COLLEGE PHYSICS 201 (sections 31-35)

Instructor: Hans Schuessler

Substituting: Alexandre Kolomenski

https://sibor.physics.tamu.edu/courses/physics-201-college-physics/

PHYS 201 College Physics Fall 2023 TR 5:30

Course Description: Fundamentals of classical mechanics, heat and sound.

Prerequisites: High school algebra and trigonometry or the equivalent.

Learning Outcomes: Upon completion of PHYS 201 a student will understand the basic laws and concepts of physics in the following areas and will be able to apply them in problems relating to physical situations: mechanics, mechanical waves, and thermodynamics.

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Office Hours: TBD

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Text: College Physics 11th ed by Young and Adams with Modified Mastering Physics

The mid-term exams are in person 7:00 to 9:00 pm, on the following Thursdays:
September 14 (Chs 1-5), October 12 (Chs 6-8), November 2 (Chs 9-11), and November 30 (Chs 12-16)

Access **Mastering Physics for homework and Webassign for lab**

There are prelecture videos and tutorial problems assigned in Mastering Physics (for grade) in addition to the problems from the textbook that are listed on the syllabus.

Grading: 4 exams 60%; Final (comprehensive) 20%; Lab 5%; Recitation 5%; Homework (Mastering Phys) 5%; in-class quizzes 5%.

Scale: 90-100 A, 80-89 B, 60-79 C, 45-59 D, <45 F. Grades may be curved upward. Follow university policy on making up missed work.

You must achieve 70% or better in the laboratory in order to pass the course.

If your grade on the Final Exam is higher than your lowest grade on one of the four exams during the semester, that lowest grade will be replaced by its average with the Final in computing the course grade. The quiz grade will come from 25 quizzes; if more quizzes than this are given during the semester the lowest grades beyond the best 25 will be dropped.

August 25 is last day for no record drop. Nov. 15 is the last day to Q-drop.

Final Exam is on Tuesday, December 12, 3:30 – 5:30 pm

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What is physics about?

- Science that studies the most general laws of nature.
- Quantifies relations (dependences) between different quantities.
- Needs units to express all these quantities and relations.
- Uses models as approximations for real processes.

Physics is the basis for many engineering disciplines.

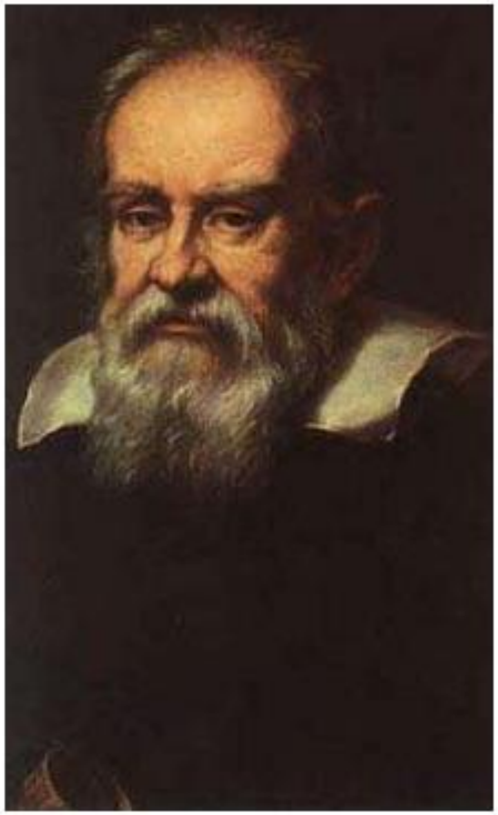
What is physics about? (cont.)

- Observations
- Experiments
- Measurements
- Instruments (rulers, clocks, etc.)
- Units
- Language of physics

In this course:

- Kinematics - description of motion
- Dynamics: why objects move
- Conservation laws
- Rotational motion
- Gases and fluids, heat, waves

Giants who created foundations of mechanics:

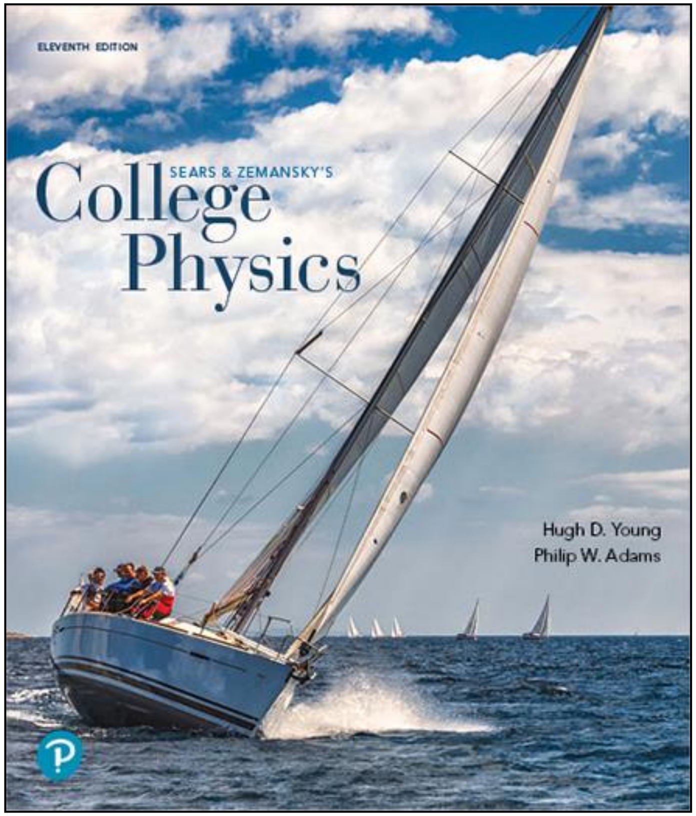


Galileo Galilei
(1564-1642)

Isaac Newton
(1642-1727)

Chapter 0: Mathematics Review

You are encouraged to review this chapter.
All topics are important for this course.
In particular: scientific notation and powers of 10.



$135{,}000 = 1.35\text{x}10^{5}$

$0.000135 = 1.35\text{x}10^{-4}$

3 significant digits

one digit to the left of the decimal point, multiplied by the appropriate power of 10.

Rules for significant figures

(1) When numbers are multiplied or divided, the number of significant figures in the final answer equals the smallest number of significant figures in any of the original factors.

(2) When adding/subtracting, the answer should have the same number of decimal places as the limiting term. The limiting term is the number with the least decimal places.

Indication of significant figures (digits) using scientific notation: decimal number with one digit to the left of the decimal point, multiplied by the appropriate power of 10.

1.5 Precision and Significant Figures

How precise can you measure a physical quantity?

For example, using a meter stick to measure lengths, you may get 0.7880 m or 0.3575 m. These quantities have 4 significant figures.

In the sense of significant figures, 0.788 m ≠ 0.7880 m.

● Multiplication and Division

$2.4 \times 2.30 = 5.5$ ($\neq 5.52$ or 5.520)

● Addition and Subtraction

$2.4 + 2.320 = 4.7$ ($\neq 4.720$)

$1.24\times10^6 + 3.23\times10^5 = 1.24\times10^6 + 0.323\times10^6 = 1.56\times10^6$

$1.24\times10^6 + 3.23\times10^4 = 1.24\times10^6 + 0.0323\times10^6 = 1.27\times10^6$

$1.24\times10^6 + 3.23\times10^3 = 1.24\times10^6 + 0.00323\times10^6 = 1.24\times10^6$

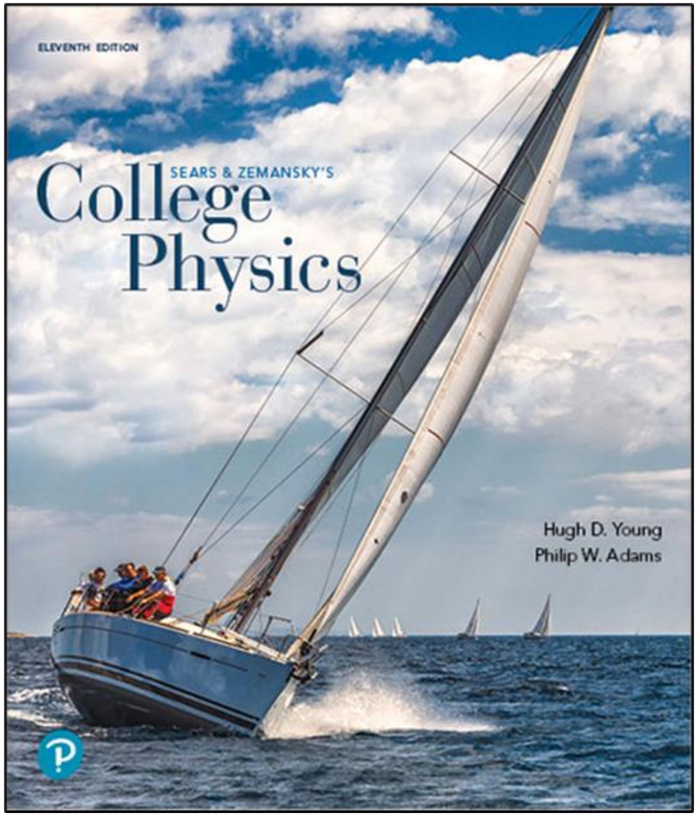
Courtesy of Wenhao Wu

Chapter 0 Math Review

Please review the following subjects

Courtesy of Wenhao Wu

Chapter 1: Models, Measurement, and Vectors



Note: Explore your textbook!

