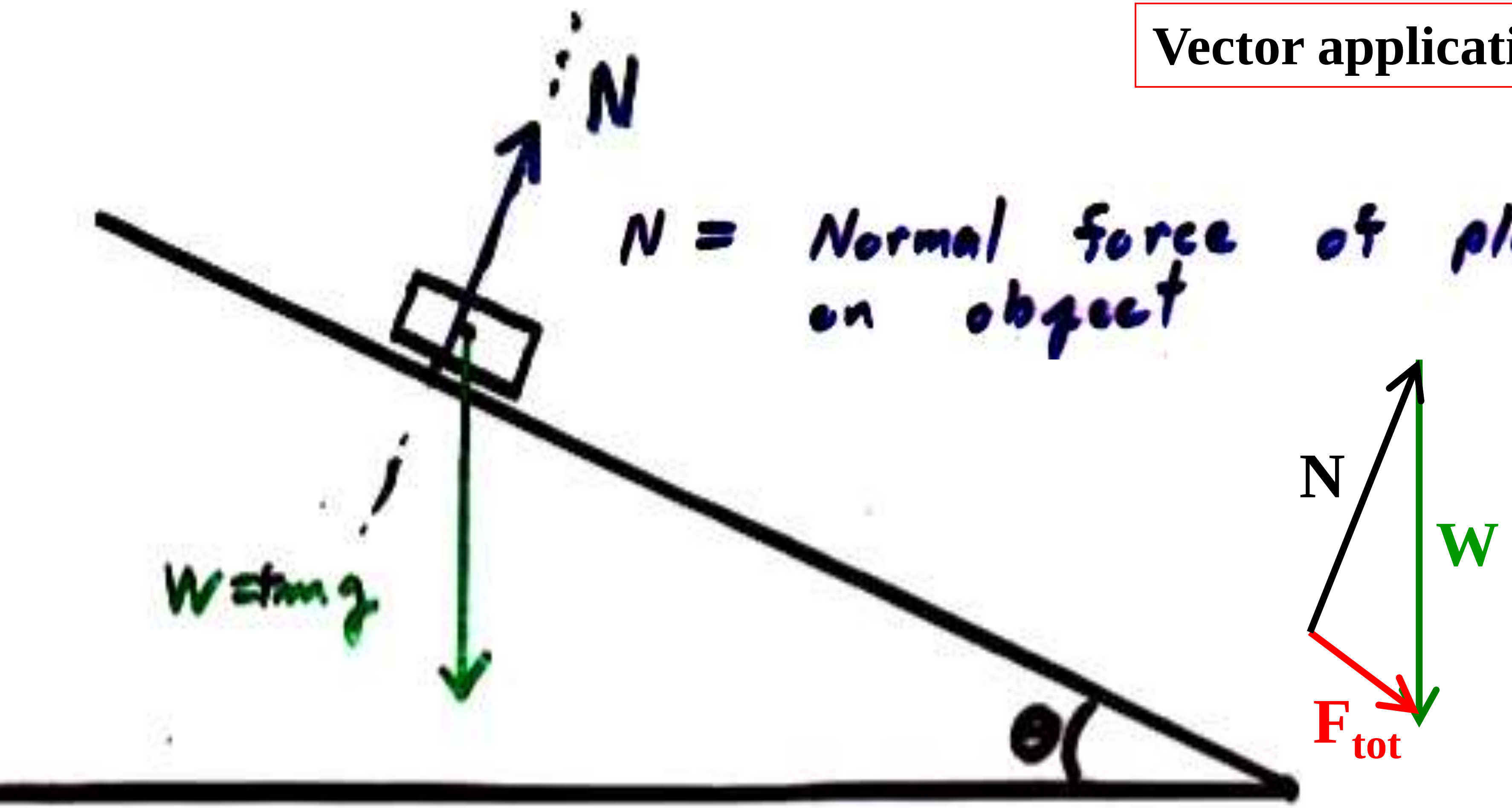
Notation allows keeping track of general vectors with unit vectors to keep track of direction and scalar multiplication to give magnitude.

