

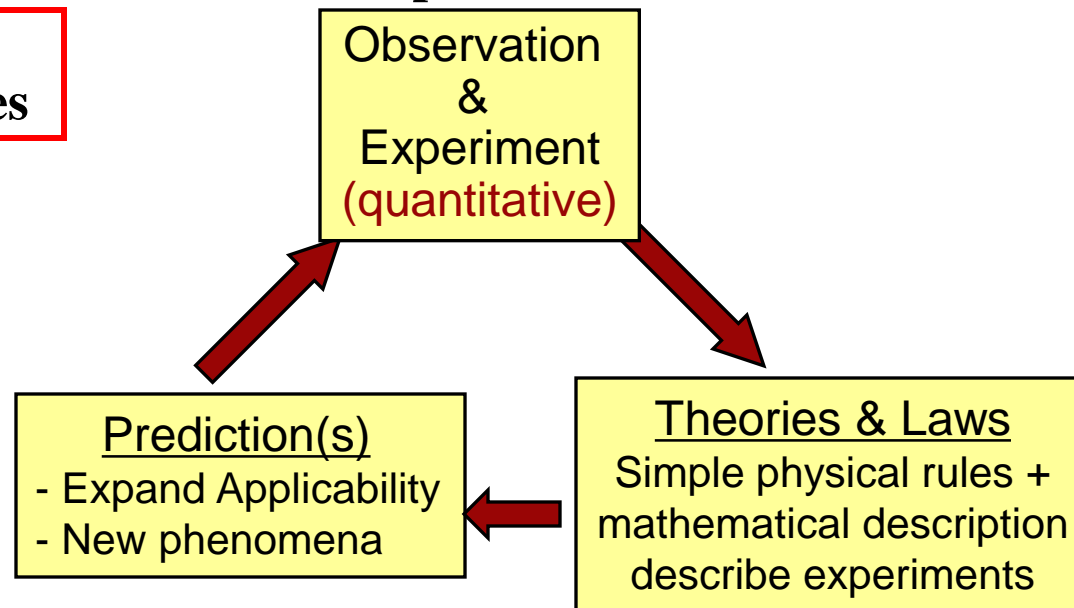
Physics 203

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/ time²

Newton = N= kg m/s² (unit of force)

Weight (in English units) = slug ft/s²=pound=lb

unit conversion- mole method

$$60 \text{ mi/hr} = ? \text{ m/s}$$

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

cancel

$$\frac{60 \cdot 5280 \cdot 12 \cdot 2.54}{60 \cdot 60 \cdot 100} = \frac{5280 \cdot (12)^2 \cdot 2.54}{1000000} = \frac{26822.4}{1000}$$

$$\frac{60 \text{ mi}}{\text{hr}} \approx 26.8 \text{ m/s}$$

$$\left[\frac{1 \text{ mi}}{\text{hr}} = 0.446 \text{ m/s} \right]$$

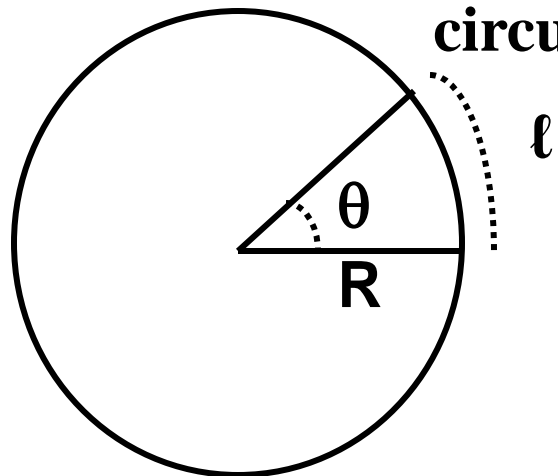
$$30 \text{ mph} \approx 13.4 \text{ m/s}$$