Unit Conversion Factors (back of the cover),
App. A: The International System of Units
App. B: The Greek Alphabet
App. C: Periodic Table
App. D: Unit Conversion Factors
App. E: Fundamental Physical Constants
Fundamental Physical Constants (end)

Goals for Chapter 1

- To know standards and units and be able to do unit conversions.
- To express measurements and calculated information with the correct number of significant figures.
- To be able to add and subtract vectors both graphically and analytically.
- To be able to break down vectors into *x*- and *y*-components.

SI Base Quantities and Units

TABLE 1–5
SI Base Quantities and Units

Quantity	Unit	Unit Abbreviation
Length	meter	m
Time	second	s
Mass	kilogram	kg
Electric current	ampere	A
Temperature	kelvin	K
Amount of substance	mole	mol
Luminous intensity	candela	cd

Objects of different dimension

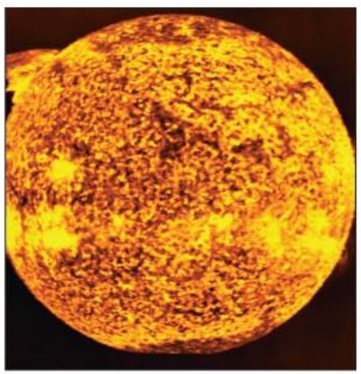
Scale → Astronomic | Macro | Micro

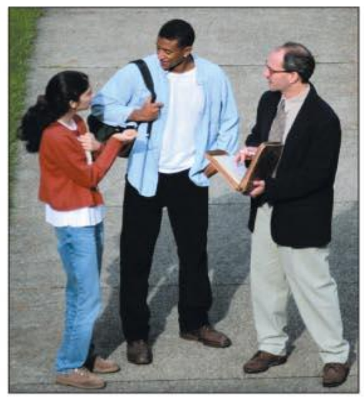
Size difference within scale

10^{21} m
A galaxy

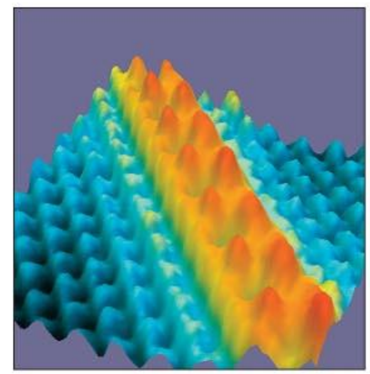
10^{-5} m
Red blood cells

10^{9} m
Our sun



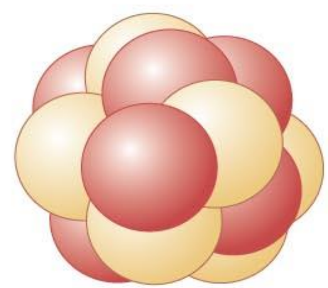


10^{0} m
You



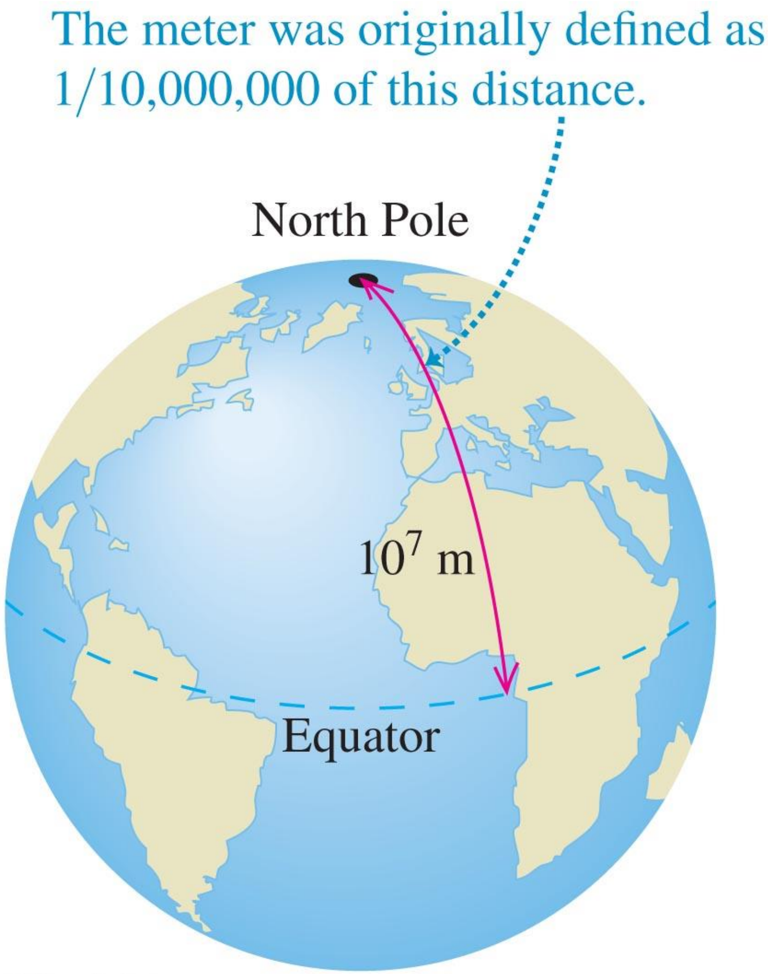
10^{-9} m
Individual atoms

10^{7} m
The earth



10^{-14} m
An atomic nucleus

The Meter – The Original Definition of 1791



The Meter – More Recently

- Now tied to Kr discharge and counting a certain number of wavelengths.
- Exceptionally accurate, in fact redefining *c*, speed of light.
- New definition is the distance that light can travel in a vacuum in 1/299,792,458 s.
- So accurate that it loses only 1 second in 30 million years.

Length

1m ≈ 10^{-7} of the distance from the equator to the pole (old definition)

1m = length of the path traveled by light in vacuum during the time interval of 1/299,792,458 of a second

Length (or distance)	Meters (approximate)
Neutron or proton (radius)	10^{-15} m
Atom	10^{-10} m
Virus [see Fig. 1–3]	10^{-7} m
Sheet of paper (thickness)	10^{-4} m
Finger width	10^{-2} m
Football field length	10^{2} m
Mt. Everest height [see Fig. 1–3]	10^{4} m
Earth diameter	10^{7} m
Earth to Sun	10^{11} m
Nearest star, distance	10^{16} m
Nearest galaxy	10^{22} m
Farthest galaxy visible	10^{26} m

Mass

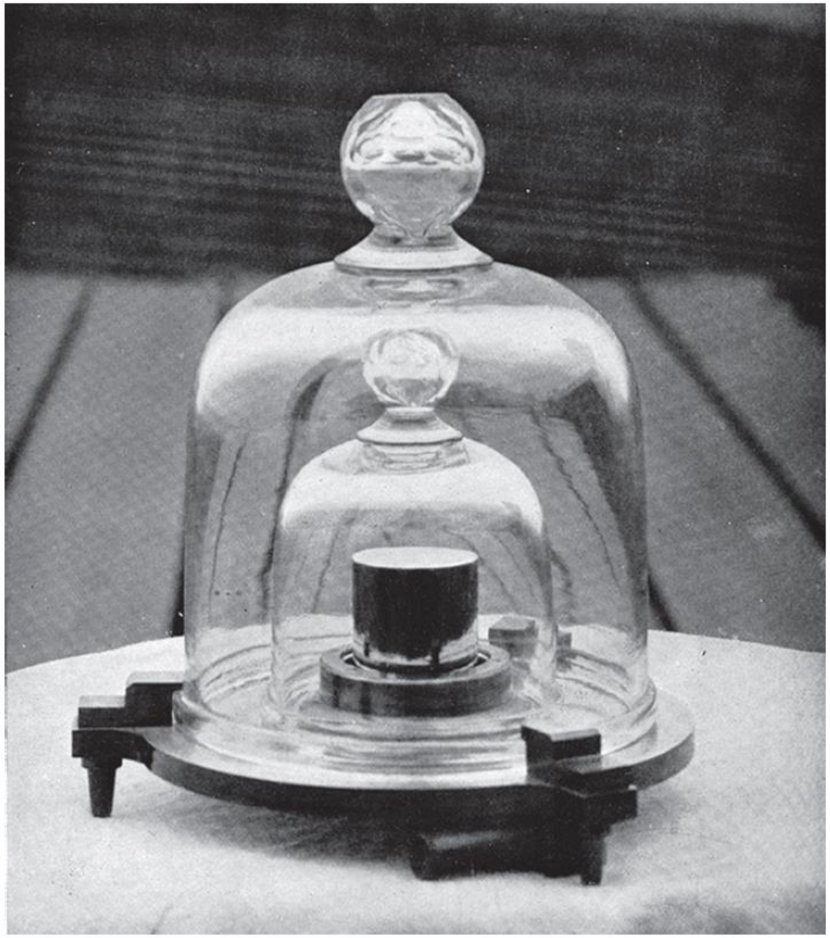
1kg = mass of the platinum-iridium cylinder in Paris

1u = 1.6605×10^{-27}kg (unified atomic mass unit)

TABLE 1–3 Some Masses

Object	Kilograms (approx.)
Electron	10^{-30} kg
Proton, neutron	10^{-27} kg
DNA molecule	10^{-17} kg
Bacterium	10^{-15} kg
Mosquito	10^{-5} kg
Plum	10^{-1} kg
Person	10^{2} kg
Ship	10^{8} kg
Earth	6×10^{24} kg
Sun	2×10^{30} kg
Galaxy	10^{41} kg

The Reference Kilogram - Figure 1.3



Time

1s = 1/24*60*60 day=1/86400 day (def. till 1967)

