College Physics 1A

for International Students

Spring 2025
February 25

Course Instructor:

Jingtian Hu (胡竞天)

About Myself

Education & Work Experiences:

University of Illinois at Urbana-Champaign 2009-2013

Bachelors' Materials Science & Engineering

Northwestern University 2013-2019

PhD Materials Science & Engineering

Northwestern University 2019-2021

Postdoctoral Chemistry Department

University of California, Los Angeles 2021-2023

Postdoctoral Electrical & Computer Engineering

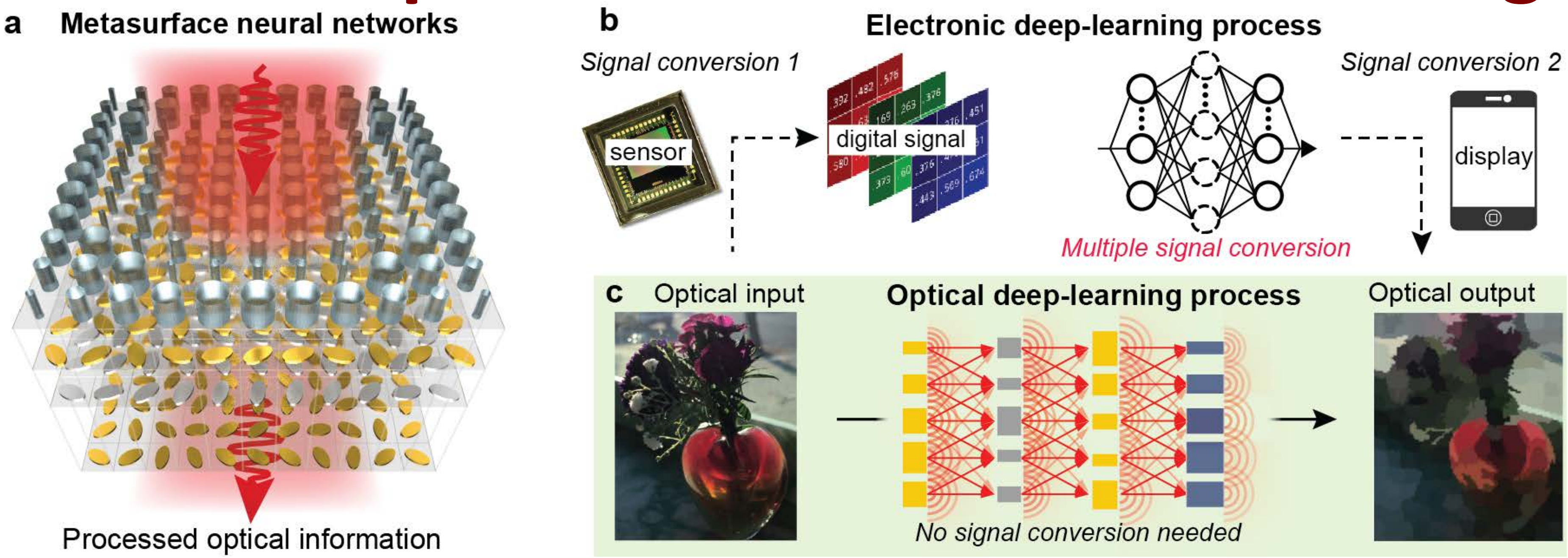
About Myself

Education & Work Experiences:

Harbin Institute of Technology (Shenzhen) 2023-Now

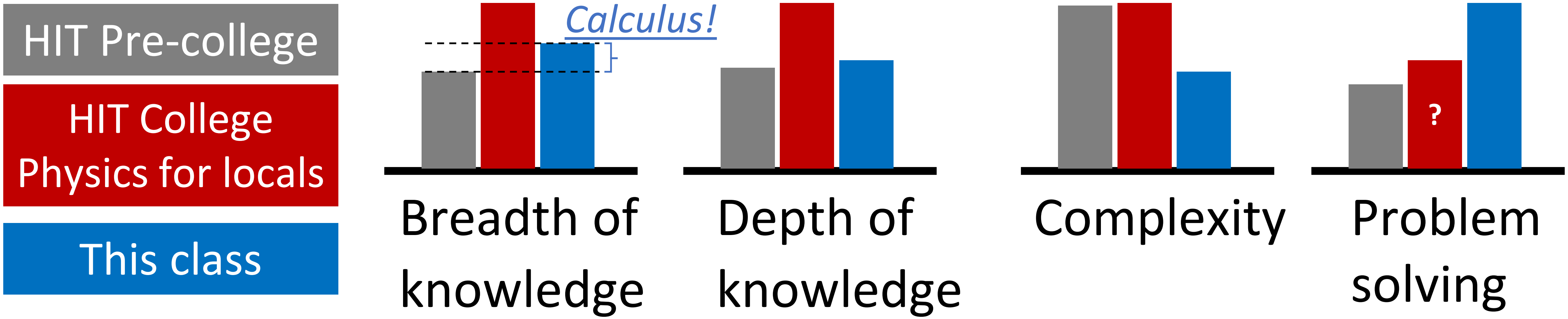
Associate Researcher School of Science

Research: Nanophotonics & Machine Learning



How "difficult" will this class be?

Well, depends on what you mean by difficult.

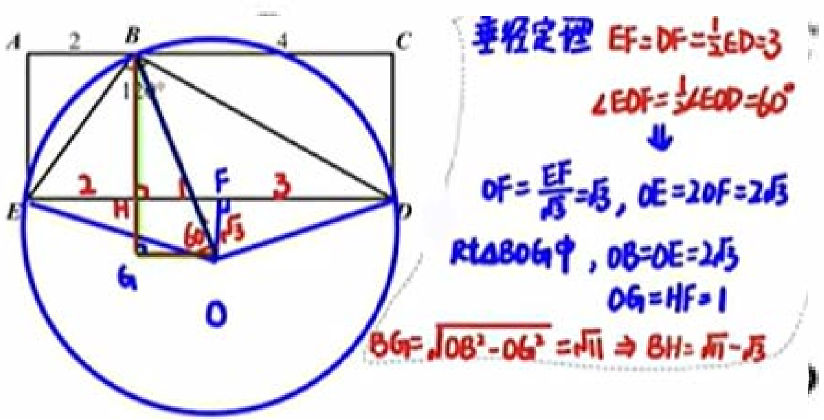


Yes, time to practice your favorite calculus!

- Too useful to miss out!
- Computer science: machine learning involves *convolution* $(f*g)' = \frac{d}{dt}\int_{-\infty}^{\infty} f(\tau)g(t-\tau)\,d\tau$
- Optoelectronics: Fourier transform is everywhere in signal processing!

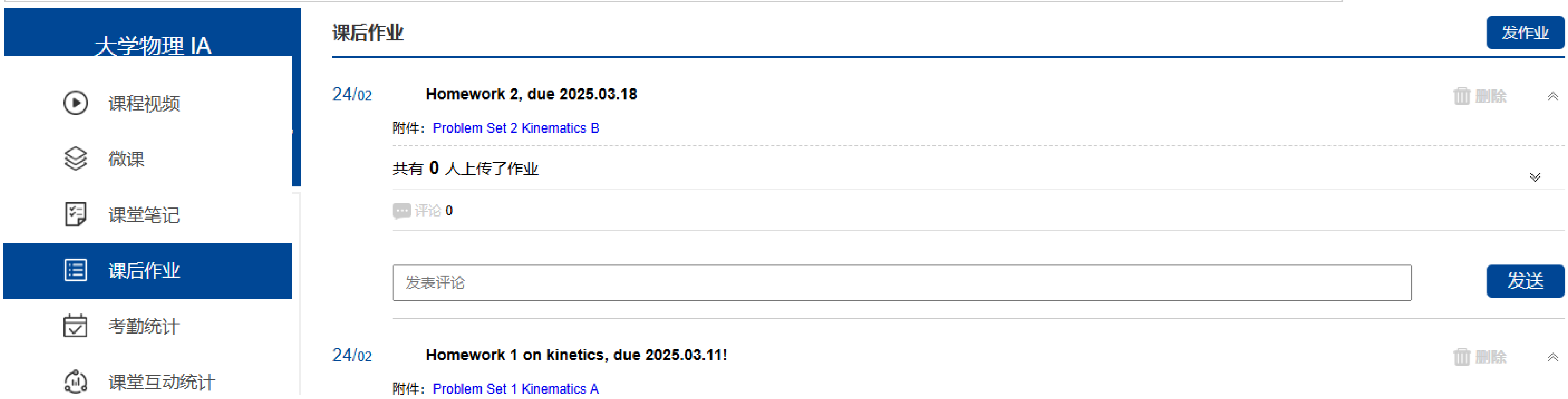
$$F(\omega) = \int_{-\infty}^{\infty} f(t)e^{-i\omega t}\,dt$$

Pre-college exams can be really complex… but not so useful



Course Grade Composition

- 20% - Homework & Quiz (first two uploaded already!)



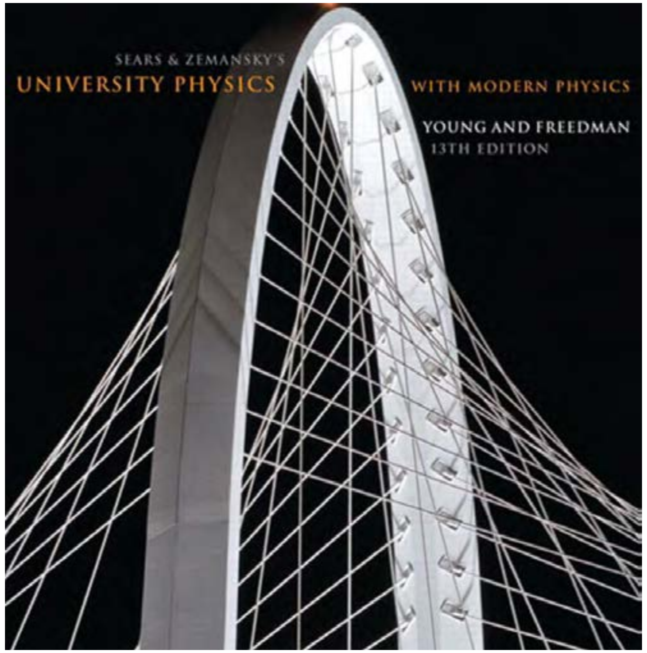
- 30% - Mid-term exam
- 50% - Final exam

Exam Questions Breakup

- 60% - High-school level for a local student
- 70% - In class examples excluding calculus
- 80% - In class examples with calculus
- 90% - Homework questions
- 100% - plus some challenging problems

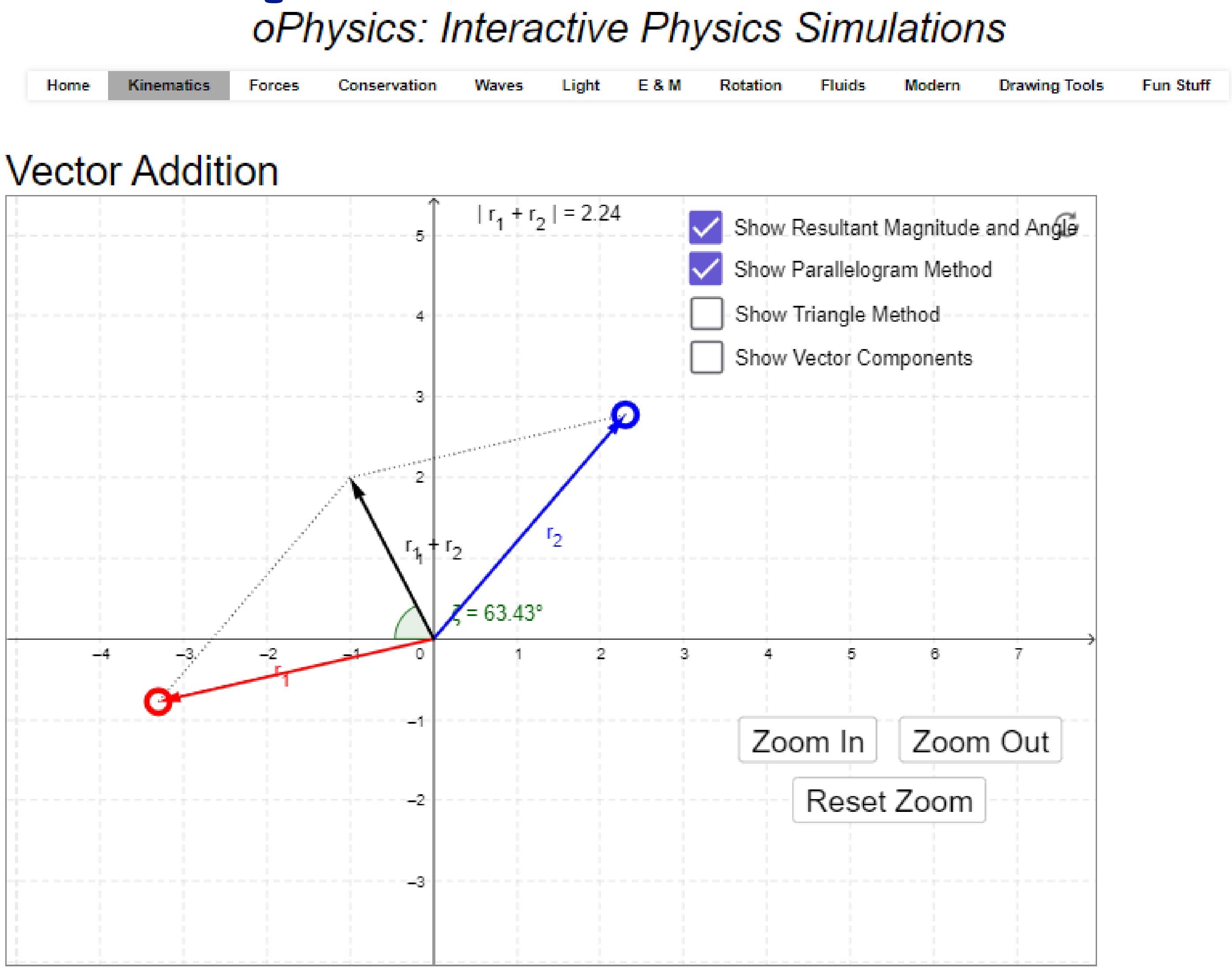
Tips for Survival

- Read the textbook before lectures
- Come to lectures
- Try to solve problems independently
- Proactive and interactive
- Study groups
- Don’t cheat