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

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

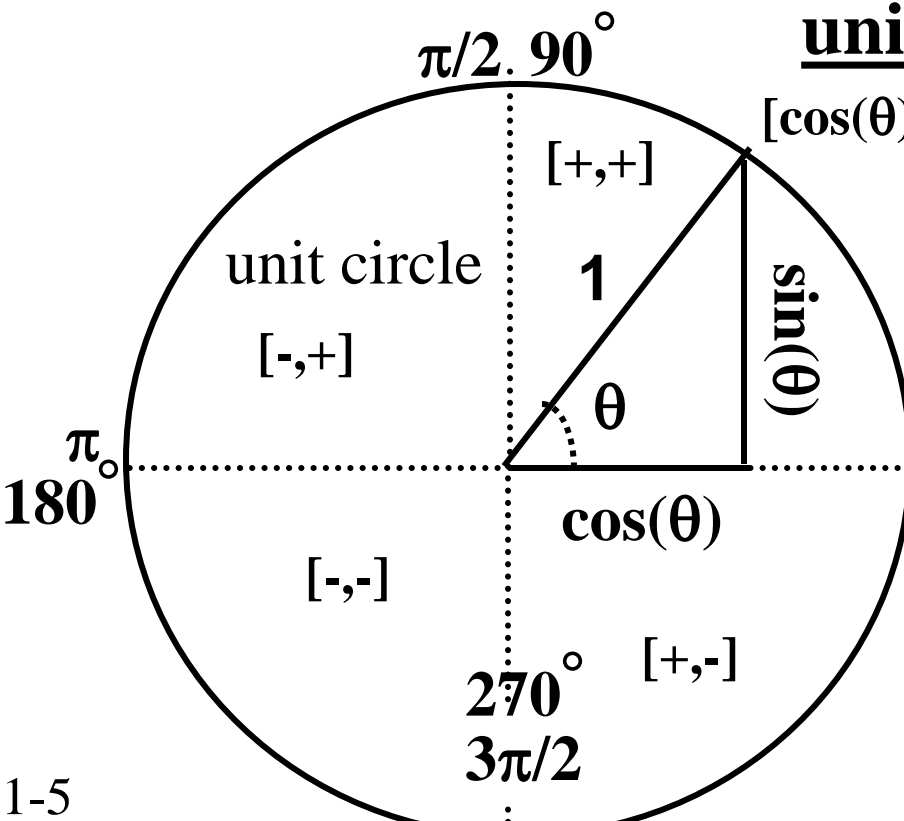


$$\text{circumference} = 2\pi R$$

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

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

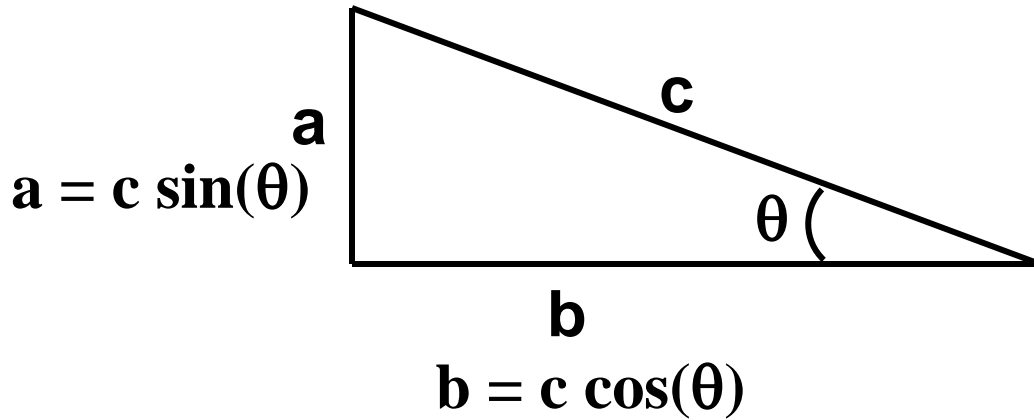
unit circle



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

$$0 \quad 2\pi \quad 360^\circ$$

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



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

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

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

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

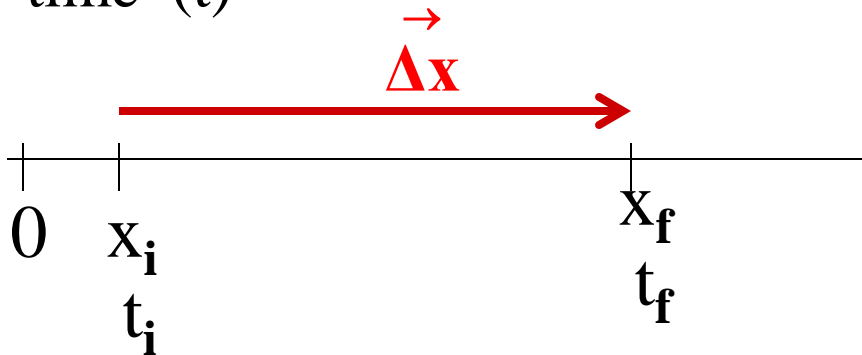
$$\theta = \cos^{-1}\left(\frac{b}{c}\right)$$

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

one dimension

position coordinate (x) – measure of position

time (t)



→ define
+ direction

initial
position
time

final
position
time

displacement $\Delta \mathbf{x} = \mathbf{x}_f - \mathbf{x}_i$

- how far
- what direction + or -

magnitude
direction

average
velocity $\bar{\mathbf{v}} = \frac{\Delta \mathbf{x}}{\Delta t} = \frac{\mathbf{x}_f - \mathbf{x}_i}{t_f - t_i}$

- how fast
- what direction + or -

two dimensions

vector (position and displacement)

- magnitude (length)

- direction

final

t_f position

(x_f, y_f) time

$$\vec{\Delta r} = \vec{r}_f - \vec{r}_i$$

\vec{r}_f

(x_i, y_i) initial

t_i position
time

\vec{r}_i

X

y

two dimensions

vector position label $\vec{\mathbf{r}}$

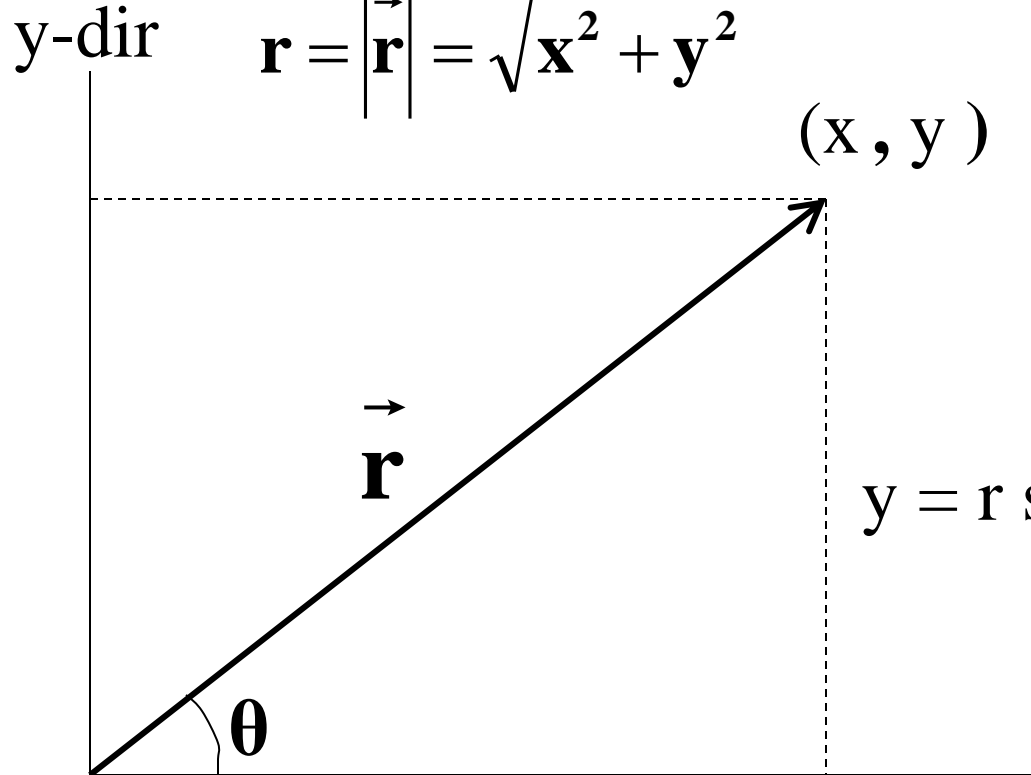
2 ways to represent position

\mathbf{x} component
\mathbf{y} component

\mathbf{r} magnitude
θ direction

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

(x, y)