1s = time required for 9,192,631,720 periods of radiation of the Cs-atom

TABLE 1–2 Some typical Time Intervals

Time interval	Seconds (approximate)
Lifetime of very unstable subatomic particle	10^{-23} s
Lifetime of radioactive elements	10^{-22} s to 10^{28} s
Lifetime of muon	10^{-6} s
Time between human heartbeats	10^{0} s (= 1 s)
One day	10^{5} s
One year	3×10^{7} s
Human life span	2×10^{9} s
Length of recorded history	10^{11} s
Humans on Earth	10^{14} s
Life on Earth	10^{17} s
Age of Universe	10^{18} s

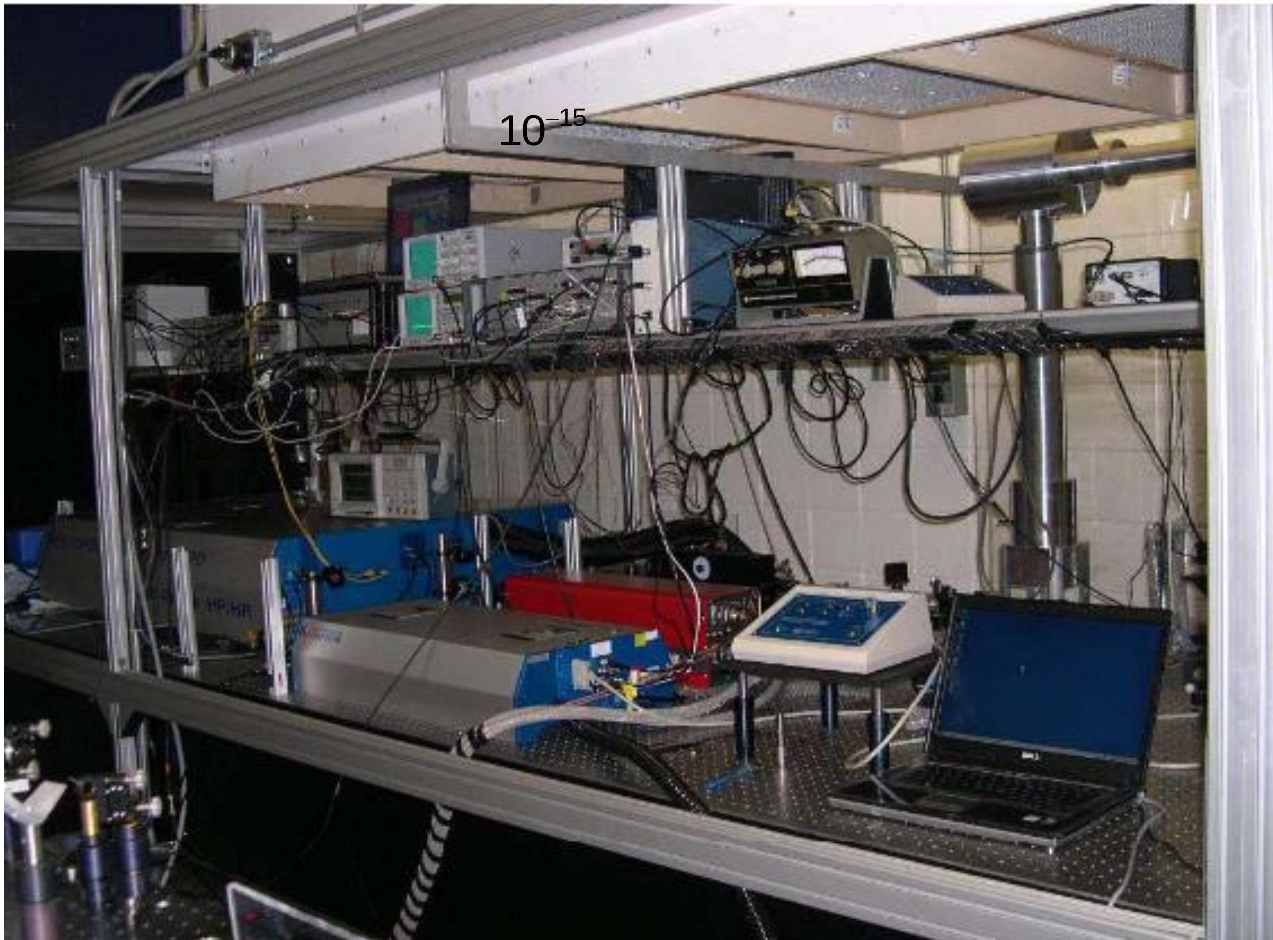
Metric(SI) Prefixes

TABLE 1–4
Metric (SI) Prefixes

Prefix	Abbreviation	Value
exa	E	10^{18}
peta	P	10^{15}
tera	T	10^{12}
giga	G	10^{9}
mega	M	10^{6}
kilo	k	10^{3}
hecto	h	10^{2}
deka	da	10^{1}
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro[†]	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}
femto	f	10^{-15}
atto	a	10^{-18}

[†] μ is the Greek letter "mu."

First Stage (operational): Carrier-Envelope Phase Stabilized Few-Cycle FEMTOLASERS System



10^{-15}

Parameters

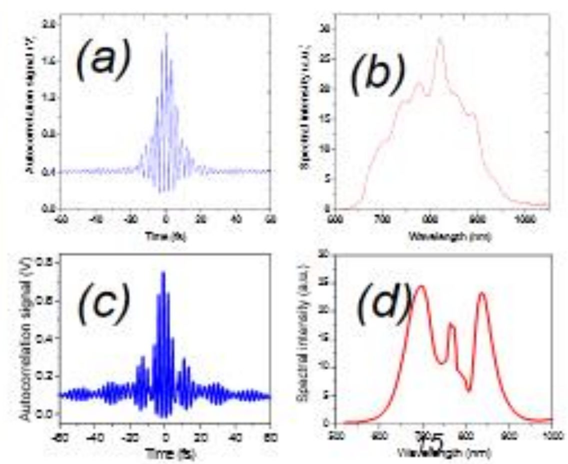
Pulse width = 6.5 fs

Output power = 4.5 W

Rep rate = 5 KHz

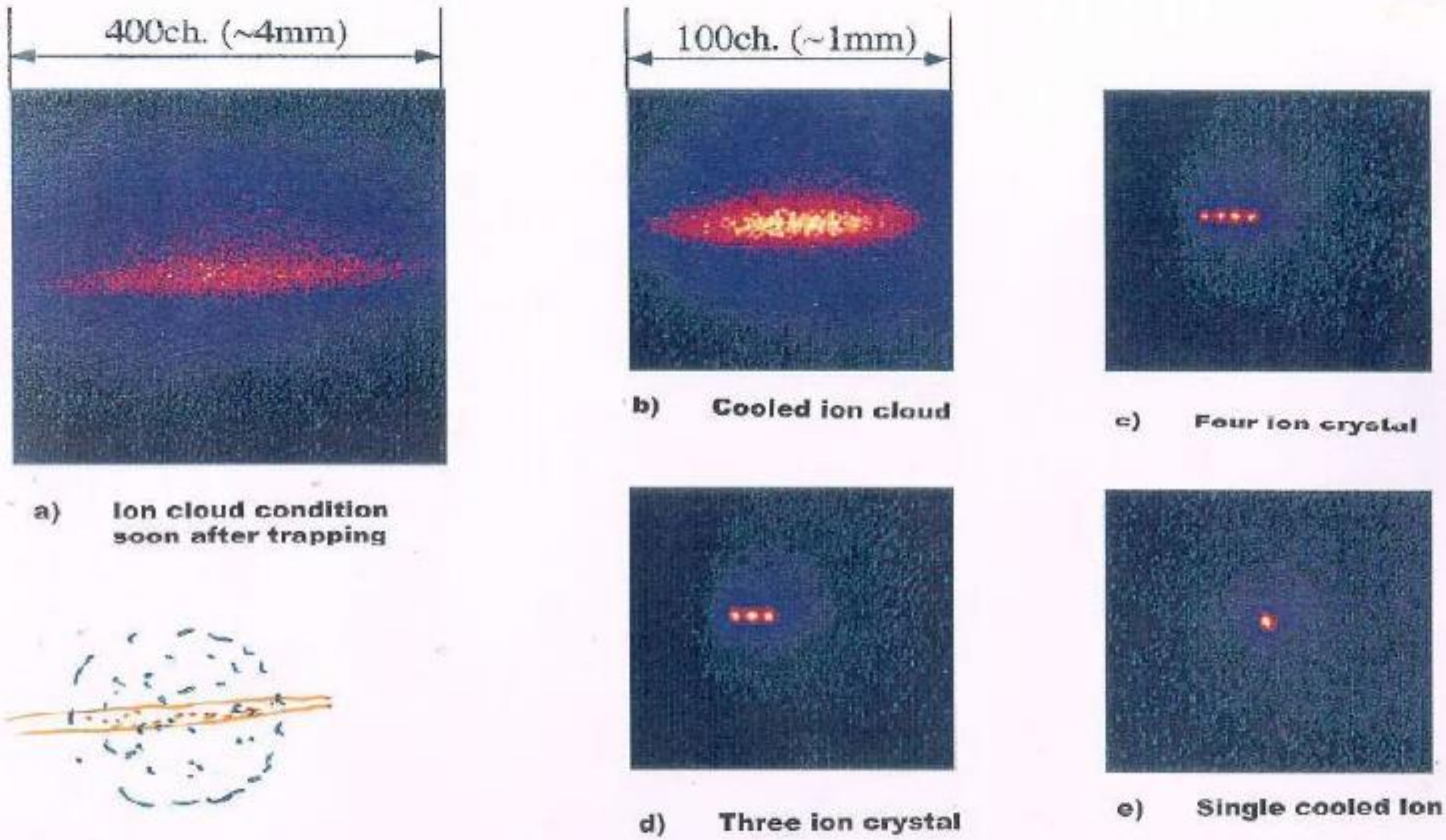
Energy per pulse = 1 mJ

Autocorrelator traces and spectra: oscillator (a), (b) and amplifier (c),(d)



femto-

Fluorescence from stored ions for different degrees of laser cooling



Space charge distributions in a linear RF ion trap (storage time ~40 sec)

Conversion of units

We would like to find how many meters in 20 miles, how do we do this?