University Physics with Modern Physics 13th Edition -Addison-Wesley (2012)

Tips for Survival



https://ophysics.com/k1.html

Attendance policies

- Don’t be late for more than 15 minutes.
  (will be considered absent)

These actions are considered cheating and your attendance for 3 lectures will be voided as a punishment

- Sign up but leave early
- Sign up without showing up in the class

If you have emergency situations or get sick, notify the course instructor by email at least 24 hours ahead with proof from hospitals etc.

QQ Discussion Group

大学物理IA

群号: 931690818

1. QQ group is mainly for students to collaborate.
2. The TAs will take turns to offer online Q&A sessions with twice a week. (time to be announced). Please don't bother the TAs during other times.
3. For both Q&A and discussion, please take screenshots of the questions you have trouble with and explain with text. Or draw a scheme.
4. Because the purpose of the Q&A is to help everyone to catch up, TAs will address fundamental questions first.

DeepSeek can be a really helpful tool as well.

Exam Policy

1.Prohibited Actions During Exams:

1. Do **not** use unauthorized materials (e.g., cheat sheets, notes on hands, phones, or calculators if disallowed).
2. Do **not** look at another student's paper or answers.
3. Do **not** communicate with others (verbally, nonverbally, or via gestures) during the exam, including while leaving for restrooms.
4. Do **not** borrow items (calculators, stationery) from classmates during the exam.
5. Do **not** wear face masks, covers, or suspicious attire (remove them during the exam).
6. Do **not** leave the exam room without permission.
7. Do **not** spend more than **4 minutes** on restroom breaks.

Exam Policy

2. Exam Conduct:

1. Keep your eyes **only on your own paper**; looking around the room may be interpreted as cheating.
2. If you finish early, **remain quiet and seated**. Do not talk, move around, or interact with others until all exams are collected.
3. At the end of the exam, **stop writing immediately**, put away writing tools, and stand quietly at your seat.

3. **Restroom Protocol:**

1. Raise your hand and **wait for permission** before leaving for the restroom.
2. Do not talk to anyone while entering/exiting or during the break.

Exam Policy

4. Reporting and Academic Integrity:

1. If you accidentally see another student’s answers, **inform the proctor immediately**.
2. If you suspect cheating, **report it to the proctor after the exam** (do not confront the student during the exam).
3. If you forget materials (e.g., calculator), **ask the proctor for assistance**—do not borrow from peers.
4. Post-exam discussion is prohibited until **all students have submitted their exams**.

What to expect in a lecture?

Tentative class organization (in 30-minute sections):

- Lecture speech (10-15 minutes each)
- Examples from the book (5-10 minutes) to strengthen your understanding
- Exercises and in-class Q&A (concurrently 5-10 minutes)

If you understand the lecture well

If you have questions

- TAs and I will go around
- Discussions are encouraged during this time (try to form study groups and sit around each other!)

Tips from Textbook

哈爾濱工業大學
HARBIN INSTITUTE OF TECHNOLOGY
100th ANNIVERSARY
1920-2020

Preparation for This Course

If you had high school physics, you will probably learn concepts faster than those who have not because you will be familiar with the language of physics. If English is a second language for you, keep a glossary of new terms that you encounter and make sure you understand how they are used in physics. Likewise, if you are farther along in your mathematics courses, you will pick up the mathematical aspects of physics faster. Even if your mathematics is adequate, you may find a book such as Arnold D. Pickar's *Preparing for General Physics: Math Skill Drills and Other Useful Help (Calculus Version)* to be useful. Your professor may actually assign sections of this math review to assist your learning.

Tips from Textbook

Learning to Learn

Each of us has a different learning style and a preferred means of learning. Understanding your own learning style will help you to focus on aspects of physics that may give you difficulty and to use those components of your course that will help you overcome the difficulty. Obviously you will want to spend more time on those aspects that give you the most trouble. If you learn by hearing, lectures will be very important. If you learn by explaining, then working with other students will be useful to you. If solving problems is difficult for you, spend more time learning how to solve problems. Also, it is important to understand and develop good study habits. Perhaps the most important thing you can do for yourself is to set aside adequate, regularly scheduled study time in a distraction-free environment.

What is physics:

- Any fans of philosophy?

Physics: the branch of science concerned with the nature and properties of matter and energy. The subject matter of physics includes mechanics, heat, light and other radiation, sound, electricity, magnetism the structure of atoms.

What is not physics?

Firstly, mathematics is probably not physics.

- Study of physics uses tools developed by mathematicians.

Computer science so far is not physics.

- Developed based on discrete math

What is not physics?

Are chemical reactions physical? Yes!

- Predictions of reactions are often based on molecular orbital theory, derived from quantum mechanics.

https://chemed.chem.purdue.edu/genchem/topicreview/bp/ch8/mo.html

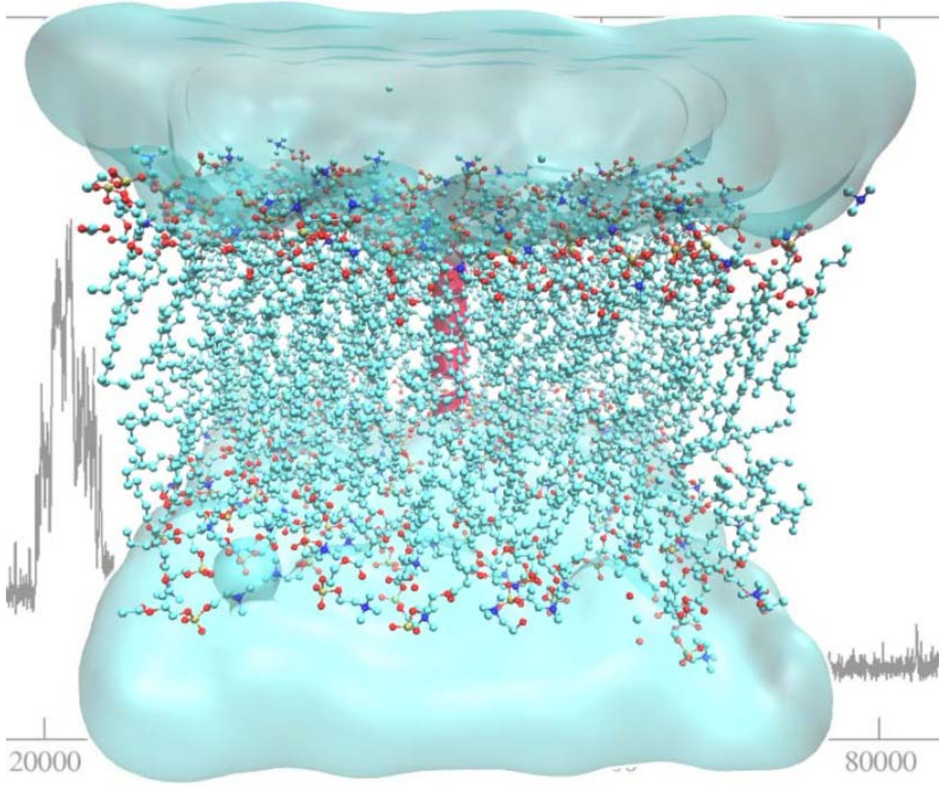
- Density functional theory (DFT), a powerful tool to study molecules and solids, is also based on quantum mechanics

https://www.sciencedirect.com/topics/physics-and-astronomy/density-functional-theory

What is not physics?

Are biological processes physical?   Yes!

- Biological processes can be modeled by molecular dynamics (MD), a method that models every single atoms/atom group with quantum mechanics and statistical mechanics



https://insilicosci.com/molecular-dynamics-simulation-concepts/

What is not physics?

Why do chemistry and biology still exist?

Historically, they are developed because we have limited knowledge and no control over the microscopic world.

Now, do we still need them?

- Think about problem solving.

What is not physics?

Why do chemistry and biology still exist?

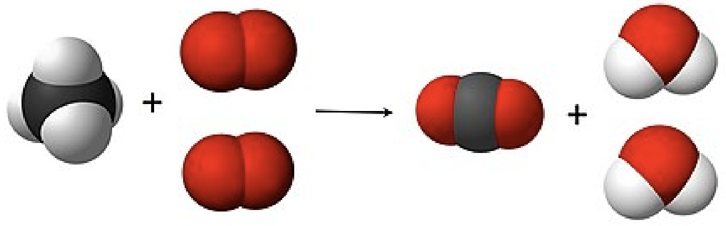
Physics

Components	Energy	Exergy balance
Compressor	$\dot{W}_c = \dot{m}_a c_p (T_j - T_i)$	$\dot{E}x_i + \dot{W}_c = \dot{E}x_j$
Heat Exchanger	$\dot{Q}_k = \dot{m}_k c_p (T_j - T_i)$	$\dot{E}x_i + \left(1 - \left(\frac{T_0}{T_k}\right)\right.$
Turbine	$\dot{W}_t = \dot{m}_g c_p (T_i - T_j)$	$\dot{E}x_i = \dot{E}x_j + \dot{W}_t$
SOFC	$\dot{W}_{SOFC} = IV$	$\sum_i \dot{E}x_i = \sum_j \dot{E}x_j$

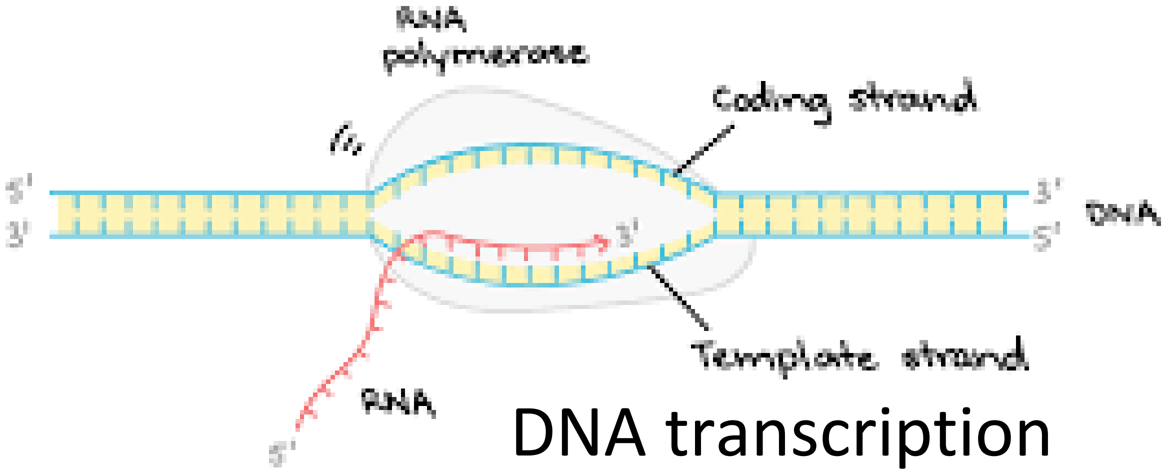
$$H(t)\,|\,\psi(t)\rangle = i\hbar \frac{d}{dt}\,|\,\psi(t)\rangle$$

	Classical	Quantum
'Path' picture →	Wiener/Kac	Feynman
Diffusion / Schrödinger	$\frac{\partial U}{\partial t} = D\,\frac{\partial^2 U}{\partial x^2}$	$\frac{\partial \psi}{\partial t} = i\,D\,\frac{\partial^2 \psi}{\partial x^2}$
Telegraph / K. G.	$\frac{\partial^2 U}{\partial t^2} = c^2\,\frac{\partial^2 U}{\partial z^2} + a^2 U$	$\frac{\partial^2 \psi}{\partial t^2} = c^2\,\frac{\partial^2 \psi}{\partial z^2} + (i\,m)^2 \psi$
Telegraph / Dirac	$\frac{\partial U}{\partial t} = c\,\sigma_z\,\frac{\partial U}{\partial z} + a\,\sigma_x U$	$\frac{\partial \Psi}{\partial t} = c\,\sigma_z\,\frac{\partial \Psi}{\partial z} + i\,m\,\sigma_x \Psi$
Decay / Oscillate	$e^{-a\,t}$	$e^{\pm i\,m\,t}$
Clock	Thermodynamic	Deterministic

Chemistry & Biology



$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$



DNA transcription

What is not physics?