$$y = r \sin(\theta)$$

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

$$x = r \cos(\theta)$$

x-dir position vector

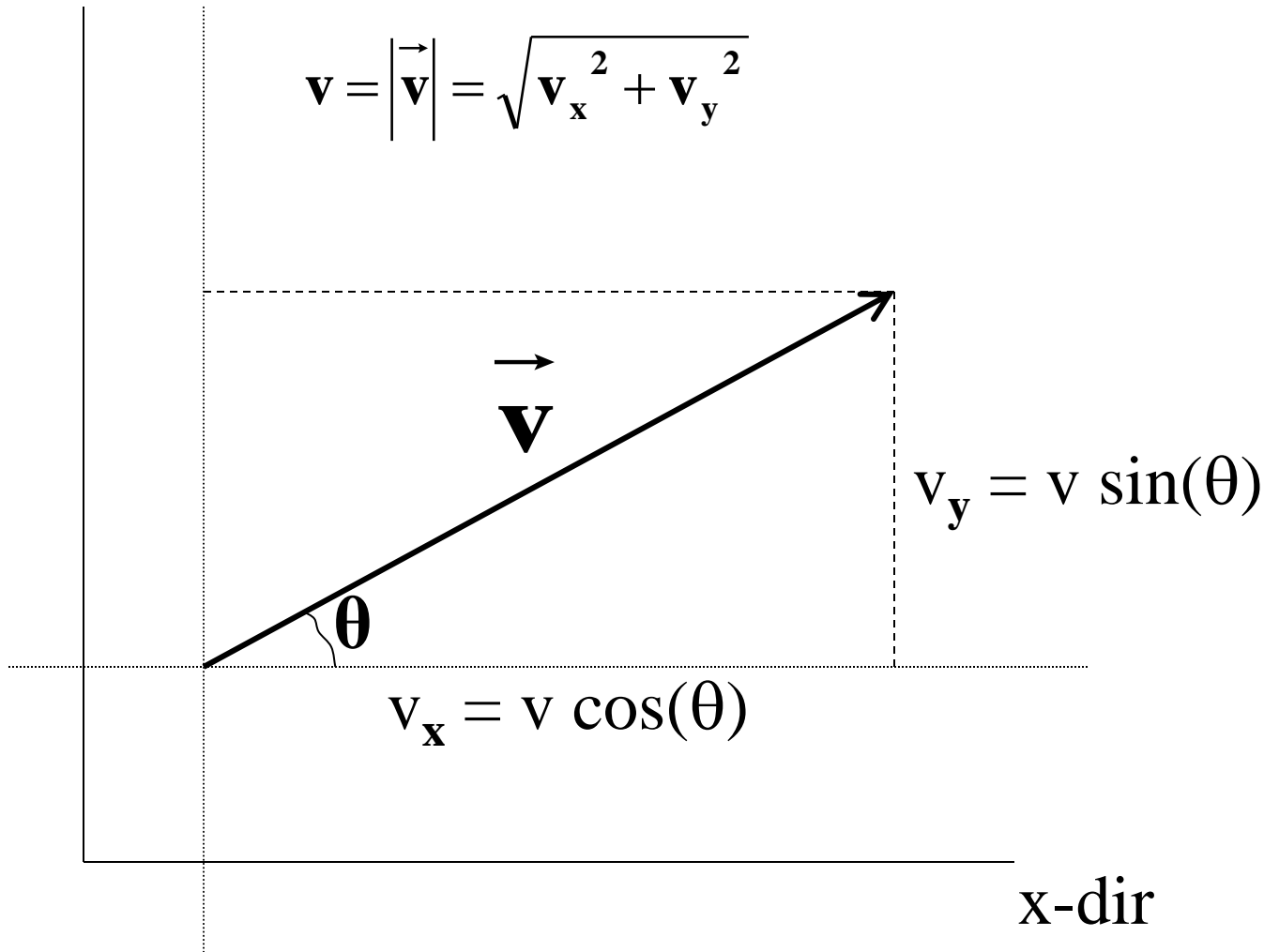
- magnitude (length)