We go to the pages in the end of the textbook, Appendix D “Unit conversion Factors” and use the formula

1 mile=1.609 km

now we know 1km=1000 m then

20 mi=20x1.609x1000 m=32180 m

Conversion of units (2nd example)

We would like to know, what will be
18 km/h in m/s?

18 km/h=18x1000m/(60x60s)=5 m/s

Conversion of units

We would like to find how many meters in 20 miles, how do we do this?
We go to the pages in the end of the textbook, Appendix D "Unit conversion Factors" and use the formula
1 mile=1.609 km
now we know 1km=1000 m then
20 mi=20x1.609x1000 m=32180 m

Unit Conversion

Alpha Centauri is the closest "star." It is 4.3 light-years away. How many kilometers away is the star from earth?

Write down: What do you know? What are we trying to get to?

4.3 light-years = time it takes for light to travel distance

Distance = time × speed

Now do it…

What's the speed (rate)?

Speed of light $= \mathbf{3 \times 10^8 \, m/s}$

$$\text{distance} = \underbrace{(4.3\ \cancel{\text{years}})\left(\frac{3.15\times10^{7}\ \cancel{\text{s}}}{1\ \cancel{\text{year}}}\right)}_{\text{time}}\underbrace{\left(\frac{3\times10^{8}\ \cancel{\text{m}}}{\cancel{\text{s}}}\right)\left(\frac{1\ \textbf{km}}{1000\ \cancel{\text{m}}}\right)}_{\text{speed}}$$

$= 40\times10^{12}$ **km** or 40 petameters (Pm)

Physical quantities and units

1. All physical quantities always have some units!
2. From relationships between these quantities one can derive new units.

Units SI and derivative units

Displacement, distance: 1 meter 1m

Velocity, speed: 1 meter/second 1m/s

Acceleration: 1 meter/second^2 1m/s^2

Pearson

Dimensional analysis

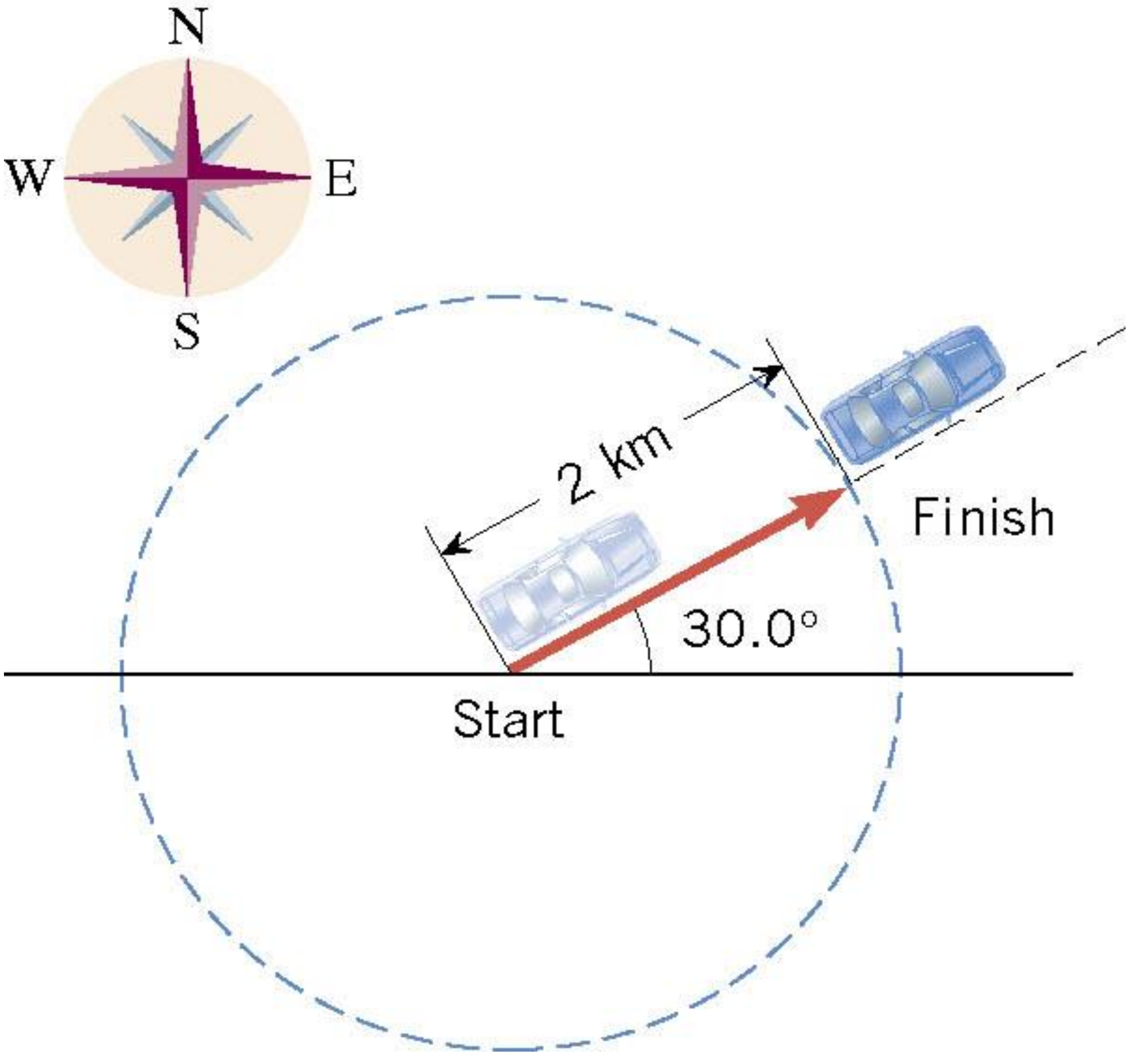
You have three equations with distance x, speed *V*, time *t* and acceleration *a*, which of them can be correct?

$$x = \frac{at^2}{2} \qquad x = \frac{Vt^2}{2} \qquad x = \frac{V^2}{2a}$$

Vectors and vector addition

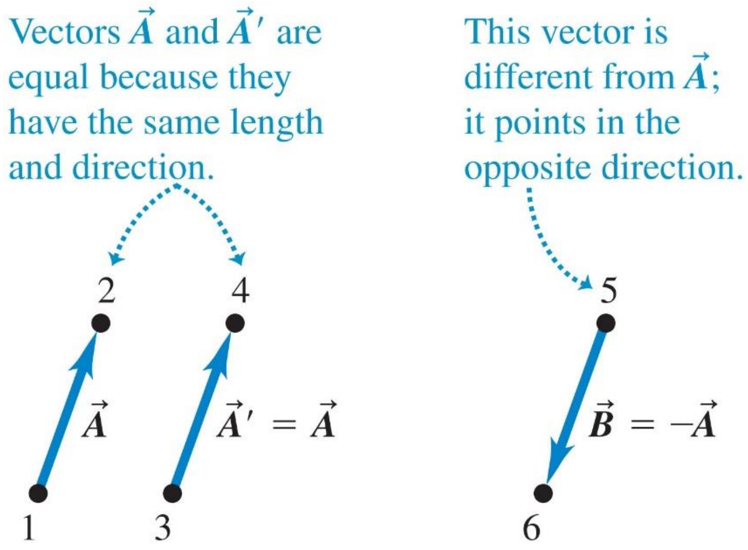
Vectors: magnitude and direction, can be translated without change of vector value

Vector: magnitude and direction

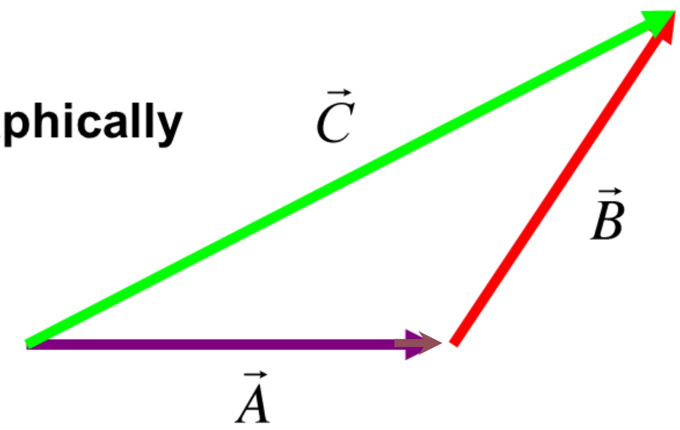


Vector Addition (1 of 2)

- In the "world of vectors" 1+1 does not necessarily equals 2.
- Graphically?