Why do chemistry and biology still exist?

So, subjects like chemistry and biology take groups of math-intensive equations in physics, **simplify** them to something easy to use for specific systems.

In short: chemistry and biology are **different strategies to simply physical models**

What is not physics?

Why do chemistry and biology still exist?

Largest simulation size for DFT: ~1000 atoms. (a 10×10×10 cubic lattice, or ~1 nm^3)

https://www.nature.com/articles/s43588-021-00034-x

Largest simulation size for MD: ~10^9 atoms on a supercomputer. A cell has ~10^{14} atoms

https://onlinelibrary.wiley.com/doi/full/10.1002/jcc.26450#:~:text=The%20largest%20system%20that%20contains,biomacromolecules%20in%20a%20living%20cell.

https://www.ck12.org/flexi/biology/blood/how-many-atoms-of-blood-is-in-a-human/#:~:text=Cells%20are%20made%20up%20of,cell%20has%20100%20trillion%20atoms.

Roadmap of Physics

This semester	Next semester
Classic mechanics	Optics
Theory of Relativity	Quantum mechanics
Electromagnetics	Thermodynamics

Simply too important – pre-requisite for everything else!

No worries – at most 2 equations

Optics & electrodynamics, **essential for optoelectronics**
Also discovery of relativity

Computer graphics in computer science
Everywhere in optoelectronics

Key to understand semiconductors
Quantum computing is coming soon!

Statistical mechanics and materials engineering

Standards and Units

To make accurate, reliable measurements, we need units of measurement that do not change and that can be duplicated by observers in various locations. The system of units used by scientists and engineers around the world is commonly called “the metric system,” but since 1960 it has been known officially as the **International System,** or **SI** (the abbreviation for its French name, *Système International*). Appendix A gives a list of all SI units as well as definitions of the most fundamental units

INTERNATIONAL SYSTEM OF UNITS (SI)

SI Base Units

Base Quantity	Name	Symbol
Length	meter	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Amount of substance	mole	mol
Luminous intensity	candela	cd

SI Derived Units

Derived Quantity	Name	Symbol	Equivalent SI Units
Frequency	hertz	Hz	s^{-1}
Force	newtown	N	$m \cdot kg \cdot s^{-2}$
Pressure	pascal	Pa	N/m^2
Energy	joule	J	$N \cdot m$
Power	watt	W	J/s
Electric charge	coulomb	C	$s \cdot A$
Electric potential	volt	V	W/A
Electric resistance	ohm	Ω	V/A
Celsius temperature	degree Celsius	°C	K*

*Unit degree Celsius is equal in magnitude to unit kelvin

SI Prefixes

Factor	Name	Symbol	Numerical Value
10^{12}	tera	T	1 000 000 000 000
10^{9}	giga	G	1 000 000 000
10^{6}	mega	M	1 000 000
10^{3}	kilo	k	1 000
10^{2}	hecto	h	100
10^{1}	deka	da	10
10^{-1}	deci	d	0.1
10^{-2}	centi	c	0.01
10^{-3}	milli	m	0.001
10^{-6}	micro	μ	0.000 001
10^{-9}	nano	n	0.000 000 001
10^{-12}	pico	p	0.000 000 000 001

Adapted from NIST Special Publication 811.
SI rules and style conventions recommend using spaces rather than commas to separate groups of three digits.

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www.flinnsci.com

AP6899

Standards and Units

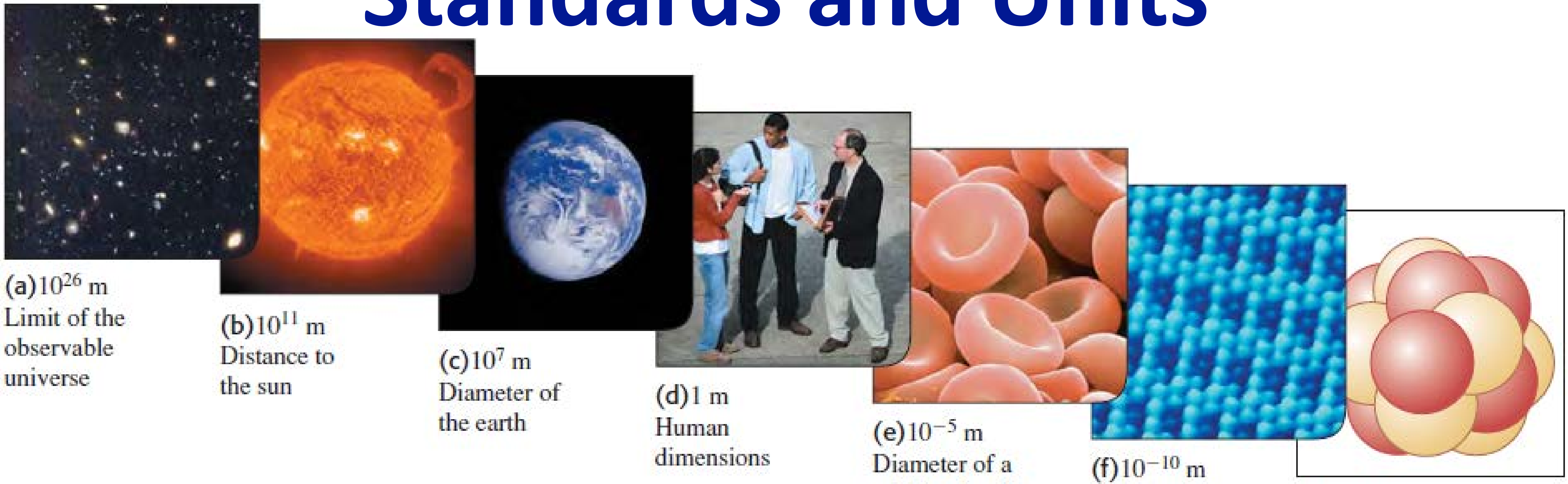
The names of the additional units are derived by adding a **prefix** to the name of the fundamental unit. For example, the prefix "kilo-," abbreviated k, always means a unit larger by a factor of 1000; thus

$$1 \text{ kilometer} = 1 \text{ km} = 10^3 \text{ meters} = 10^3 \text{ m}$$

Table 1.1 Some Units of Length, Mass, and Time

Length	Mass	Time
1 nanometer $= 1$ nm $= 10^{-9}$ m (a few times the size of the largest atom)	1 microgram $= 1\ \mu$g $= 10^{-6}$ g $= 10^{-9}$ kg (mass of a very small dust particle)	1 nanosecond $= 1$ ns $= 10^{-9}$ s (time for light to travel 0.3 m)
1 micrometer $= 1\ \mu$m $= 10^{-6}$ m (size of some bacteria and living cells)	1 milligram $= 1$ mg $= 10^{-3}$ g $= 10^{-6}$ kg (mass of a grain of salt)	1 microsecond $= 1\ \mu$s $= 10^{-6}$ s (time for space station to move 8 mm)
1 millimeter $= 1$ mm $= 10^{-3}$ m (diameter of the point of a ballpoint pen)	1 gram $= 1$ g $= 10^{-3}$ kg (mass of a paper clip)	1 millisecond $= 1$ ms $= 10^{-3}$ s (time for sound to travel 0.35 m)
1 centimeter $= 1$ cm $= 10^{-2}$ m (diameter of your little finger)		
1 kilometer $= 1$ km $= 10^{3}$ m (a 10-minute walk)		

Standards and Units



(a) 10^{26} m
Limit of the observable universe

(b) 10^{11} m
Distance to the sun

(c) 10^{7} m
Diameter of the earth

(d) 1 m
Human dimensions

(e) 10^{-5} m
Diameter of a red blood cell

(f) 10^{-10} m
Radius of an atom

(g) 10^{-14} m
Radius of an atomic nucleus

$$d = vt \quad \Rightarrow \quad 10\ \text{m} = \left(2\,\frac{\text{m}}{\cancel{\text{s}}}\right)(5\ \cancel{\text{s}})$$

CAUTION Always use units in calculations When a problem requires calculations using numbers with units, *always* write the numbers with the correct units and carry the units through the calculation as in the example above as a very useful check.

Uncertainty and Significant Figures

Multiplication or division:
Result may have no more significant figures than the starting number with the fewest significant figures:

$$\frac{0.745 \times 2.2}{3.885} = 0.42$$

$$1.32578 \times 10^{7} \times 4.11 \times 10^{-3} = 5.45 \times 10^{4}$$

Addition or subtraction:
Number of significant figures is determined by the starting number with the largest uncertainty (i.e., fewest digits to the right of the decimal point):

$$27.153 + 138.2 - 11.74 = 153.6$$

Questions so far?

5 minutes of Q&A time

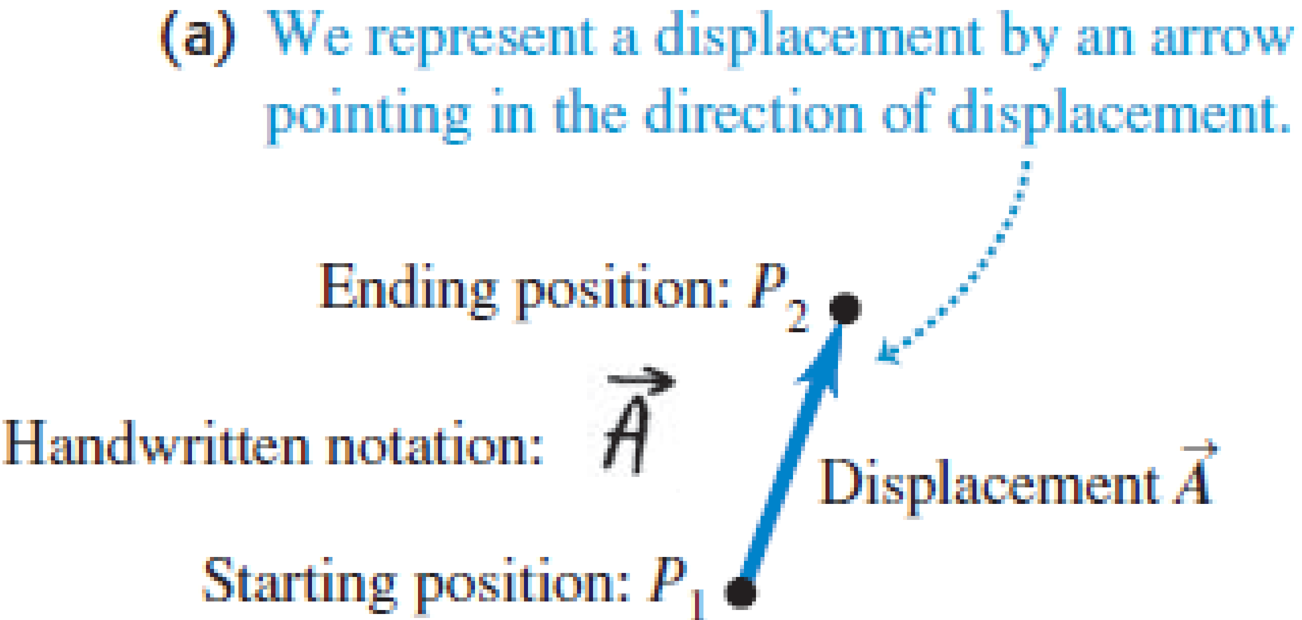
Vectors and Vector Addition

Scalar: physical quantities, such as time, temperature, mass, and density, can be described ***completely by a single number*** with a unit.