- direction

general vector not tied to particular origin

y-dir

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



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

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

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

x-dir

vector components can be found using different angles

or - #

$$A_x = A \cos(\theta)$$

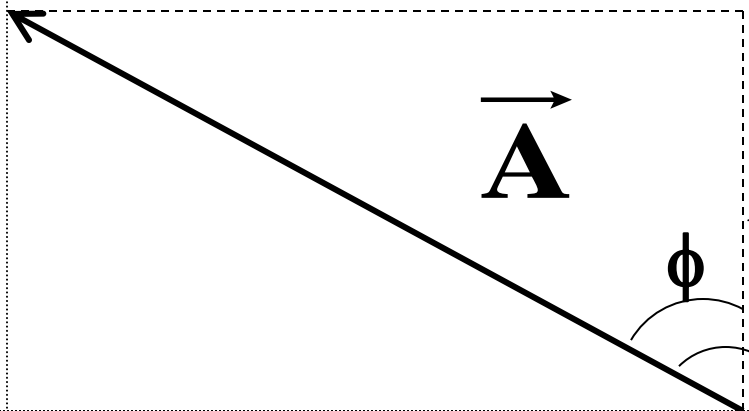
$$A_y = A \sin(\theta)$$

+ #

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

y-dir

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



+ #

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

- #

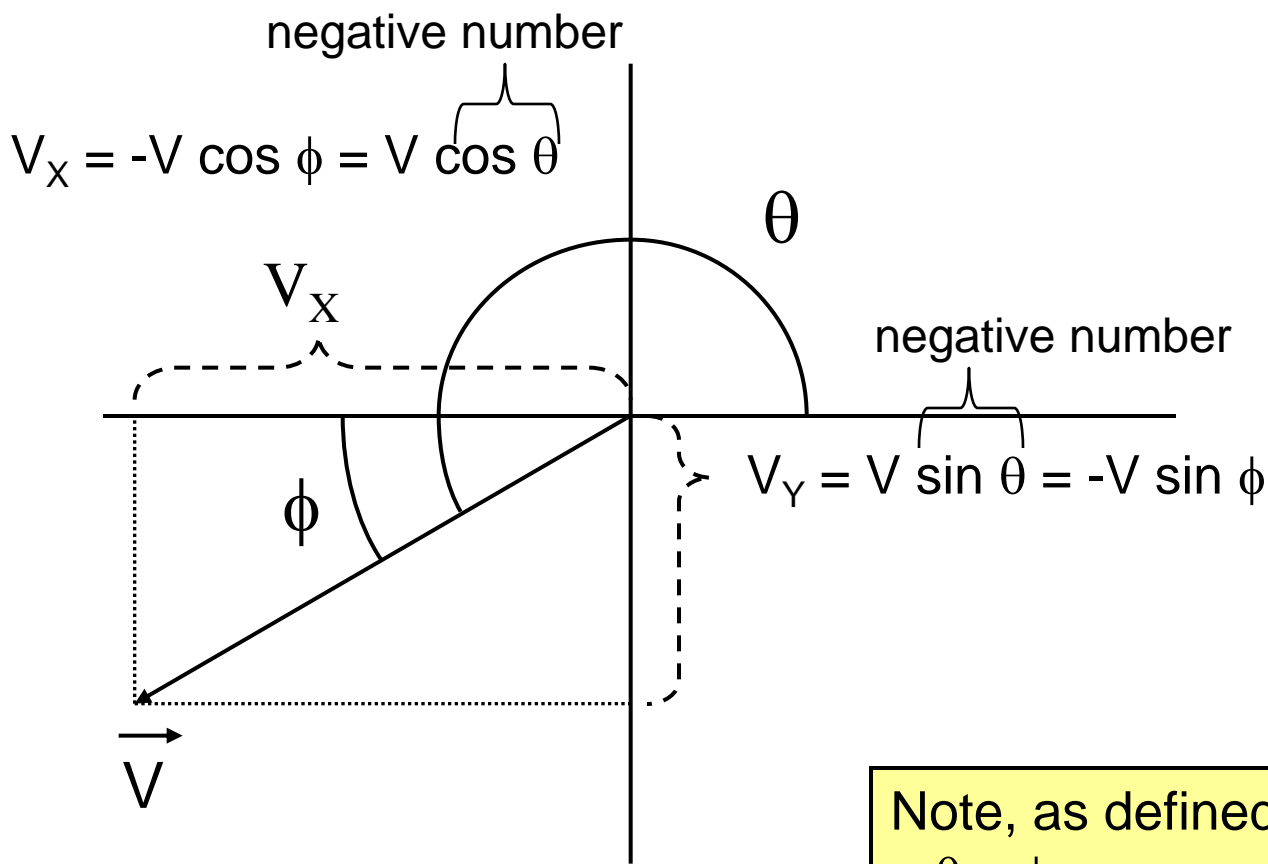
$$A_x = -A \sin(\phi)$$

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

x-dir

vector components can be found using different angles

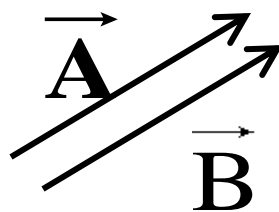
(angle bigger than 90° example)



Note, as defined above:
 $\theta = \phi + \pi$
 $\theta = \phi + 180^\circ$
 $\sin \theta = \sin (\theta+2\pi)$

Vector equality

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



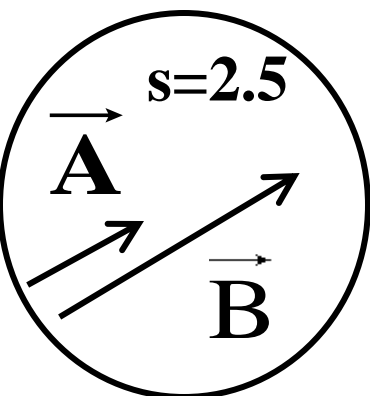
$$A_x = B_x$$

$$A_y = B_y$$

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

$$\theta_A = \theta_B$$

Scalar Multiplication



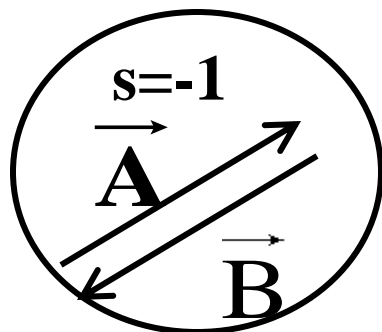
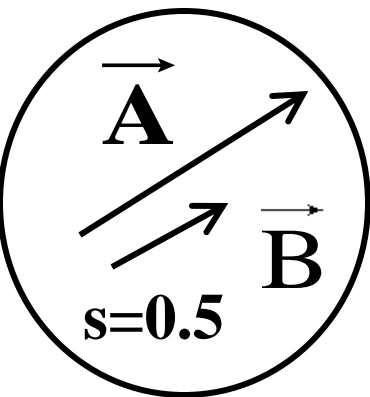
$$s = \#$$

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

or

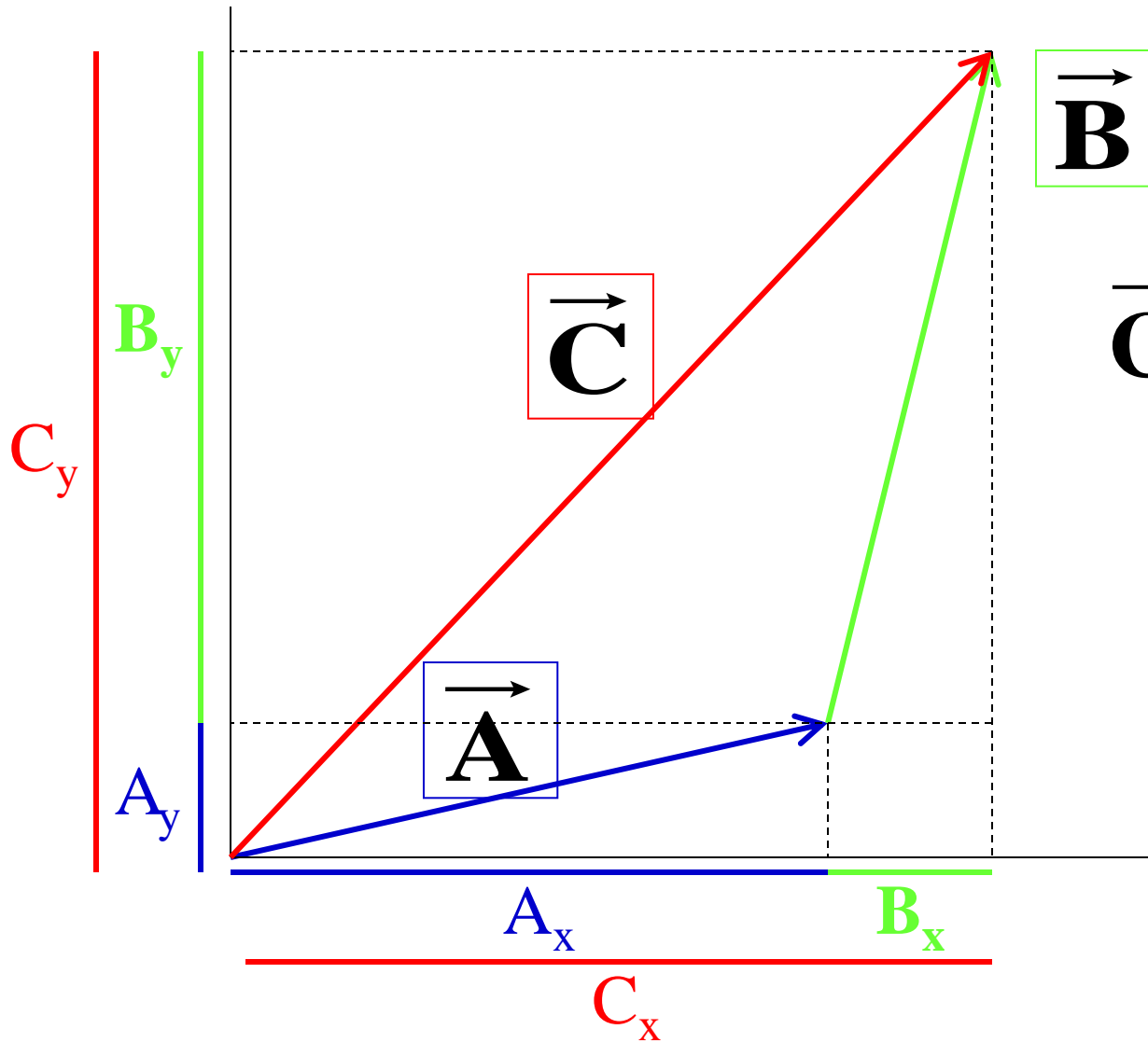
$$\text{same direction} \begin{cases} \theta_A = \theta_B \\ |\vec{B}| = s |\vec{A}| \end{cases}$$