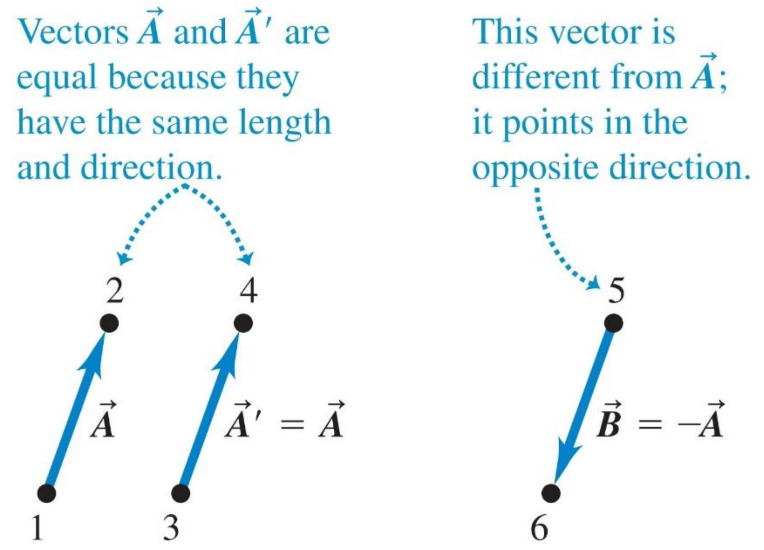
Adding graphically

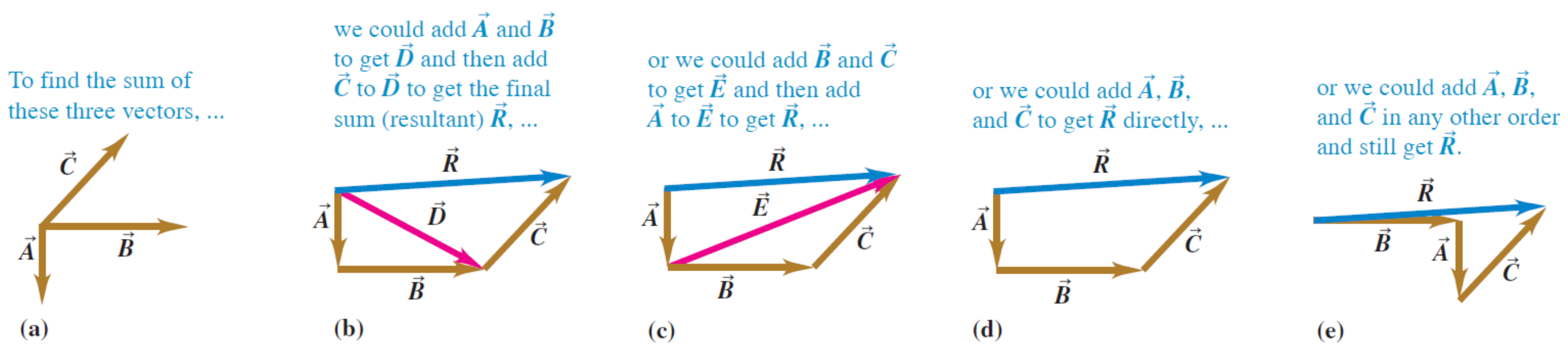


$$\vec{A} + \vec{B} = \vec{C}$$

Vector Addition (2 of 2)

- In the "world of vectors" 1+1 does not necessarily equal 2.
- Graphically?



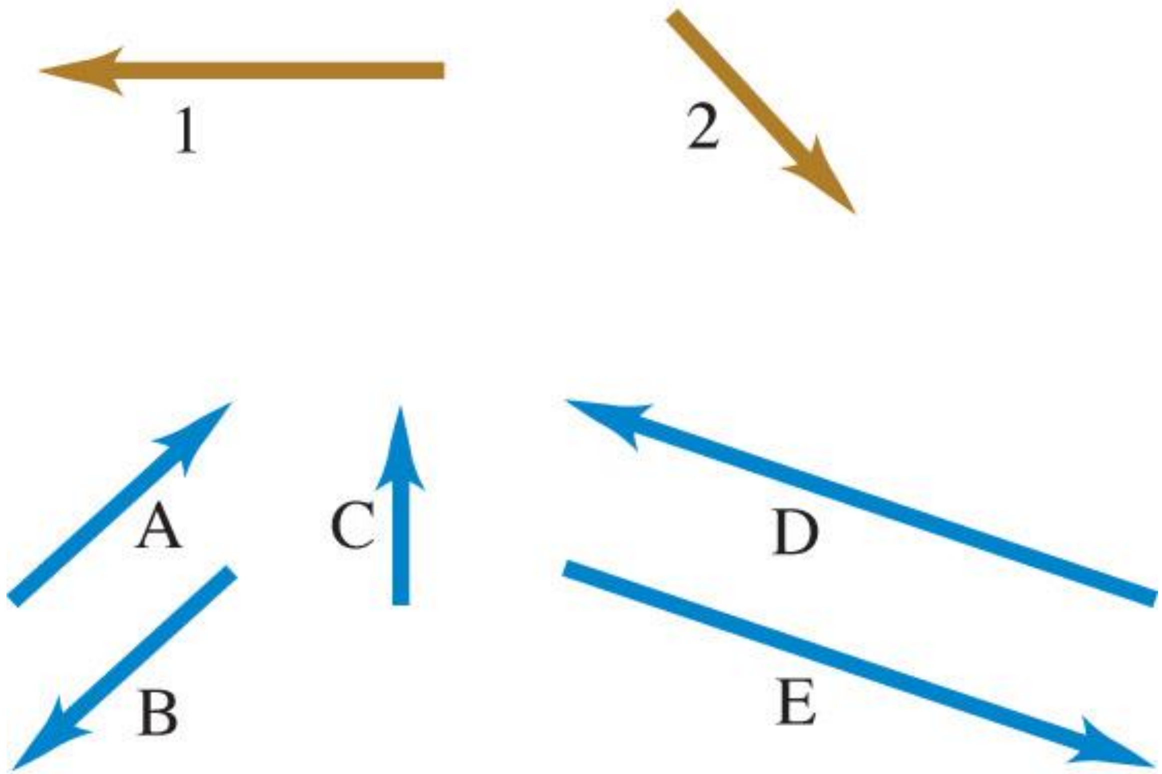


Pearson

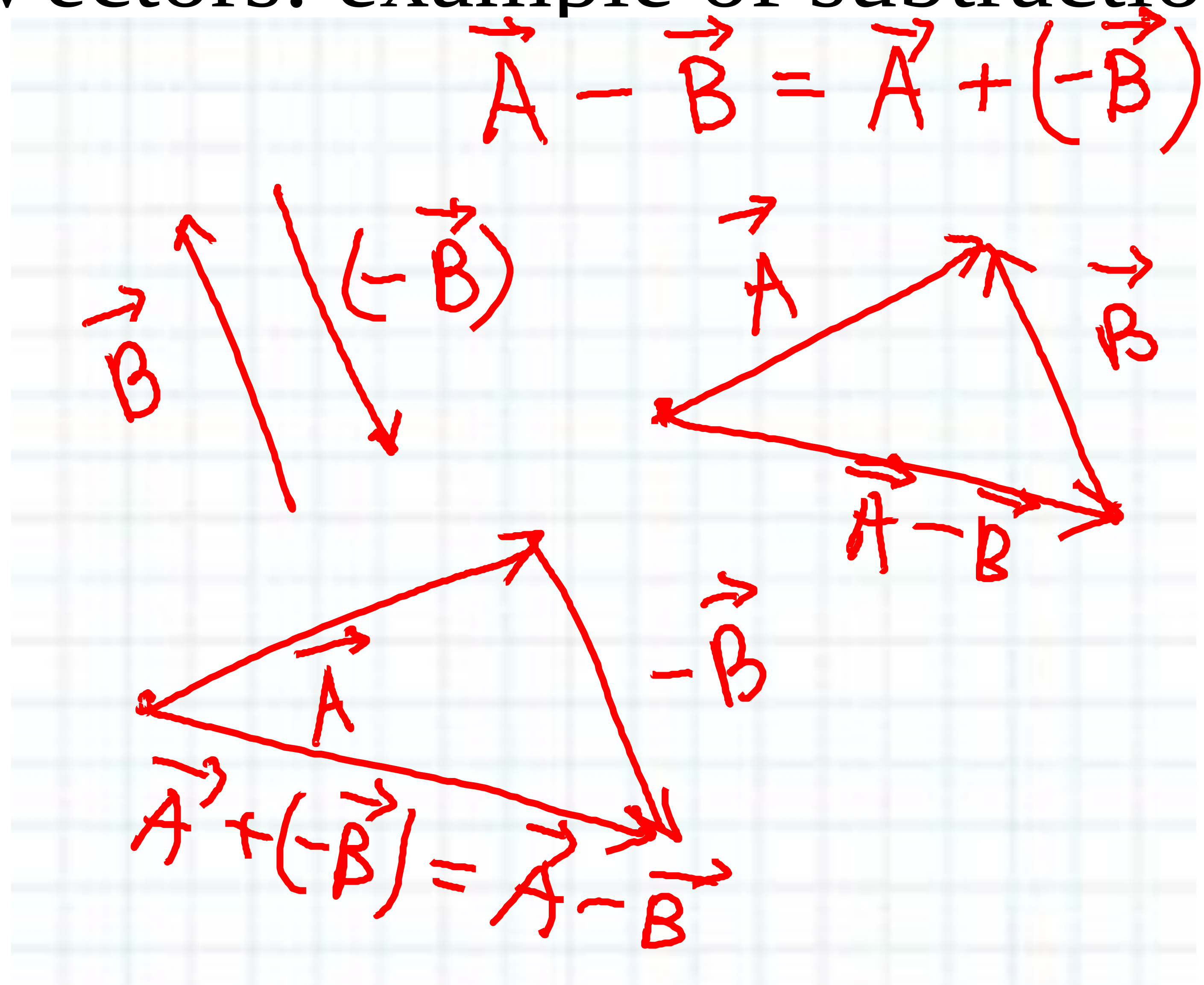
Clicker question

Which of the vectors A–E represents the vector sum of vectors 1 and 2?