Vector: quantities with a magnitude and a ***direction***:

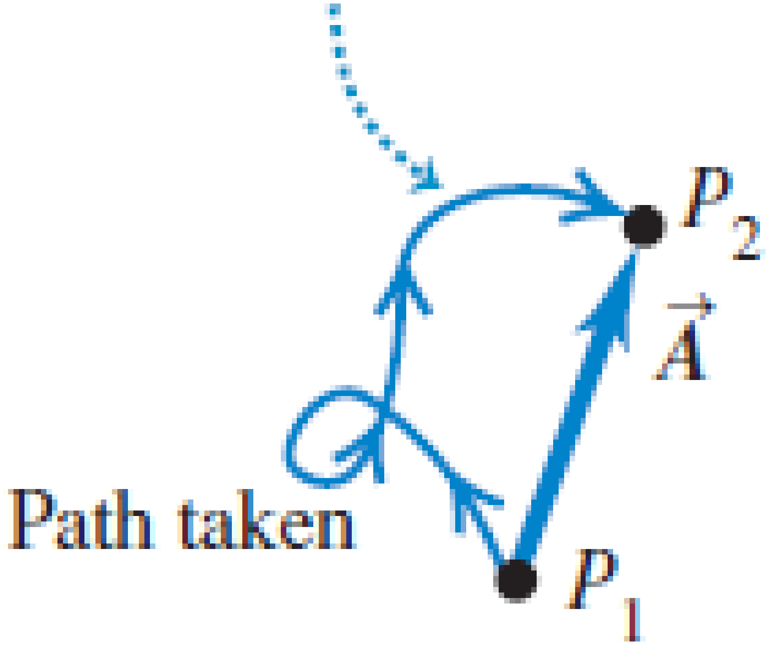
- Velocity: speed of the airplane combined with its ***direction*** of motion together
- Force: a push or pull exerted on a body.

In the textbook we always print vector symbols in ***boldface italic type with an arrow above them.***

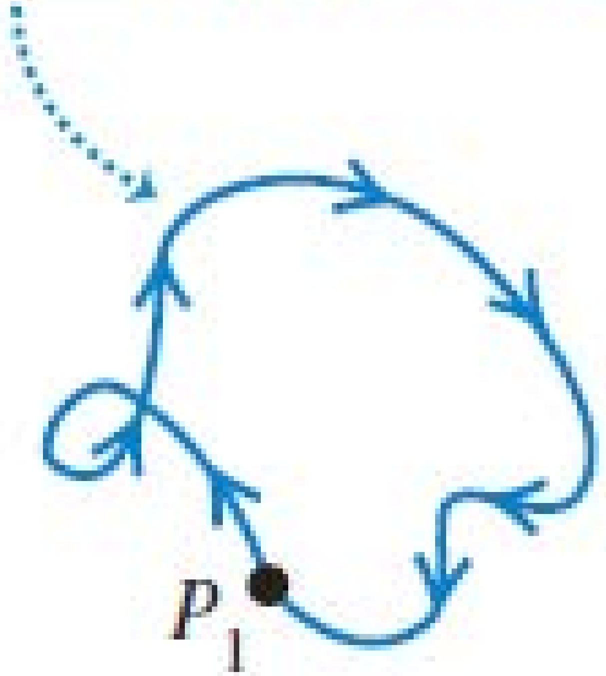


Example of Vector: Displacement

Displacement depends only on the starting and ending positions—not on the path taken.

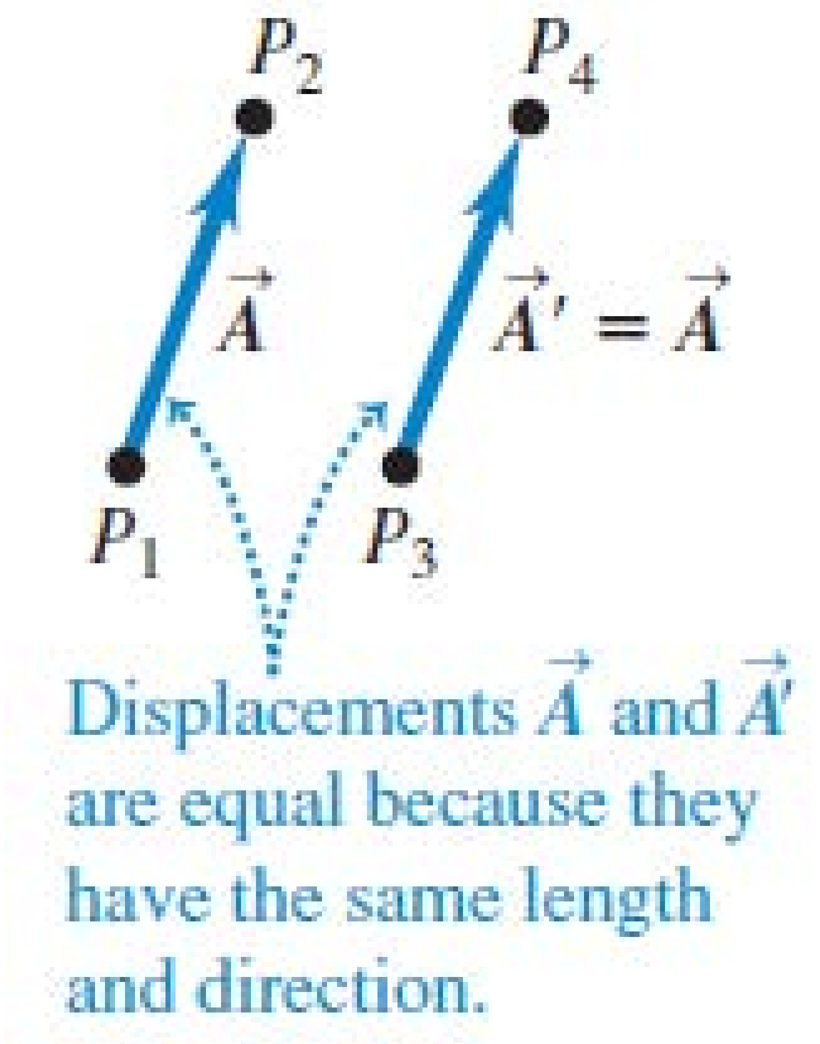


Total displacement for a round trip is 0, regardless of the distance traveled.



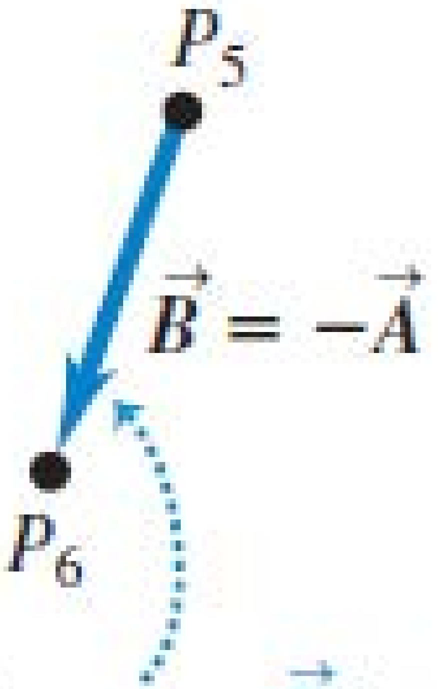
Some Properties of Vectors

If two vectors have the same direction, they are **parallel.** If they have the same magnitude *and* the same direction, they are *equal*, no matter where they are located in space.



Some Properties of Vectors

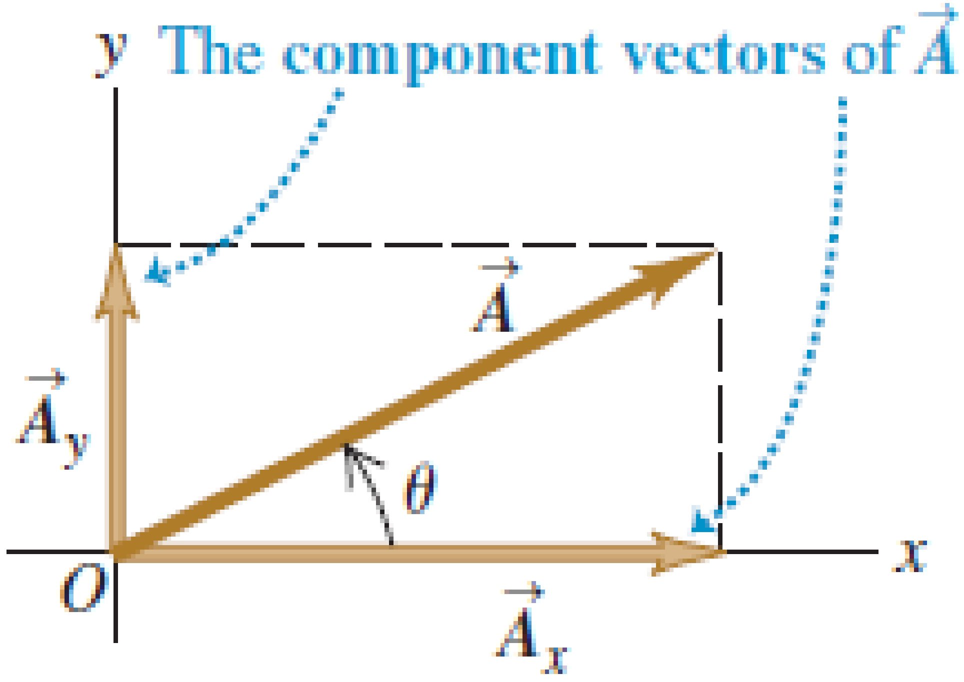
We define the **negative of a vector** as a vector having the same magnitude as the original vector but the ***opposite*** direction

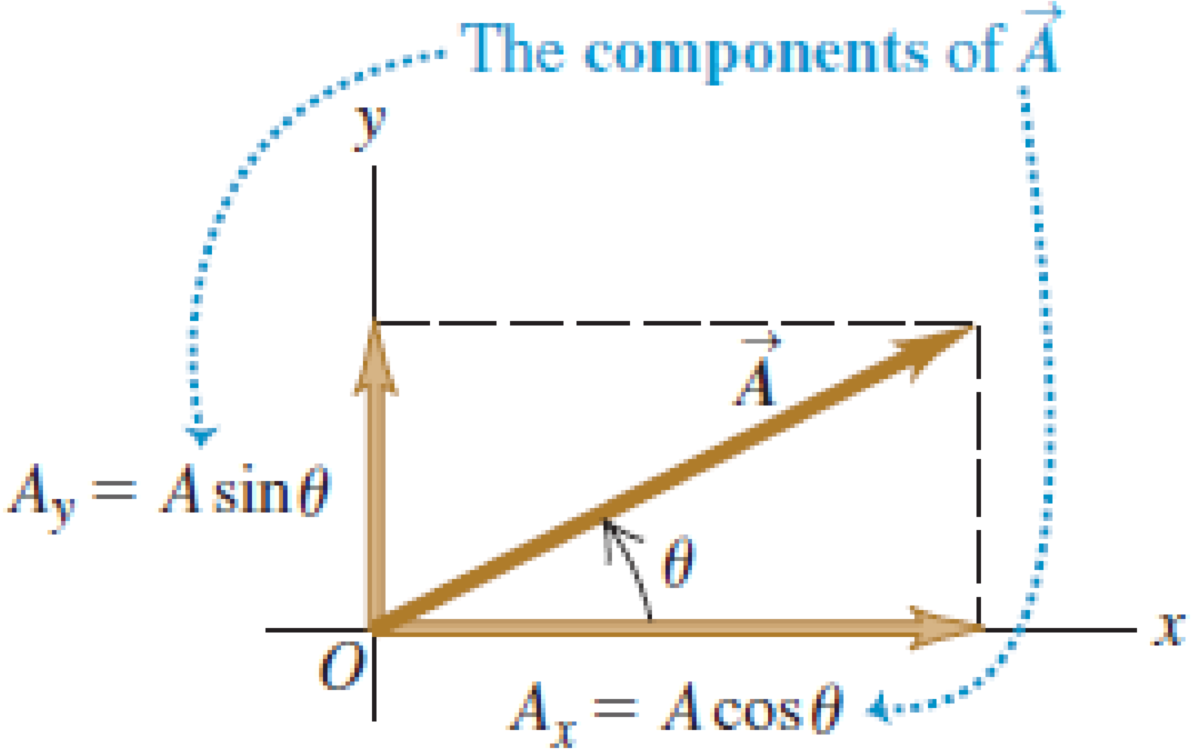


Displacement $\vec{B}$ has the same magnitude as $\vec{A}$ but opposite direction; $\vec{B}$ is the negative of $\vec{A}$.