s times longer



**note: if $s < 0$ then
reverse vector direction**

vector addition

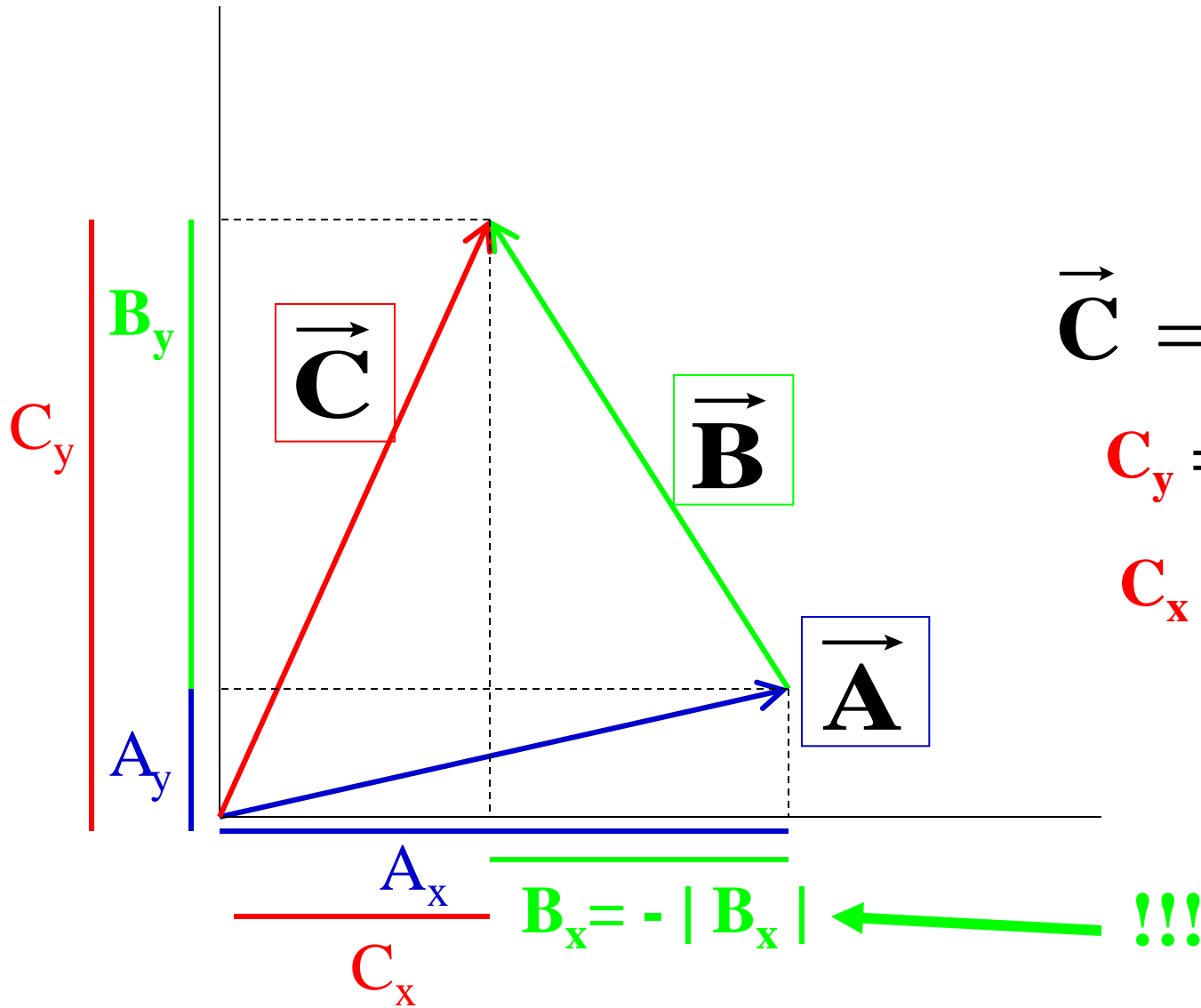


$$\vec{C} = \vec{A} + \vec{B}$$

$$C_x = A_x + B_x$$

$$C_y = A_y + B_y$$

vector addition



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

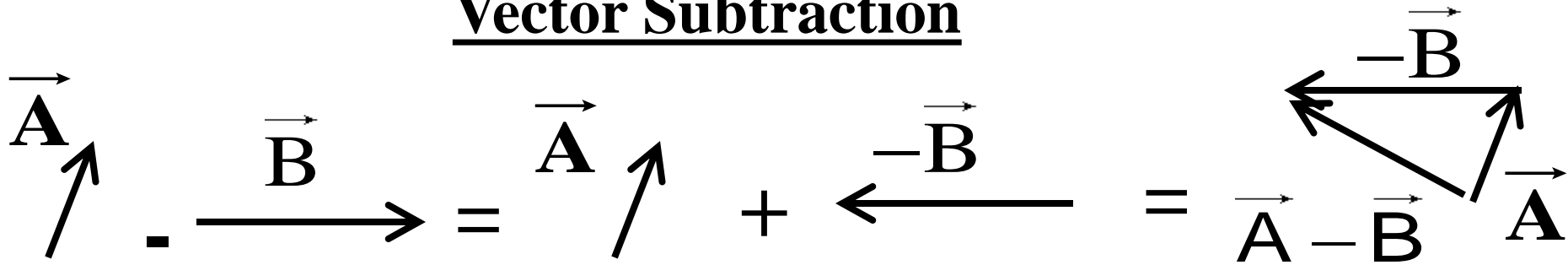
$$C_y = A_y + B_y$$

$$C_x = A_x + B_x$$

$$= A_x - |B_x|$$

!!!