a)
b)
c)
d)
e)



Vectors: example of subtraction



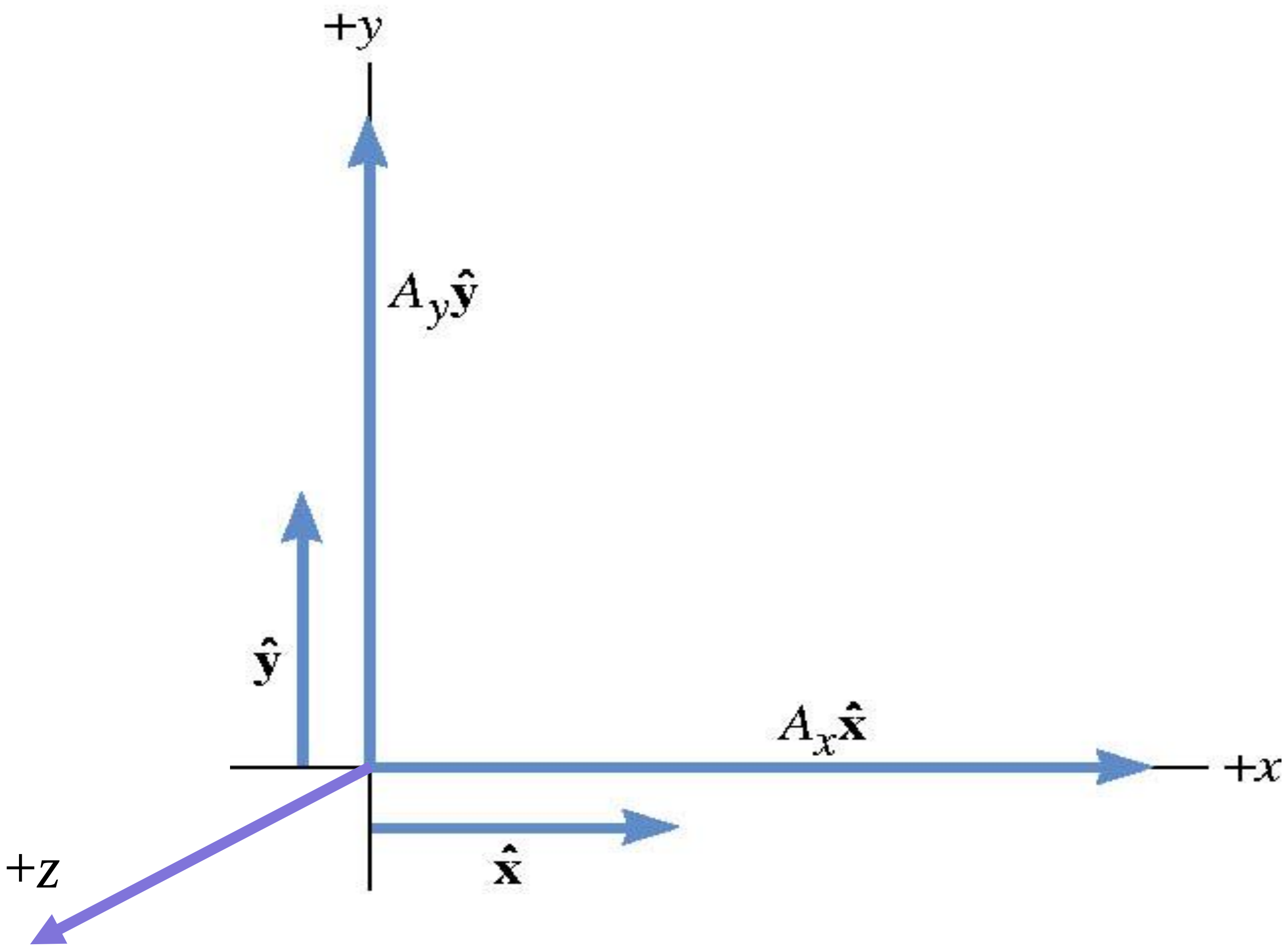
Simple Multiplication

- Multiplication of a vector by a scalar
- Let's say Mr.X travelled 1 km east. What if Mr.X had gone 4 times as far in the same direction?
  - Just stretch it out: multiply the magnitude and preserve the direction
- Negatives:
  - Multiplying by a negative number turns the vector around

Reference frame or system of coordinates

Almost any problem in mechanics starts with selection of the reference system. To determine the location of an object we provide its position in respect to some other object or point that we select as an origin.

Reference frame and unit vectors



Description of position and displacement: vectors

Simplest object: a dot

To locate a dot on a line: number

To locate a dot on a plane: 2 numbers, 2D

To locate a dot in space: 3 numbers, 3D

System of coordinates: $\{x,y,z\}$

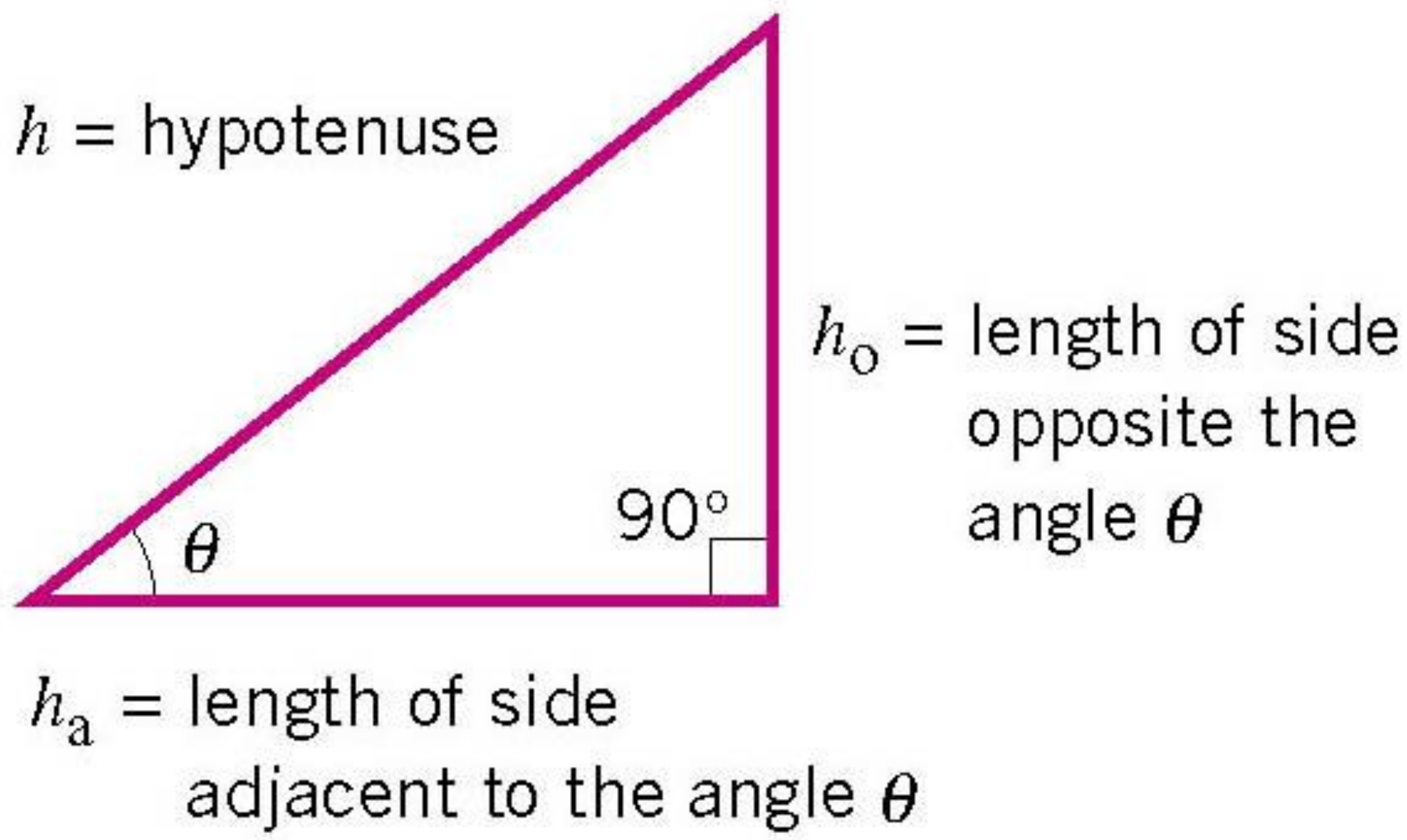
Position vector (radius-vector)

The tale of this vector is always in the origin of the reference frame.

Describes position of a point on a plane (in 2D, 2 numbers: {x,y}), or in space (in 3D, 3 numbers, {x,y,z}).

Displacement- change of the position, this is a vector!

Trigonometry



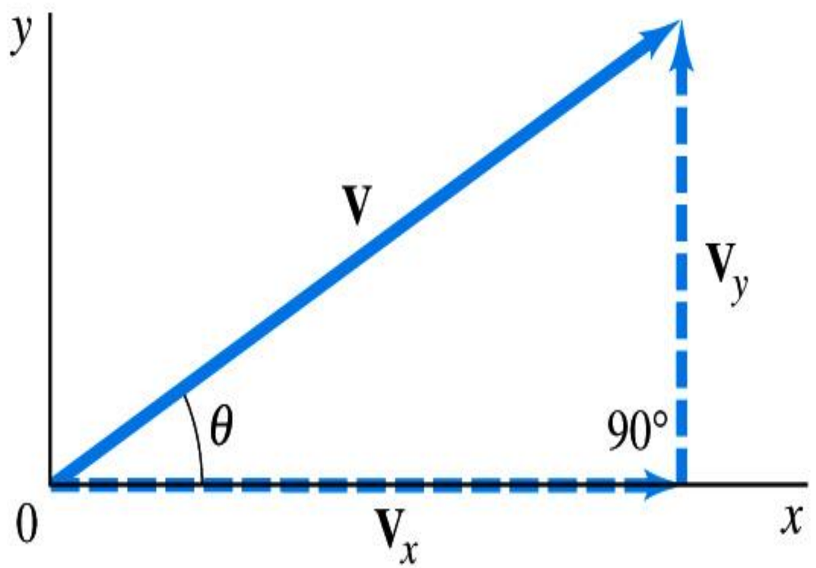
Vectors by Components

How do you do it?