$$\vec{A} = A_x \ \hat{x} + A_y \ \hat{y}$$

$$\vec{B} = B_x \ \hat{x} + B_y \ \hat{y}$$

$$\vec{A} + \vec{B} = (A_x + B_x) \ \hat{x} + (A_y + B_y) \ \hat{y}$$

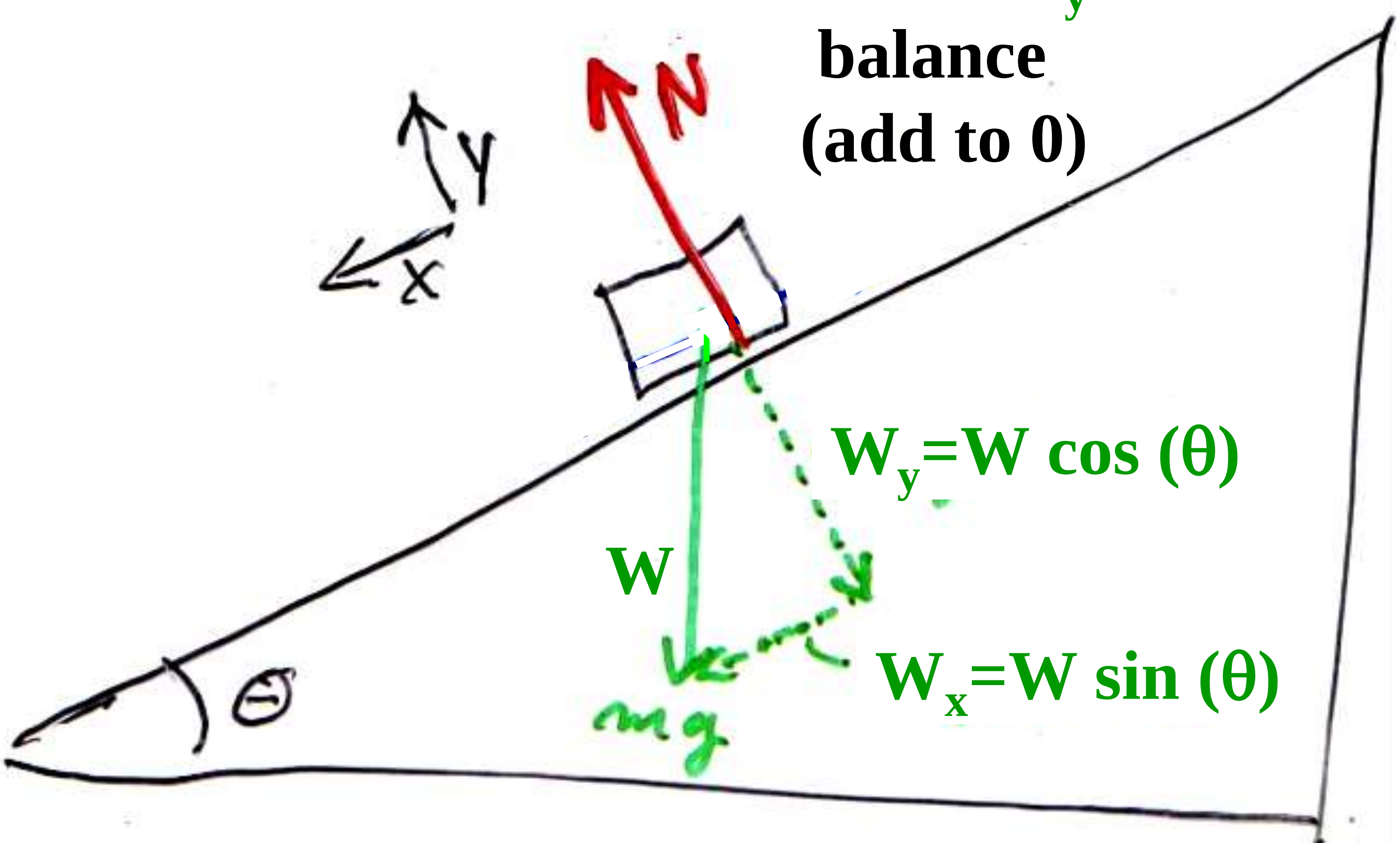
Vector application



N = Normal force of plane on object

W = +mg = Force of gravity on object
(Pull of earth on object)