Components of Vectors

x-y component vectors of vector: $\vec{A} = \vec{A}_x + \vec{A}_y$

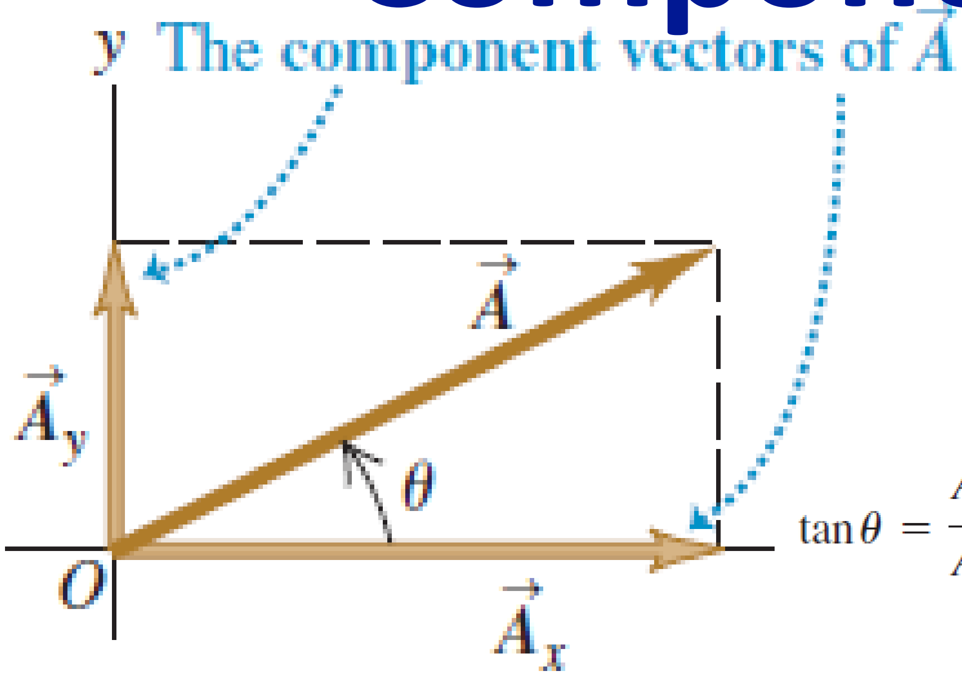




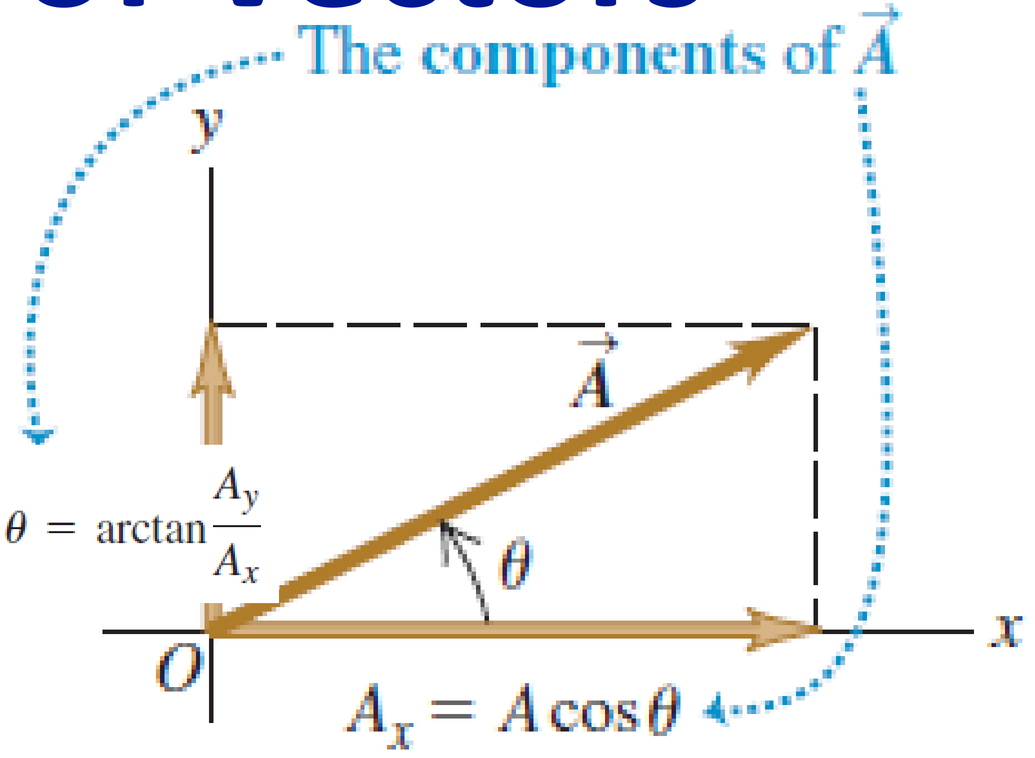
A_x and A_y without the arrows are the components (no vector)

Components are not vectors The components A_x and A_y of a vector are just numbers; they are *not* vectors themselves.

Components of Vectors



$$\tan\theta = \frac{A_y}{A_x} \quad \text{and} \quad \theta = \arctan\frac{A_y}{A_x}$$

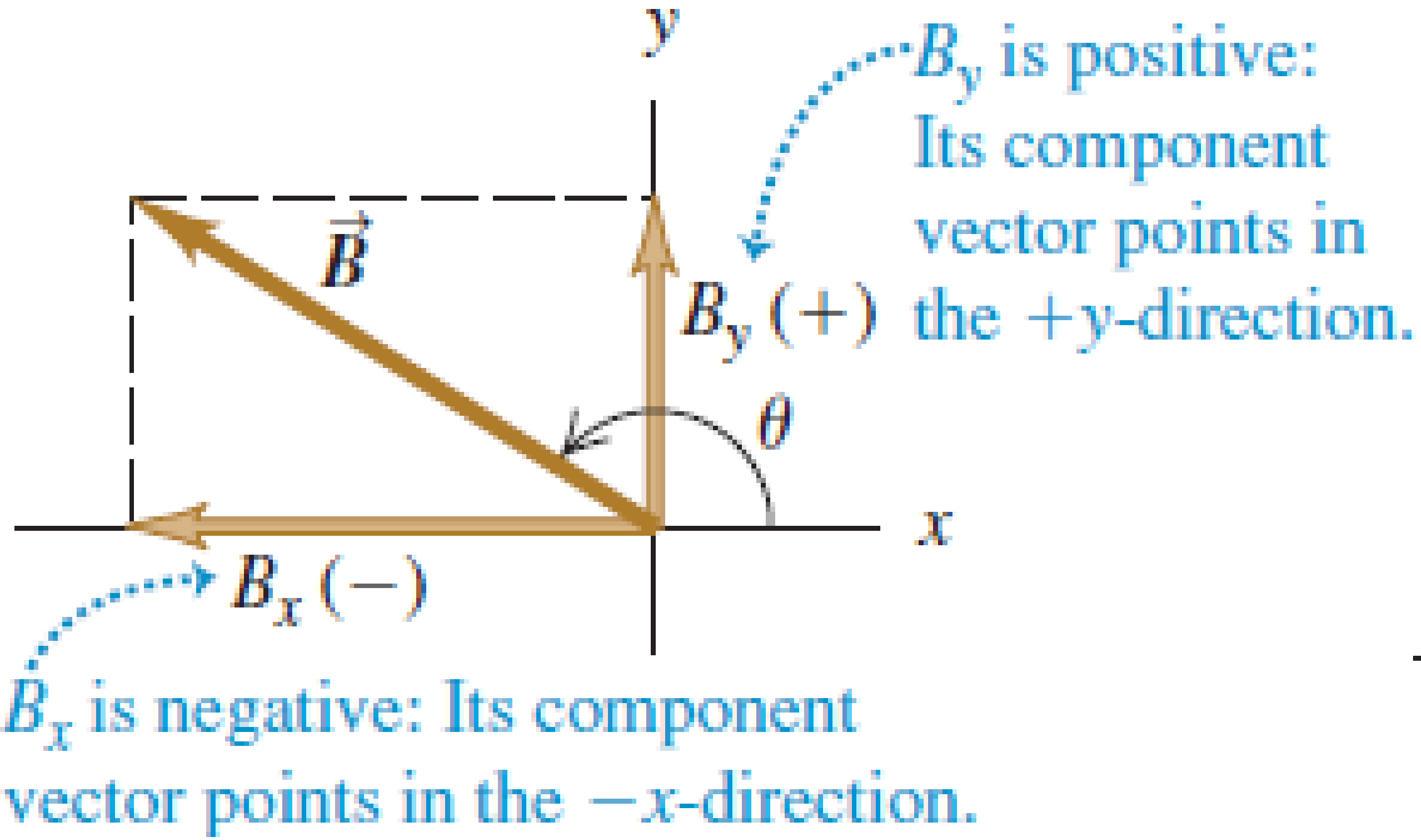


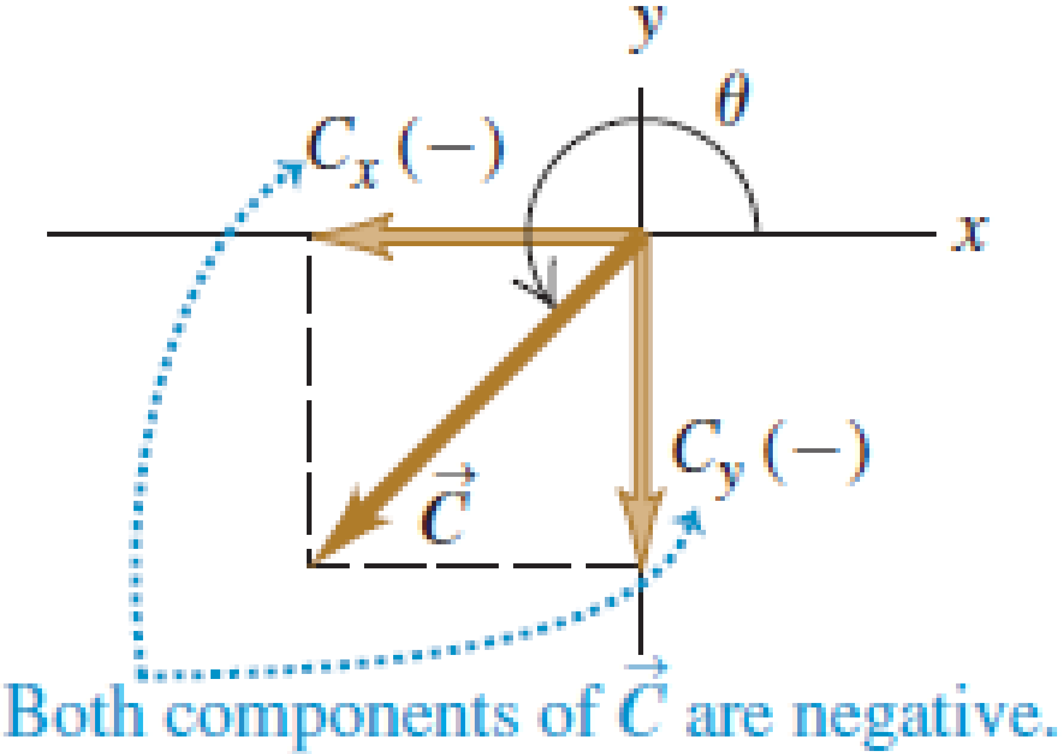
$$A = \sqrt{A_x^2 + A_y^2}$$

$$\frac{A_x}{A} = \cos\theta \quad \text{and} \quad \frac{A_y}{A} = \sin\theta \qquad \tan\theta = \frac{A_y}{A_x} \quad \text{and} \quad \theta = \arctan\frac{A_y}{A_x}$$

$$A_x = A\cos\theta \quad \text{and} \quad A_y = A\sin\theta$$

Components of Vectors

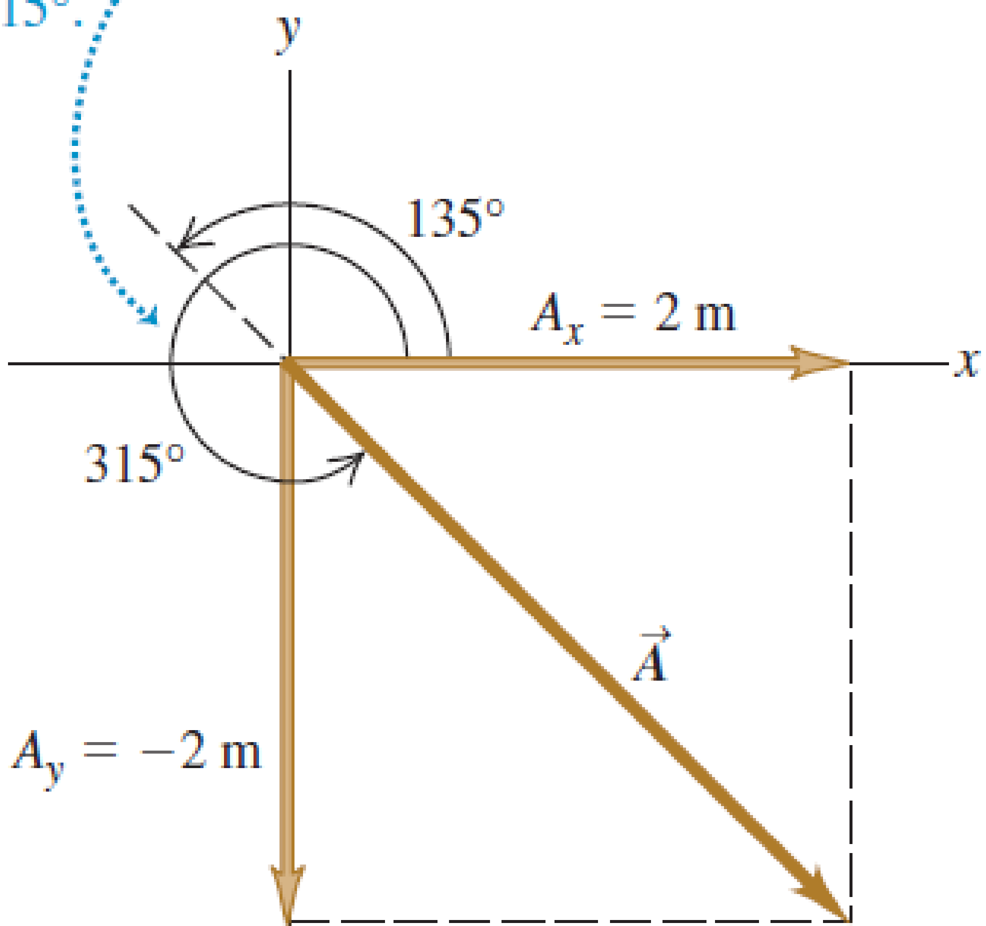




Components of Vectors

Suppose that $\tan\theta = \dfrac{A_y}{A_x} = -1$. What is θ?