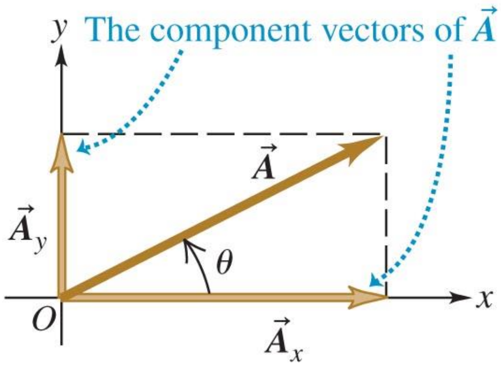
- First RESOLVE the vector by its components! Turn one vector into two

$$\vec{V} = \vec{V}_X + \vec{V}_Y$$
$$|V_X| = |V| \cos \Theta$$
$$|V_Y| = |V| \sin \Theta$$

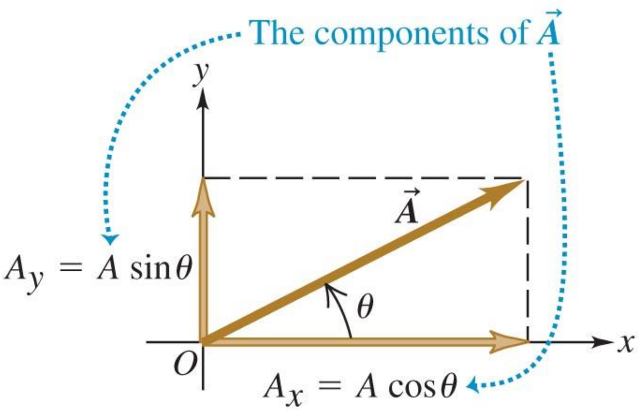
- Careful when using the sin and cos: don't mix them up!



Or, Decompose the Vectors into Components, Then Solve



(a)



(b)

vector $\vec{A}$ as a sum of component vectors

$$\vec{A} = \vec{A}_x + \vec{A}_y$$

vector component of $\vec{A}$

$$A_x = A \cos\theta$$

$$A_y = A \sin\theta$$

magnitutde and direction of $\vec{A}$

$$A = \sqrt{A_x^2 + A_y^2}$$

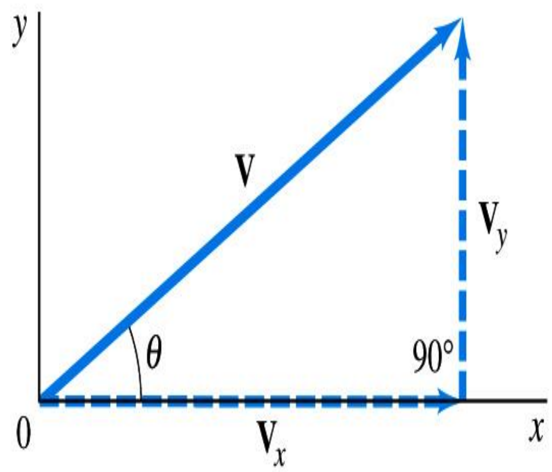
$$\tan\theta = \frac{A_y}{A_x}$$

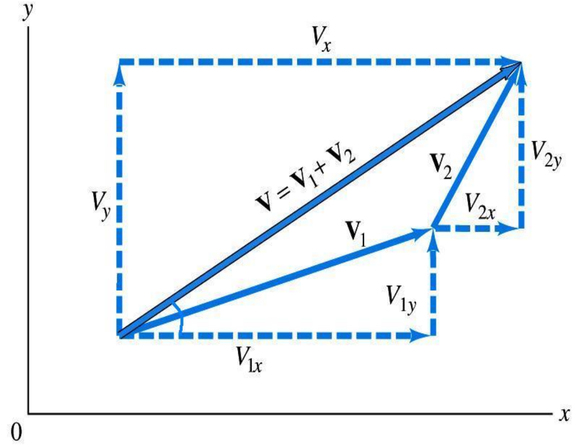
Angle is measured counterclockwise!

Pearson

Vector addition (by components)

Components are projections along the axis





$$\sin\theta = \frac{V_y}{V}$$

$$\cos\theta = \frac{V_x}{V}$$

$$\tan\theta = \frac{V_y}{V_x}$$

$$V^2 = V_x^2 + V_y^2$$

$$V_x = V_{1x} + V_{2x}$$

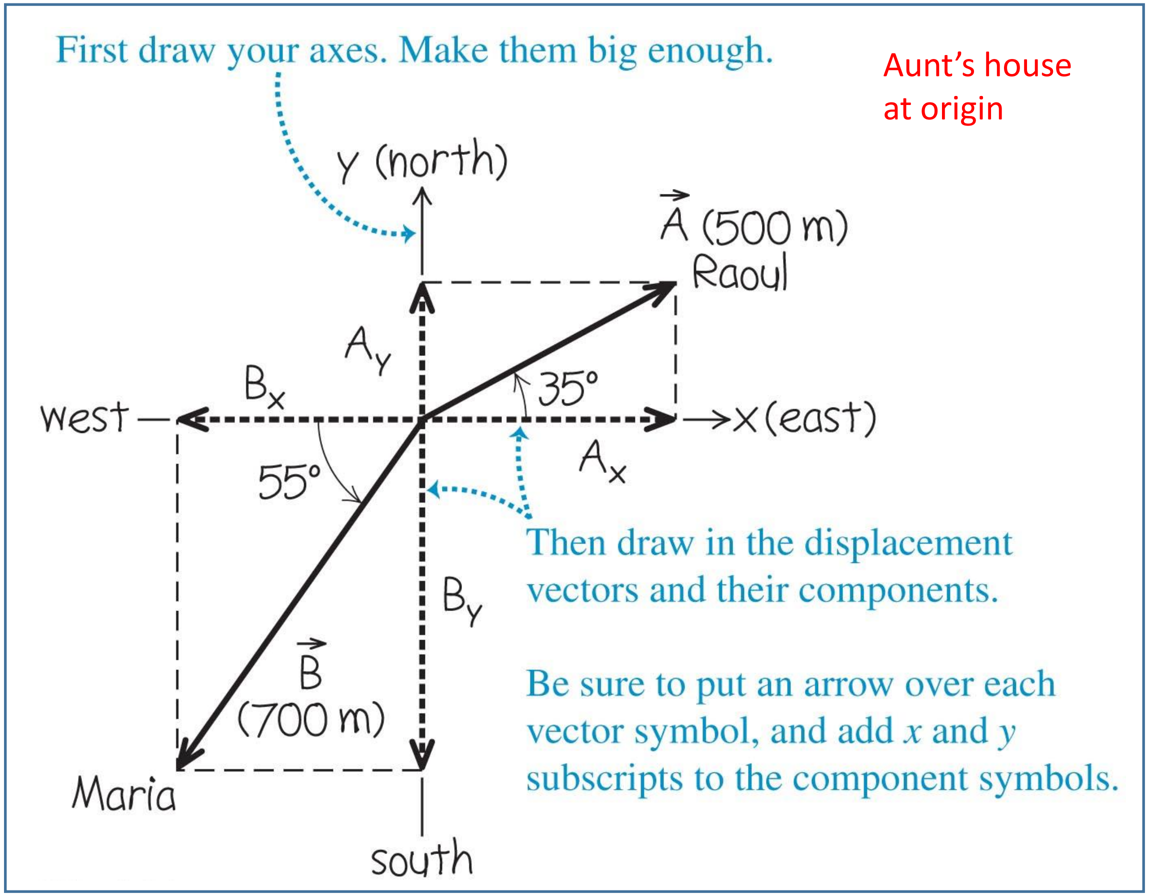
$$V_y = V_{1y} + V_{2y}$$

$$V^2 = V_x^2 + V_y^2$$

$$\tan\theta = \frac{V_y}{V_x}$$

Find components by trigonometry

Example 1.6 on P. 17-18



How far did Raoul walk?

(a) on the east leg of the trip

$A_x = A\cos(35°) = 500\cos(35°)$
$= 410$ m

(a) on the north leg of the trip

$A_y = A\sin(35°) = 500\sin(35°)$
$= 287$ m

How far did Maria walk?