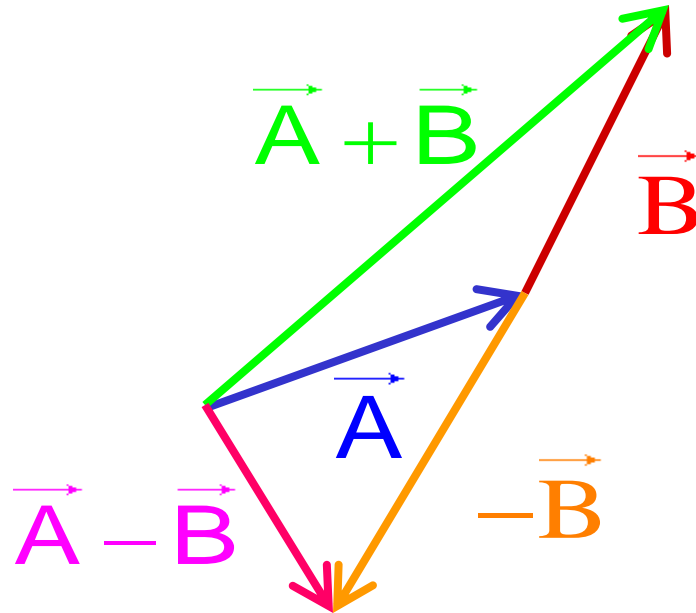
Vector Subtraction

$$\vec{A} - \vec{B} = \vec{A} + (-\vec{B}) = \vec{A} - \vec{B}$$


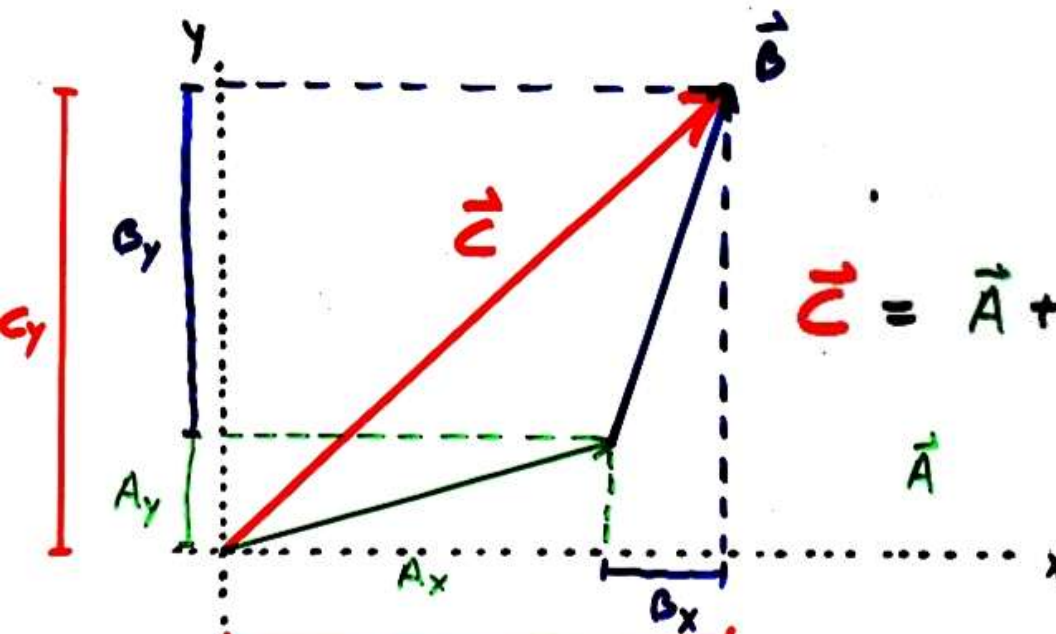
$$\vec{A} - \vec{B} = \vec{A} + \{-\vec{B}\}$$

{ follows from vector addition + -1 vector reversal }

Comparison
vector
addition
subtraction



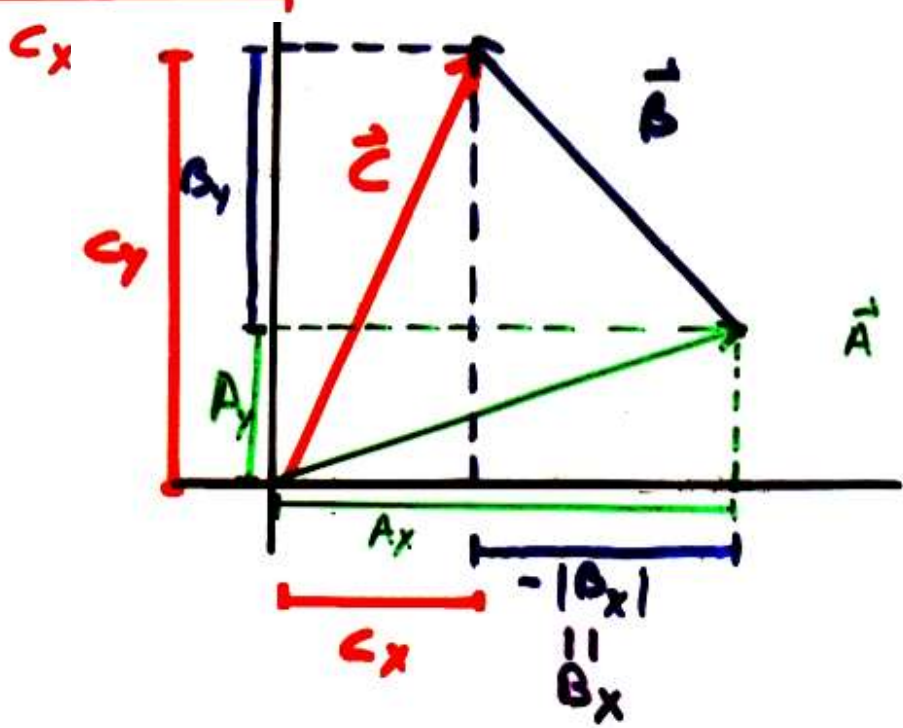
Vector Addition



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

$$C_x = A_x + B_x$$

$$C_y = A_y + B_y$$



$$C_y = A_y + B_y$$

$$C_x = A_x + B_x$$

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

Unit vectors their uses (book sometimes uses)

$$\begin{array}{c} \uparrow y \\ \rightarrow x \end{array} \quad |y|^2 = |x|^2 = 1$$