Two angles have tangents of -1: 135° and 315°. Inspection of the diagram shows that θ must be 315°.



$$\tan\theta = \frac{A_y}{A_x} \quad \text{and} \quad \theta = \arctan\frac{A_y}{A_x}$$

Vector Components

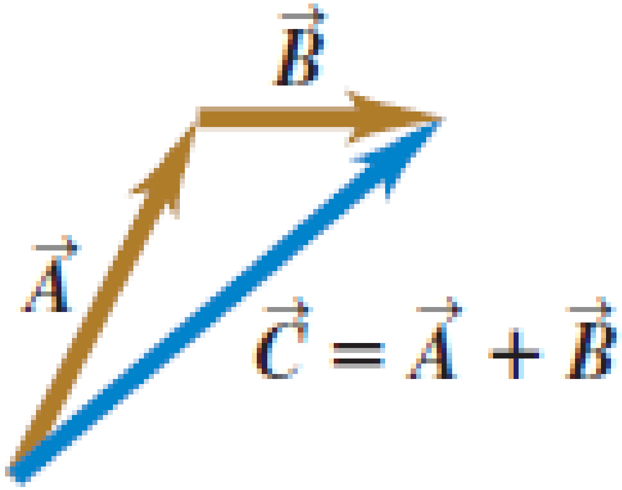
https://ophysics.com/k3.html

Questions so far?

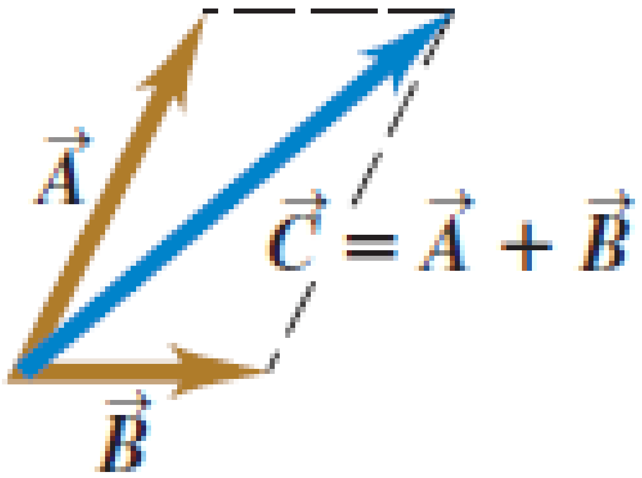
5 minutes of Q&A time

Vector Addition and Subtraction

(a) We can add two vectors by placing them head to tail.

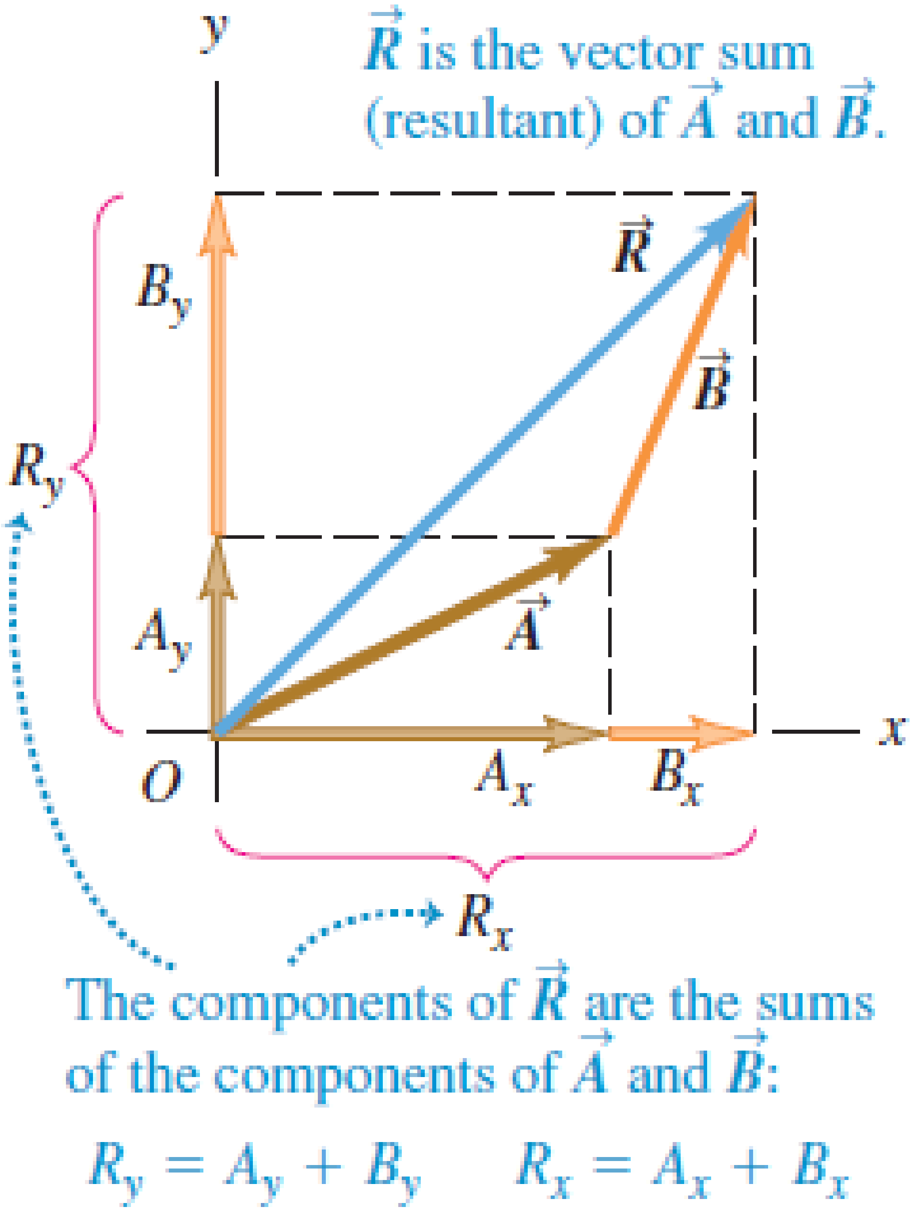


(c) We can also add them by constructing a parallelogram.



CAUTION Magnitudes in vector addition It's a common error to conclude that if then the magnitude C should equal the magnitude A plus the magnitude B. In general, this conclusion is *wrong;*