(c) on the west leg of the trip

$B_x = B\cos(180°+55°) = 700\cos(235°)$
$= -402$ m

Or, $B_x = -B\cos(55°) = -700\cos(55°)$
$= -402$ m

(d) on the south leg of the trip

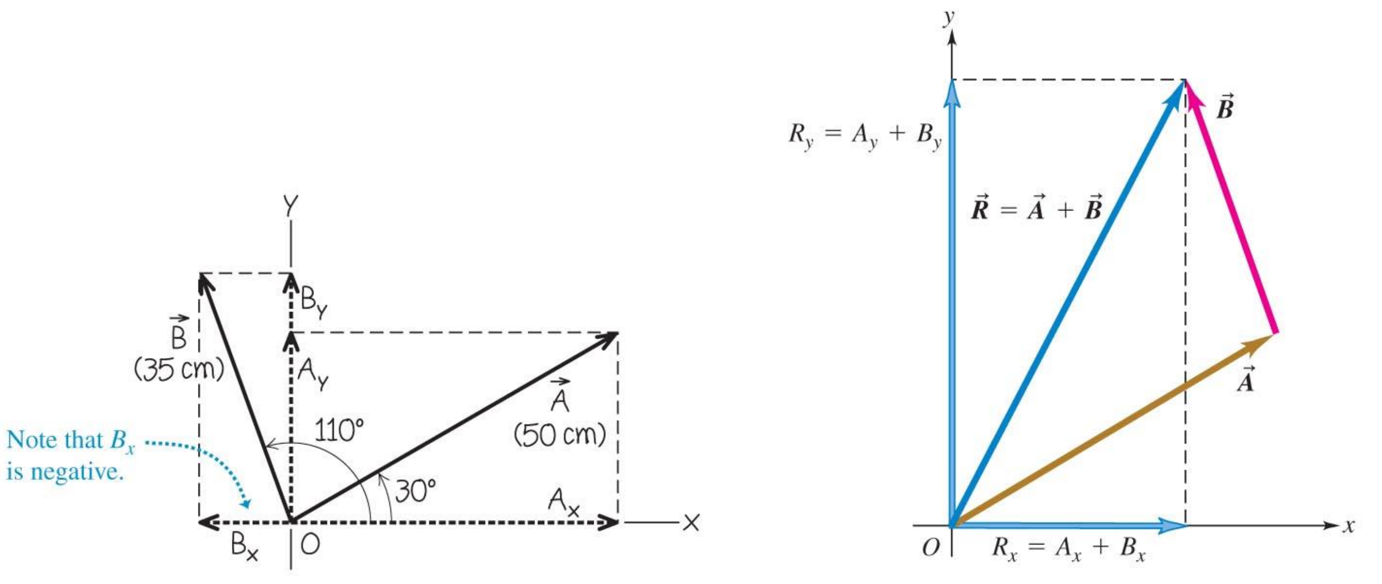
$B_y = B\sin(180°+55°) = 700\sin(235°)$
$= -573$ m

Or, $B_y = -B\sin(55°) = -700\sin(55°)$
$= -573$ m

Courtesy of Wenhao WU

Using Components to Add Vectors

Example 1.7: Vector $\vec{A}$ has a magnitude of 50 cm and direction of 30º, and vector $\vec{B}$ has a magnitude of 35 cm and direction 110º (both angles measured *ccw* from $+\hat{x}$). What is the resultant vector $\vec{R}$?



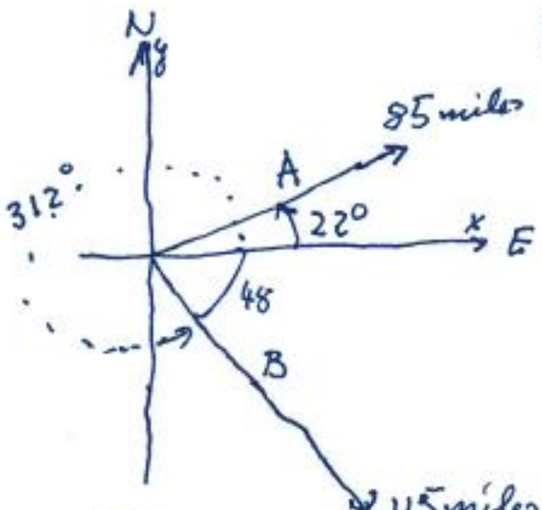
(a) Our diagram for this problem

(b) The resultant $\vec{R}$ and its components

Pearson

Problem (similar to1-43)

A plane flies 85 miles at 22° north of east, then it changes direction to 48° south of east flying 115 miles more. Then it lands, where is the plane?



plan: add the vector components and find the resultant R, and ϕ

$A_x = A\cos 22° = 85(\cos 22°) = 78.8$ miles

$A_y = A\sin 22° = 85(\sin 22°) = 31.8$ miles

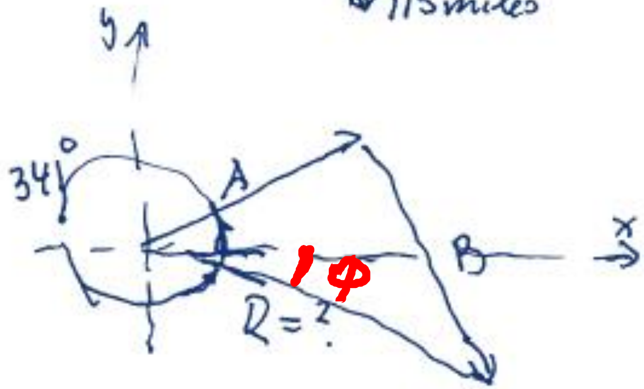
$B_x = B\cos 312° = 115\cos 312 = 77$ miles

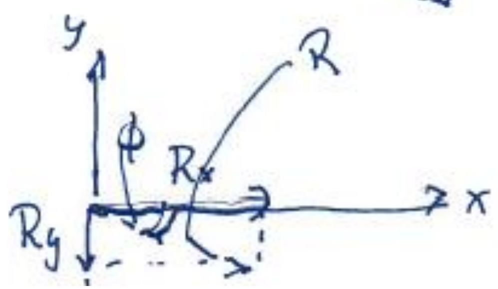
$B_y = B\sin 312 = -85.5$ miles

$R_x = A_x + B_x = 78.8 + 77 = 155.8$ miles

$R_y = A_y + B_y = 31.8 + (-85.5) = -53.7$ miles

$R = \sqrt{R_x^2 + R_y^2} = \sqrt{(155.8)^2 + (-53.7)^2} = 165$ miles





$\tan\phi = \frac{R_y}{R_x} = \frac{-53.7}{155.8}$ and $\phi = 341°$

or ϕ=19 deg. south of east

Examples: vector or scalar?

1. Displacement
2. Velocity
3. Acceleration
4. Force

1. Distance
2. Speed
3. Time
4. Mass

Clicker question

A radio-controlled model car moves 3 m in one direction and then 5 m in another direction. The car's resultant displacement could have a magnitude as small as

- –2 m.
- 0 m.
- 2 m.
- 3 m.
- 8 m.

Summary of simple operations on vectors

1. Sum and subtract
2. Multiply by a number

You can do this by components!

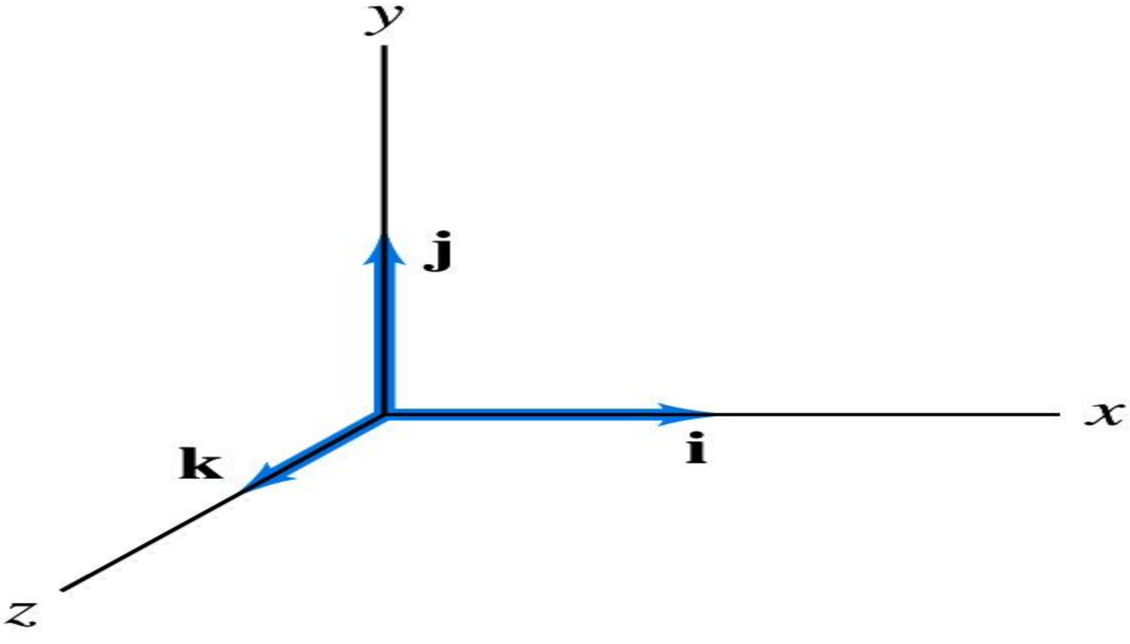
For components it works just as with numbers, but signs should be taken into account!

However, multiplication of vectors is different!

Vector Multiplication

Scalar (dot) product $\vec{A}\cdot\vec{B} = AB\cos\theta = A_x B_x + A_y B_y + A_z B_z$

Vector product $\left|\vec{A}\times\vec{B}\right| = AB\sin\theta = \left|\vec{C}\right|$



$$\vec{A}\times\vec{B} = \begin{pmatrix} \hat{i} & \hat{j} & \hat{k} \\ A_x & A_y & A_z \\ B_x & B_y & B_z \end{pmatrix} = (A_y B_z - A_z B_y)\hat{i} + (A_z B_x - A_x B_z)\hat{j} + (A_x B_y - A_y B_x)\hat{k}$$

Thank you for your attention!