General Physics

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Homework is through "mastering physics"

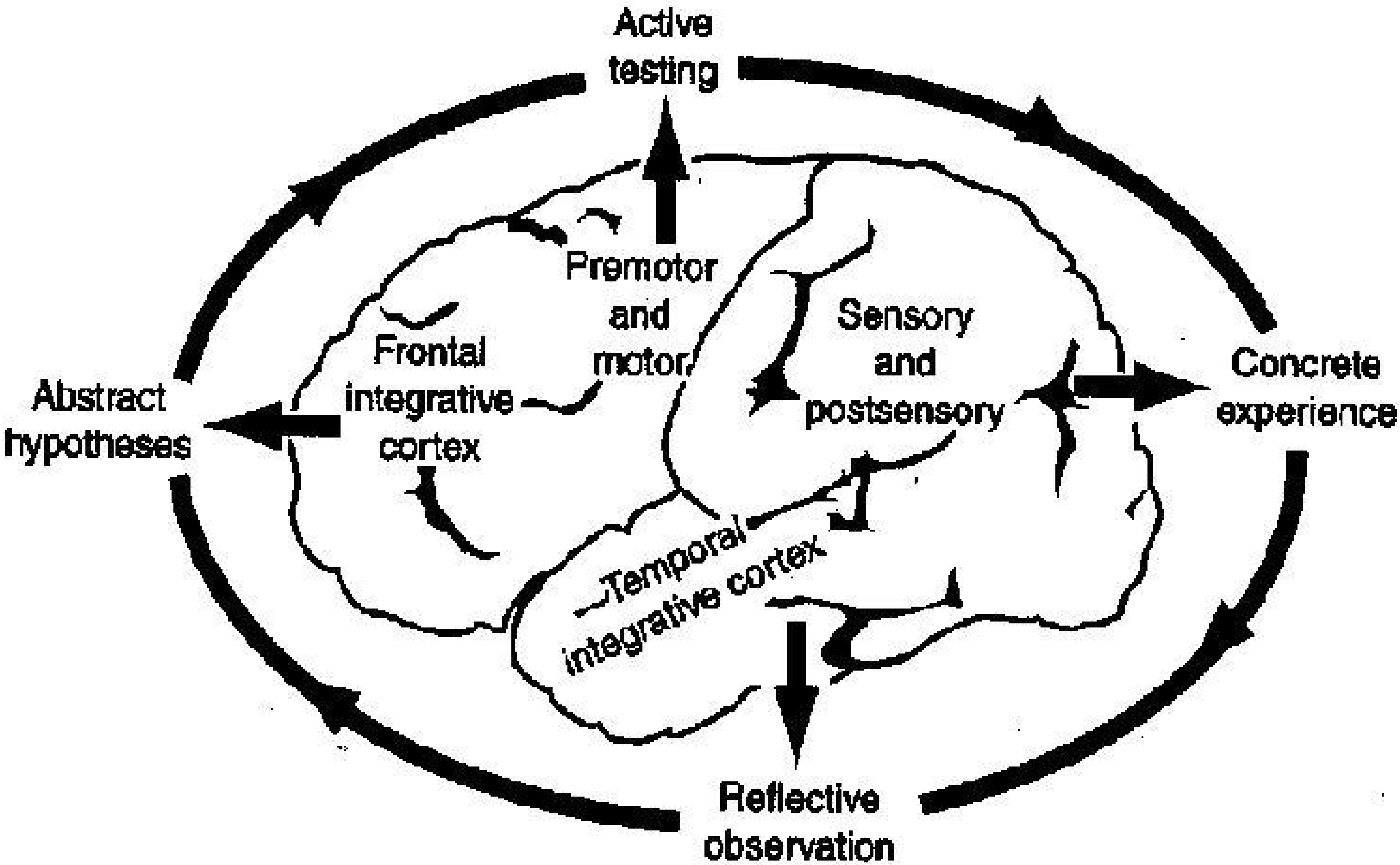
Course ID: PHYS2050F17

Physiology of Learning*.