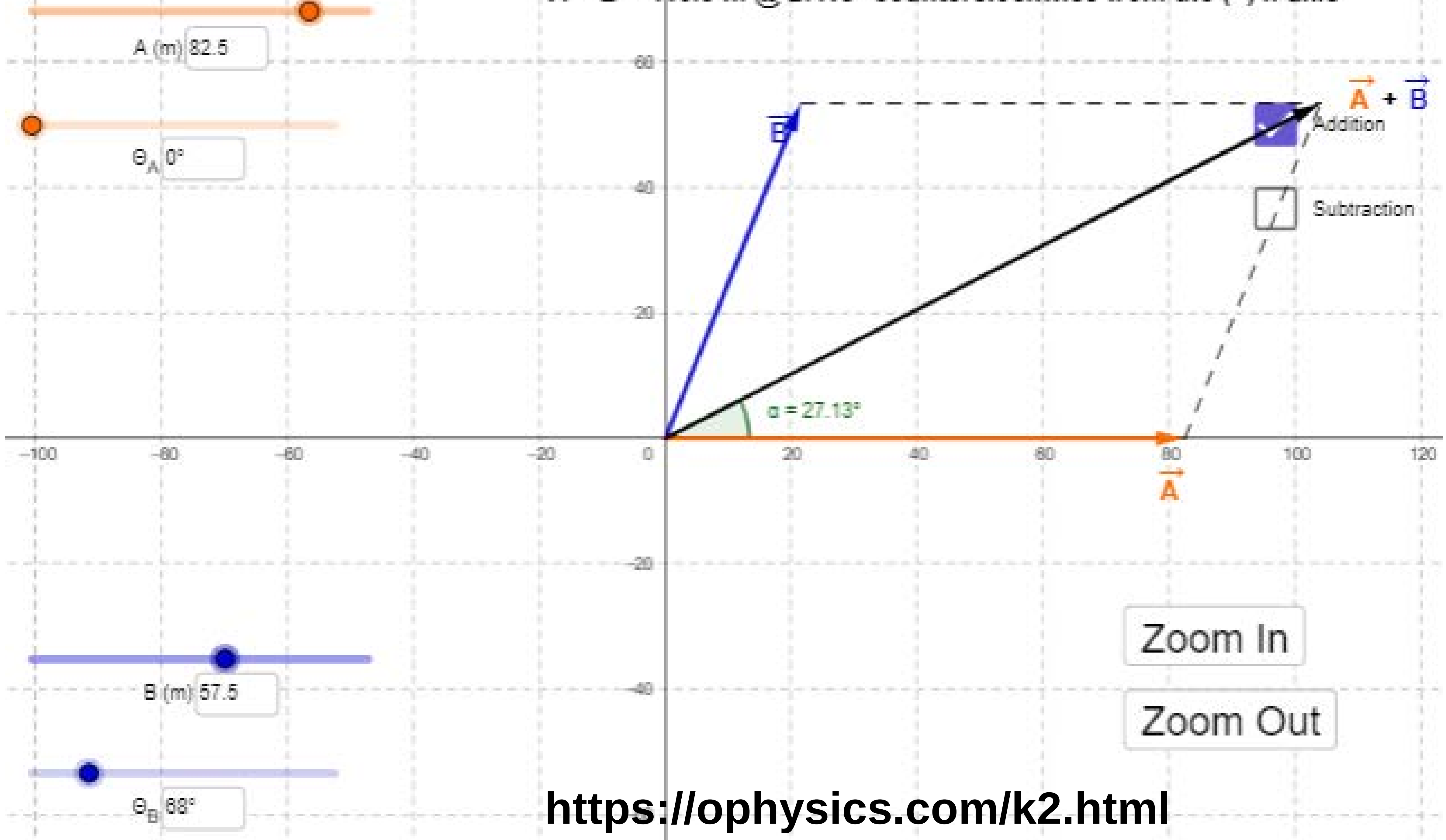
Addition of Vectors



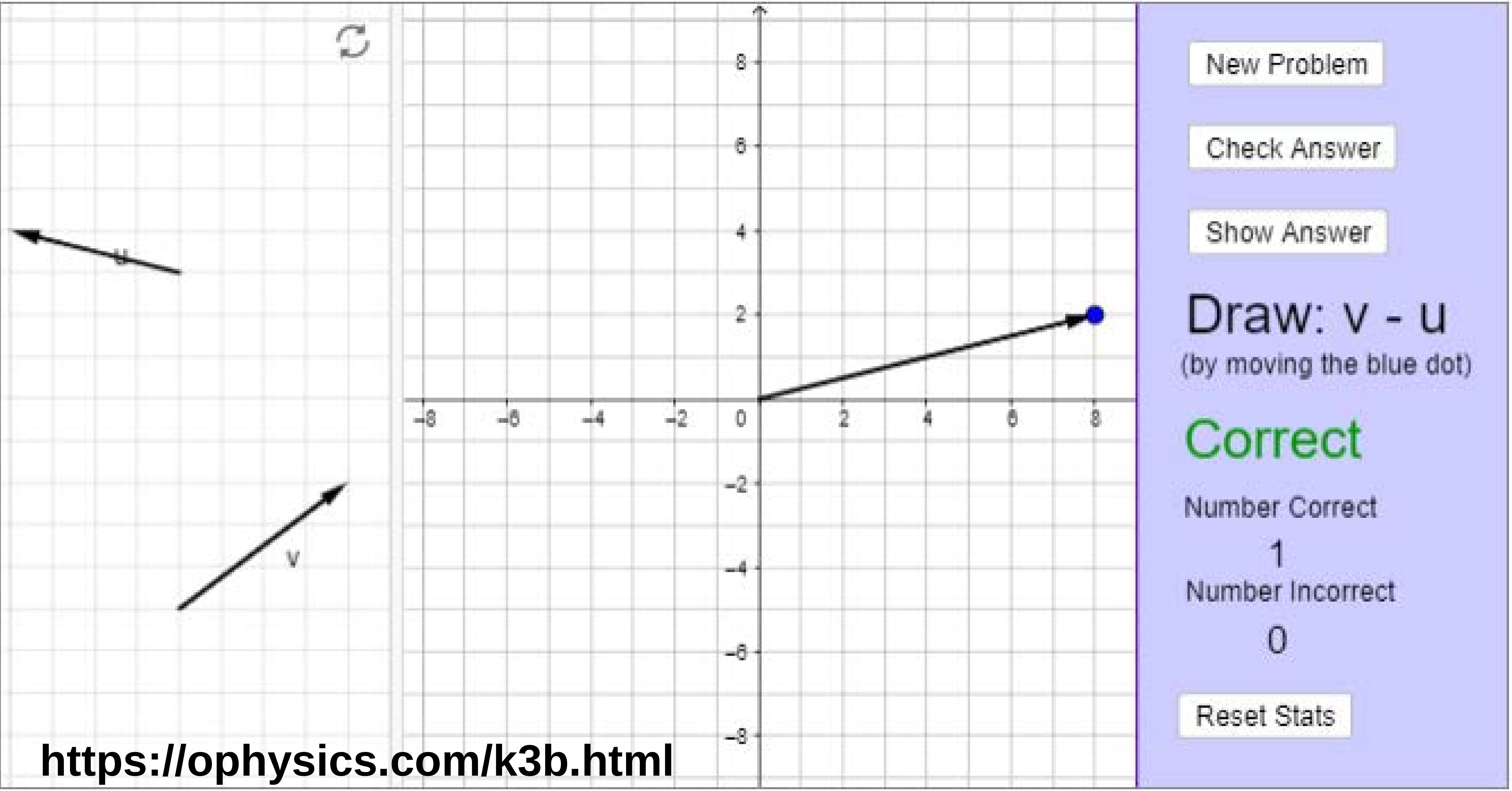
$$R_x = A_x + B_x \qquad R_y = A_y + B_y$$

$$\left(\text{components of } \vec{R} = \vec{A} + \vec{B}\right)$$

$\vec{A} + \vec{B}$ = 116.9 m @ 27.13° counterclockwise from the (+) x-axis



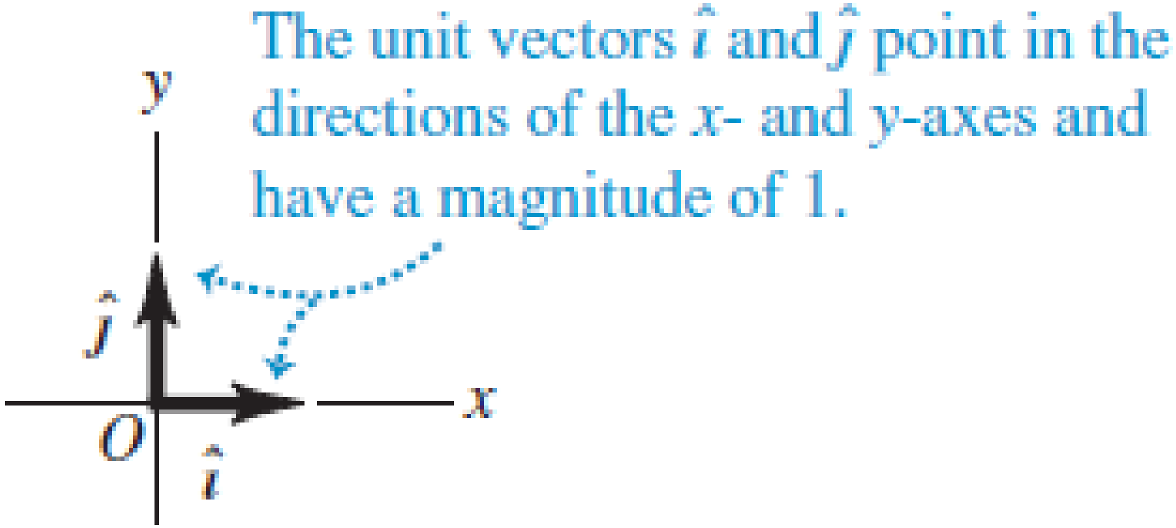
https://ophysics.com/k2.html

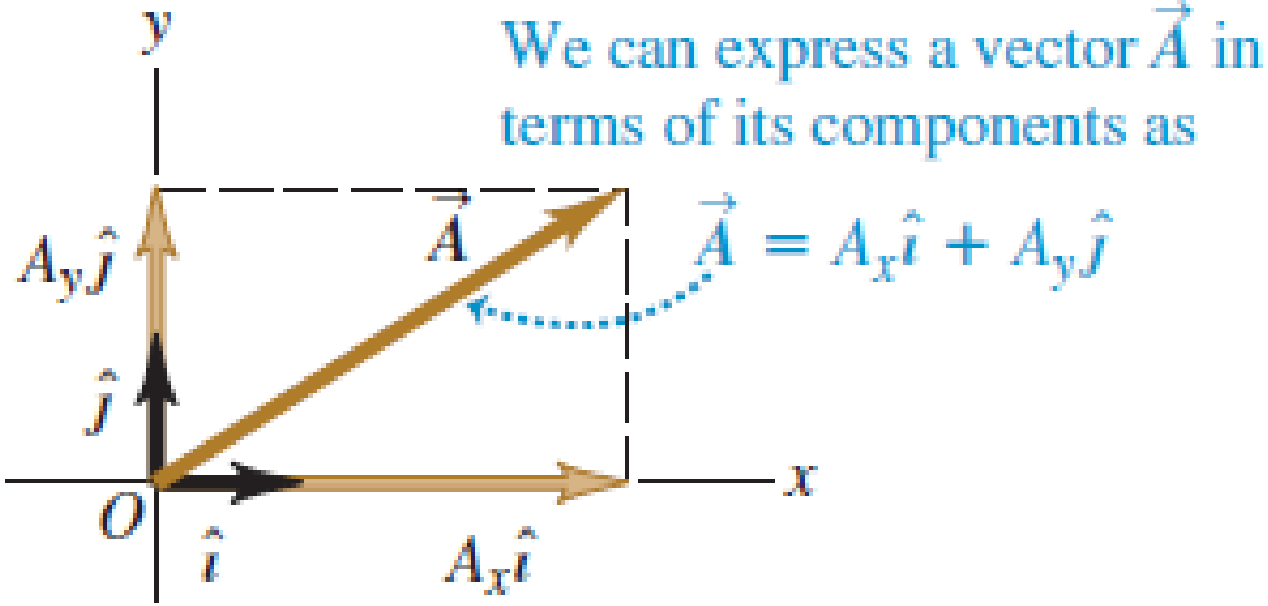


https://ophysics.com/k3b.html

Unit Vectors

A **unit vector** is a vector that has a magnitude of 1, with no units. Its only purpose is to *point*—that is, to describe a direction in space. Unit vectors provide a convenient notation for many expressions involving components of vectors. We will always include a caret or “hat” (^) in the symbol for a unit vector to distinguish it from ordinary vectors whose magnitude may or may not be equal to 1.



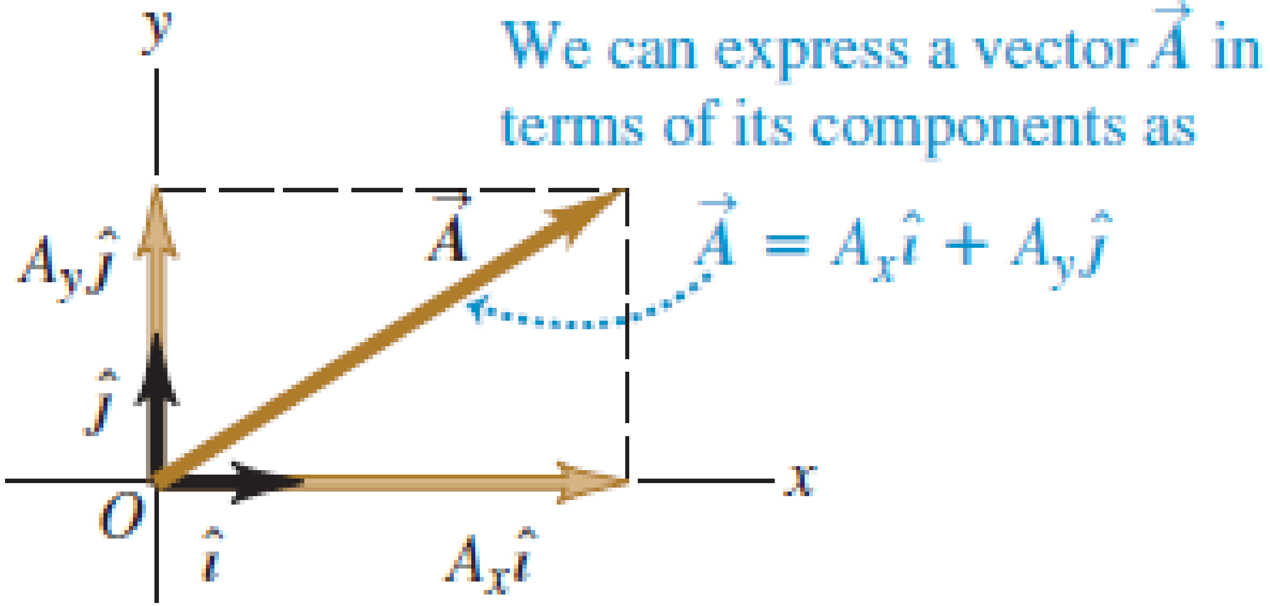


Unit Vectors

$$\vec{A}_x = A_x\hat{\imath}$$
$$\vec{A}_y = A_y\hat{\jmath}$$

$$\Rightarrow \quad \vec{A} = A_x\hat{\imath} + A_y\hat{\jmath}$$

$$\vec{A} = A_x\hat{\imath} + A_y\hat{\jmath}$$
$$\vec{B} = B_x\hat{\imath} + B_y\hat{\jmath}$$
$$\begin{aligned}\vec{R} &= \vec{A} + \vec{B}\\ &= (A_x\hat{\imath} + A_y\hat{\jmath}) + (B_x\hat{\imath} + B_y\hat{\jmath})\\ &= (A_x + B_x)\hat{\imath} + (A_y + B_y)\hat{\jmath}\\ &= R_x\hat{\imath} + R_y\hat{\jmath}\end{aligned}$$



3D Vectors

$$\vec{A} = A_x\hat{\imath} + A_y\hat{\jmath} + A_z\hat{k}$$

$$\vec{B} = B_x\hat{\imath} + B_y\hat{\jmath} + B_z\hat{k}$$

$$\begin{aligned}\vec{R} &= (A_x + B_x)\hat{\imath} + (A_y + B_y)\hat{\jmath} + (A_z + B_z)\hat{k} \\ &= R_x\hat{\imath} + R_y\hat{\jmath} + R_z\hat{k}\end{aligned}$$

Questions so far?

5 minutes of Q&A time

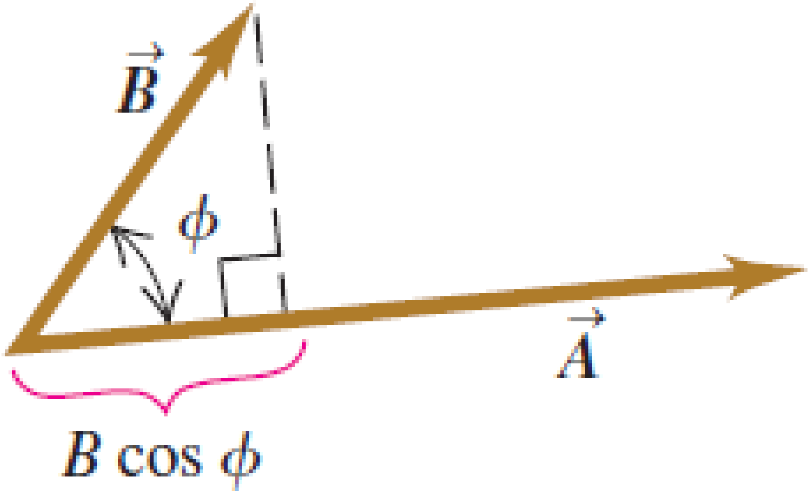
Dot Product

Place the vectors tail to tail.