\hat{x} Unit vectors along x and y directions
 On length “1”

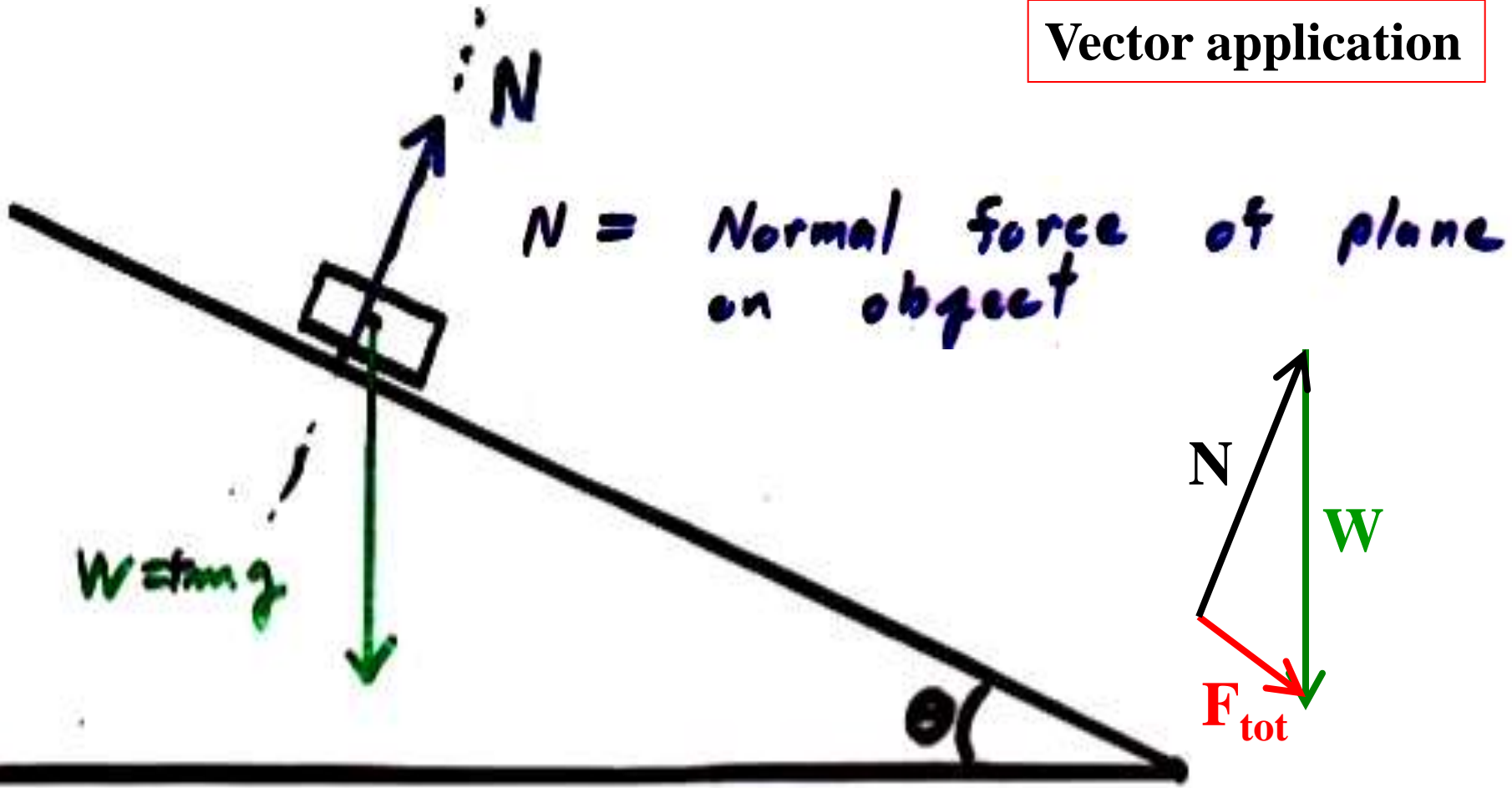
$$\vec{A} = A_x \hat{x} + A_y \hat{y}$$

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

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

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

Vector application



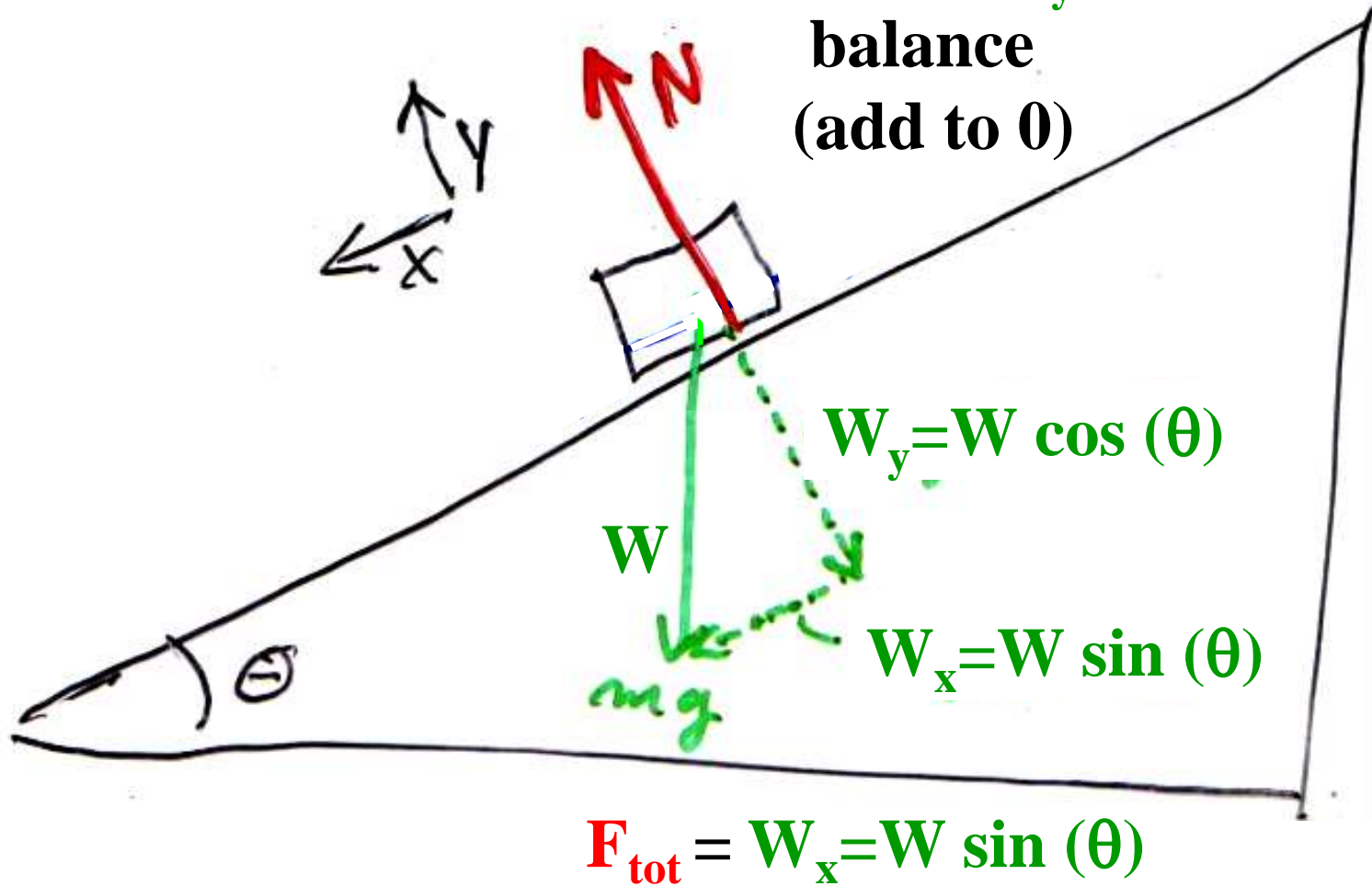
$N =$ Normal force of plane on object

$W = mg$

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

Forces add like vectors

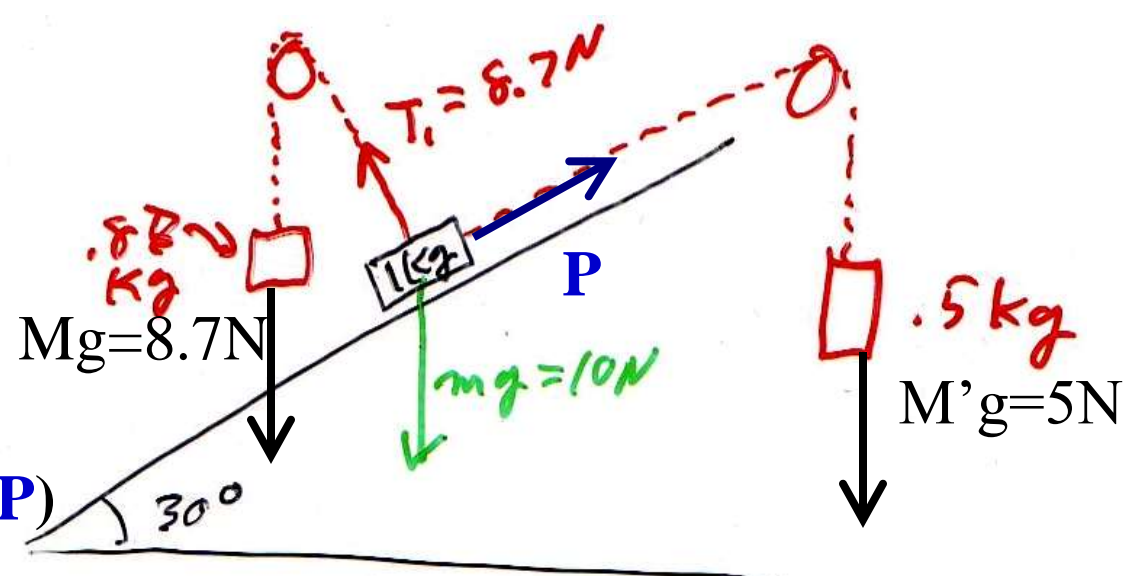
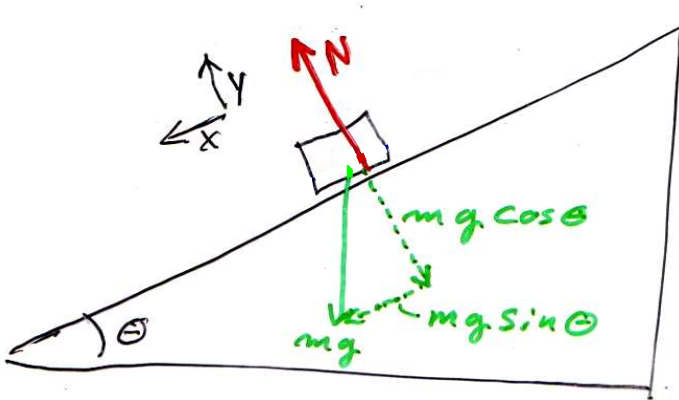
**N and W_y
balance
(add to 0)**



1-18b

As we will see later:

unbalanced force causes acceleration down plane



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

$$\sum F_x = -P + mg \sin \theta = \bar{F}_x = 0$$

$$\sum F_y = +T_1 - mg \cos \theta = \bar{F}_y = 0$$

1-18c \Rightarrow

$$P = mg \sin \theta$$

$$T_1 = mg \cos \theta$$

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

$$m = 1 \text{ kg} \quad \theta = 30^\circ \quad \left\{ \begin{array}{l} \sin \theta = \frac{1}{2} \\ \cos \theta = .866 \end{array} \right.$$

$$P = 1 (\text{kg}) \cdot 9.8 \frac{\text{m}}{\text{s}^2} \cdot \frac{1}{2}$$

$$T_1 = 1 (9.8) \cdot .866$$

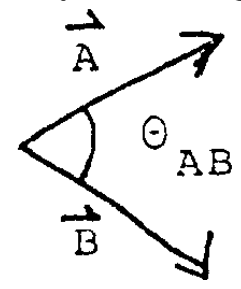
Vector application

$$P \approx 5 \text{ N}$$

$$T_1 \approx 8.7 \text{ N}$$

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

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

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

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

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

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

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.