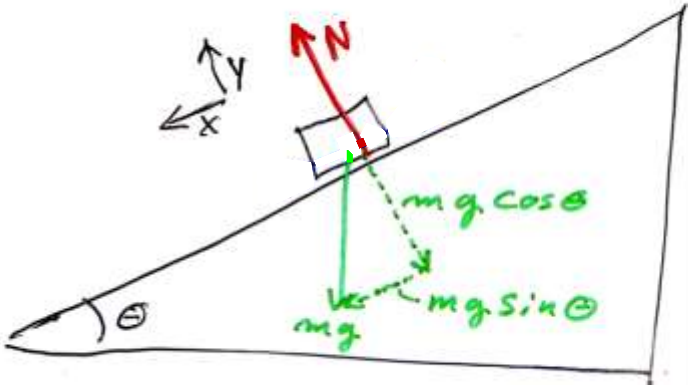
Forces add like vectors

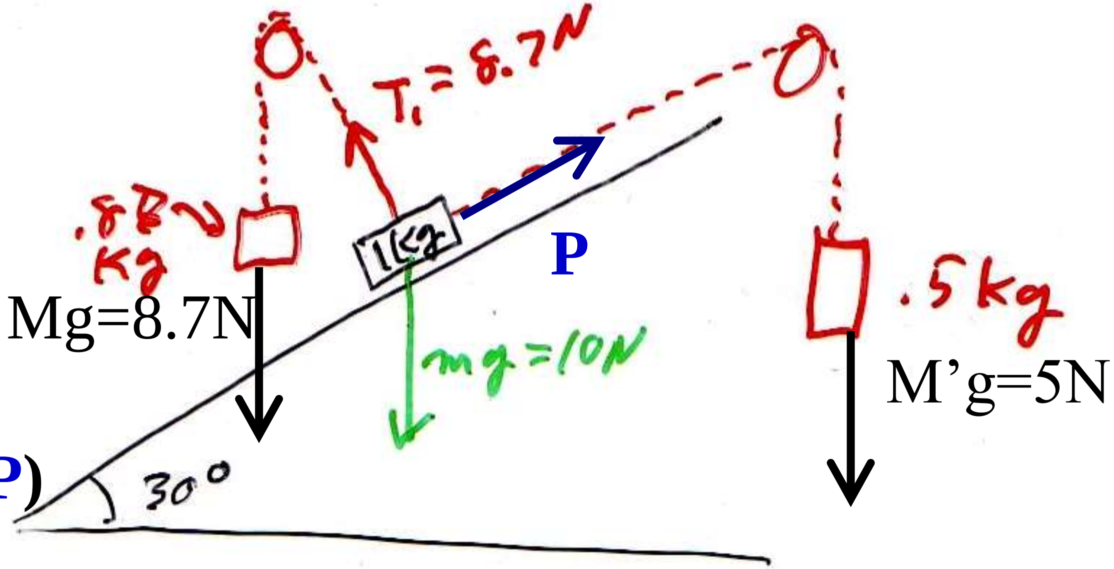


1-18b

$$F_{tot} = W_x = W \sin(\theta)$$

As we will see later:
unbalanced force causes acceleration down plane





Tension in ropes (T_1 and P) replace N and W.

$\underline{x}$: $-P + mg\sin\theta = F_x = 0$

$\underline{y}$: $+T_1 - mg\cos\theta = F_y = 0$

1-18c

$\Rightarrow$ $\underline{P = mg\sin\theta}$ $\underline{T_1 = mg\cos\theta}$

$m = 1\text{ kg}$ $\theta = 30°$ $\begin{cases} \sin\theta = \frac{1}{2} \\ \cos\theta = .866 \end{cases}$

Demo
Forces add like vectors
$F_{tot}=0 \Leftrightarrow a=0$

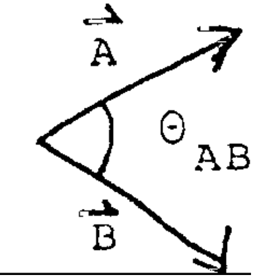
$P = 1(\text{kg})\, 9.8 \frac{m}{s^2} \frac{1}{2}$ $T_1 = 1(9.8)\,.866$

$\underline{P \simeq 5N}$ $T_1 \simeq 8.7\,N$

Vector application

THIS PAGE IS BEYOND THE SCOPE OF THIS COURSE

Physics/engineering and advanced students should be aware of the following.



Dot product (or inner product, or scalar product) of 2 vectors is defined as

$$\vec{A} \cdot \vec{B} = |A|\,|B| \cos \Theta_{AB}$$

$$\vec{A} = A_x \;\; x + A_y \;\; y$$

Here A_x (A_y), is the x (y) component of $\vec{A}$ along the x (y) axis and x (y) is the unit vector along the x (y) direction. (Note A_x (A_y) are just scalar numbers.).

For unit vectors one has $\hat{x} \bullet \hat{y} = 0 \quad \hat{x} \bullet \hat{x} = |\hat{x}|^2 = 1 \quad \hat{y} \bullet \hat{y} = |\hat{y}|^2 = 1$

Therefore $\hat{x} \bullet \vec{A} = A_x \quad \hat{y} \bullet \vec{A} = A_y$

Thus the dot product with a unit vector can be obtain ("project out") the component of the vector in the direction of the unit vector.

Advanced (not required for this course) topic. For physics, engineering, math, … majors "An introduction to generalized vector spaces and Fourier analysis" see below

http://www.physics.rutgers.edu/~croft/lectures/zFOURIER%20ANALYSIS.pdf