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

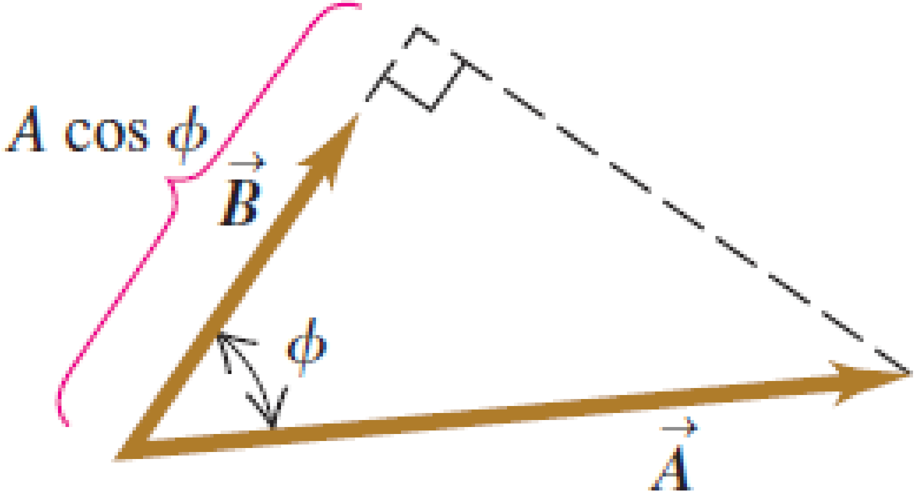
$\vec{A}\cdot\vec{B}$ equals $\underbrace{A}_{\text{(Magnitude of }\vec{A})}\underbrace{(B\cos\phi)}_{\text{times (Component of }\vec{B}\text{ in direction of }\vec{A})}$.

(Magnitude of $\vec{A}$) times (Component of $\vec{B}$ in direction of $\vec{A}$)



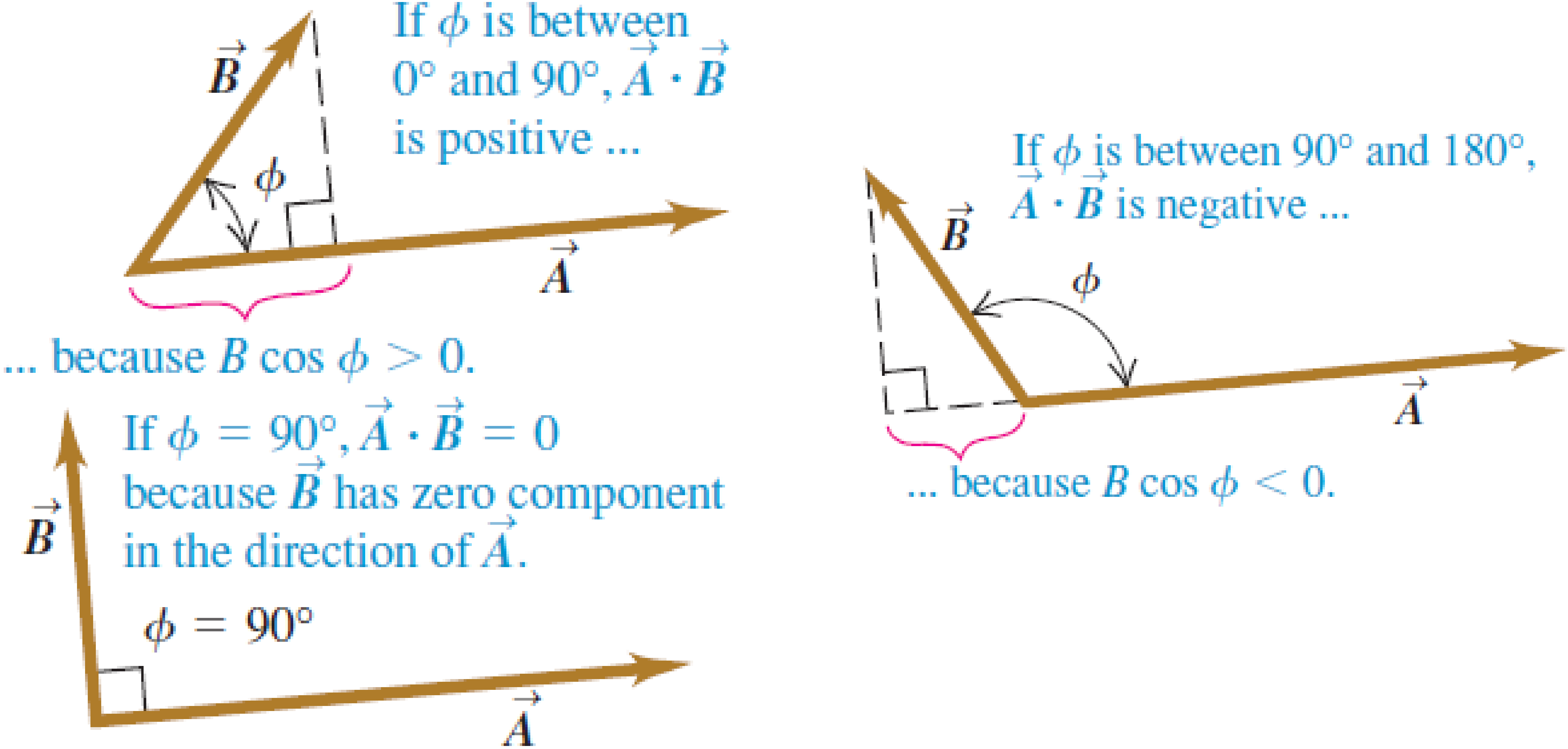
(c) $\vec{A}\cdot\vec{B}$ also equals $B(A\cos\phi)$

(Magnitude of $\vec{B}$) times (Component of $\vec{A}$ in direction of $\vec{B}$)



Dot Product

Result of dot product can be positive, negative, or zero



Calculating the Scalar Product Using Components

$$\hat{\imath}\cdot\hat{\imath} = \hat{\jmath}\cdot\hat{\jmath} = \hat{k}\cdot\hat{k} = (1)(1)\cos 0^\circ = 1$$

$$\hat{\imath}\cdot\hat{\jmath} = \hat{\imath}\cdot\hat{k} = \hat{\jmath}\cdot\hat{k} = (1)(1)\cos 90^\circ = 0$$

$$\begin{aligned}\vec{A}\cdot\vec{B} &= (A_x\hat{\imath} + A_y\hat{\jmath} + A_z\hat{k})\cdot(B_x\hat{\imath} + B_y\hat{\jmath} + B_z\hat{k}) \\ &= A_x\hat{\imath}\cdot B_x\hat{\imath} + A_x\hat{\imath}\cdot B_y\hat{\jmath} + A_x\hat{\imath}\cdot B_z\hat{k} \\ &\quad + A_y\hat{\jmath}\cdot B_x\hat{\imath} + A_y\hat{\jmath}\cdot B_y\hat{\jmath} + A_y\hat{\jmath}\cdot B_z\hat{k} \\ &\quad + A_z\hat{k}\cdot B_x\hat{\imath} + A_z\hat{k}\cdot B_y\hat{\jmath} + A_z\hat{k}\cdot B_z\hat{k}\end{aligned}$$

Calculating the Scalar Product

$$\vec{A} \cdot \vec{B} = (A_x\hat{\imath} + A_y\hat{\jmath} + A_z\hat{k}) \cdot (B_x\hat{\imath} + B_y\hat{\jmath} + B_z\hat{k})$$

$$= A_x\hat{\imath} \cdot B_x\hat{\imath} + A_x\hat{\imath} \cdot B_y\hat{\jmath} + A_x\hat{\imath} \cdot B_z\hat{k}$$

$$+ A_y\hat{\jmath} \cdot B_x\hat{\imath} + A_y\hat{\jmath} \cdot B_y\hat{\jmath} + A_y\hat{\jmath} \cdot B_z\hat{k}$$

$$+ A_z\hat{k} \cdot B_x\hat{\imath} + A_z\hat{k} \cdot B_y\hat{\jmath} + A_z\hat{k} \cdot B_z\hat{k}$$

$$= A_xB_x\hat{\imath} \cdot \hat{\imath} + A_xB_y\hat{\imath} \cdot \hat{\jmath} + A_xB_z\hat{\imath} \cdot \hat{k}$$

$$+ A_yB_x\hat{\jmath} \cdot \hat{\imath} + A_yB_y\hat{\jmath} \cdot \hat{\jmath} + A_yB_z\hat{\jmath} \cdot \hat{k}$$

$$+ A_zB_x\hat{k} \cdot \hat{\imath} + A_zB_y\hat{k} \cdot \hat{\jmath} + A_zB_z\hat{k} \cdot \hat{k}$$

Calculating the Scalar Product

$$\vec{A}\cdot\vec{B} = (A_x\hat{\imath} + A_y\hat{\jmath} + A_z\hat{k})\cdot(B_x\hat{\imath} + B_y\hat{\jmath} + B_z\hat{k})$$

$$= A_x\hat{\imath}\cdot B_x\hat{\imath} + A_x\hat{\imath}\cdot B_y\hat{\jmath} + A_x\hat{\imath}\cdot B_z\hat{k}$$

$$+ A_y\hat{\jmath}\cdot B_x\hat{\imath} + A_y\hat{\jmath}\cdot B_y\hat{\jmath} + A_y\hat{\jmath}\cdot B_z\hat{k}$$

$$+ A_z\hat{k}\cdot B_x\hat{\imath} + A_z\hat{k}\cdot B_y\hat{\jmath} + A_z\hat{k}\cdot B_z\hat{k}$$

$$\vec{A}\cdot\vec{B} = A_xB_x + A_yB_y + A_zB_z$$ (scalar (dot) product in terms of components)

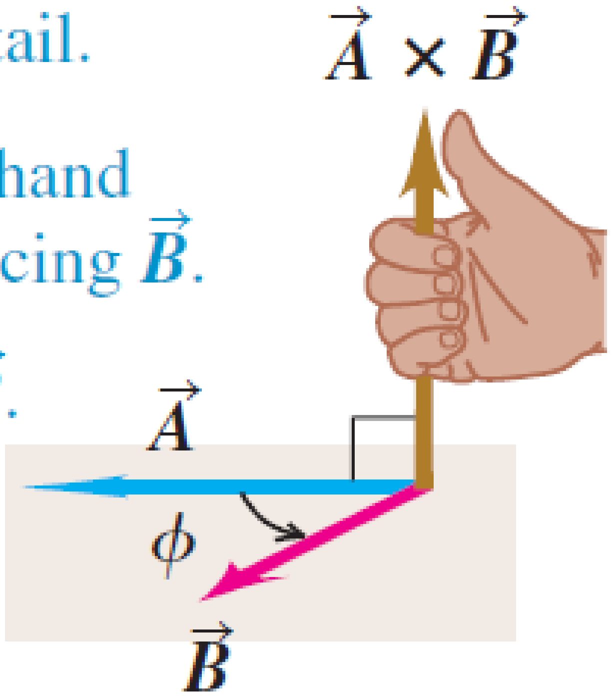
Cross Product (Or vector product)

Magnitude of the vector (cross) product $\vec{C} = \vec{A} \times \vec{B}$

$$C = AB \sin\phi$$

(a) Using the right-hand rule to find the direction of $\vec{A} \times \vec{B}$

1. Place $\vec{A}$ and $\vec{B}$ tail to tail.
2. Point fingers of right hand along $\vec{A}$, with palm facing $\vec{B}$.
3. Curl fingers toward $\vec{B}$.
4. Thumb points in direction of $\vec{A} \times \vec{B}$.



(b) $\vec{B} \times \vec{A} = -\vec{A} \times \vec{B}$ (the vector product is anticommutative)

That is, *the vector product of two parallel or antiparallel vectors is always zero*. In particular, *the vector product of any vector with itself is zero.*

Cross Product (Or vector product)

Vector form for the vector (cross) product $\vec{C} = \vec{A} \times \vec{B}$

$$C_x = A_y B_z - A_z B_y \qquad C_y = A_z B_x - A_x B_z \qquad C_z = A_x B_y - A_y B_x$$

$$(\text{components of } \vec{C} = \vec{A} \times \vec{B})$$