- Learning requires cycles.
  - Experience (sensory cortex)
  - Reflection (back integrative cortex)
  - Abstraction/hypotheses (front integrative cortex)
  - Active testing of ideas (motor cortex→sensory cortex)

***J. E. Zull, *The Art of Changing the Brain* (Stylus, Sterling VA, 2002).**

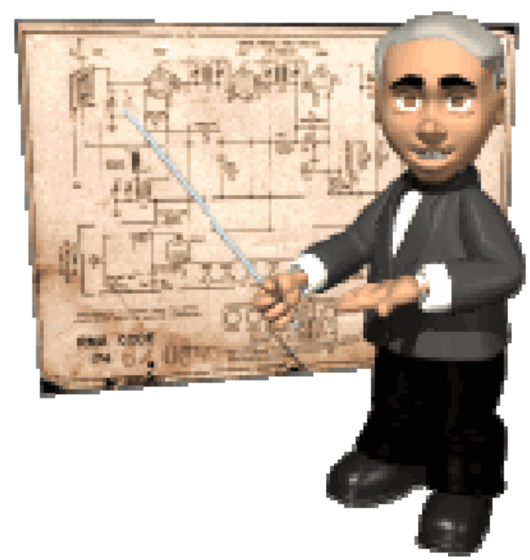
The brain



Neuronal networks are knowledge.

Read the syllabus.

- Grading policies
- Homework
- Tests
- Academic honesty



Look for patterns, practice.

- Read ahead, check for extra homework assignments.
- Ask questions, talk about physics in class
- Reread, but look for logic and focus on what you don't understand.
- Do physics (homework, workbook, additional exercises)
- Work together outside of class to teach each other.

Describing physical systems

- A **model** is a simplified version of a physical system
- A **theory** is an explanation of natural phenomena based on observation and accepted fundamental principles.
- A theory is considered a **law** of nature if it is well established and widely accepted by the scientific community.

DO NOT confuse a model or a theory with the real system or the observed phenomena.

This course requires basic knowledge of calculus!

Some derivatives of
basic functions

Powers

$$f(x) = ax^n$$

$$\frac{d\,f(x)}{d\,x} = anx^{n-1}$$

Exponential

$$f(x) = a\,e^{bx}$$

$$\frac{d\,f(x)}{d\,x} = ab\,e^{bx}$$

Sinusoidal

$$f(x) = \sin(ax)$$

$$\frac{d\,f(x)}{d\,x} = a\cos(ax)$$

$$f(x) = \cos(ax)$$

$$\frac{d\,f(x)}{d\,x} = -a\sin(ax)$$

Anti-derivatives and integrals

If you know the slope of a function f(x), $\dfrac{d\,f(x)}{d\,x} = g(x)$

then the function, out to a constant, may be determined by integrating,

$$f(x) = \int g(x)\,dx$$

where the constant may be determined by special conditions relating to a specific example.

International System of Units (SI)

Measurement		**Unit**
Length	→	meter
Mass	→	kilogram
Time	→	second
Charge	→	Coulomb

Any number that is used to describe a physical phenomenon quantitatively is called a **physical quantity**

Physical **dimensions** are properties given to physical quantities to distinguish the type of quantity. Examples are time, energy, and angular momentum

SI Units from meters-kilograms-seconds (mks)

(Just a few of many that we will learn in the college physics courses)

Measurement		**Unit**	**mks**
Force	$\longrightarrow$	Newton	$1\ N = 1\ kg \cdot m/s^2$
Energy	$\longrightarrow$	Joule	$1\ J = 1\ kg \cdot m^2/s^2$
Power	$\longrightarrow$	Watt	$1\ W = 1\ kg \cdot m^2/s^3$

What is 1 W/N equivalent to in mks units?

Significant Figures

(Precision)

34.57 has four significant figures

2400 has two significant figures.

Q. Why?

A. The rightmost zeros that are still *left of the decimal point* don’t contribute.

1001 has four significant figures.

1000.0 and 3.0000 both have five significant figures.

Q. Why?

A. The rightmost zeros that are *right of the decimal point* contribute to the significant digits.

Q. How do we write **2400** with three significant figures?

A. We use <u>Scientific Notation</u>, and write $\mathbf{2.40 \times 10^3}$.

Rules for Operations with Significant Figures

<u>Addition and Subtraction Significant Digits.</u>

- Perform the operation.
- Round off to the least precise value involved, the position of the last digit in the least precise measurement.

<u>Multiplication & Division Significant Digits.</u>

- Perform the operation.
- Round off to the number of digits in the least precise factor of the problem

The quantity 0.120×10^4 m/s has how many significant figures?

A. 1

B. 2

C. 3

D. 4

E. 5

Compute 33.24 m + 0.532 m to the correct number of significant figures:

1. 33.7 m
2. 33.77 m
3. 33.772 m
4. 33.7720 m

$$3.999 \times 10^{3} + 2.5 \times 10^{-5} =$$

A. 3.999×10^{3}

B. 3.9×10^{3}

C. 4.0×10^{3}

D. 4.002×10^{-2}

E. None of the above

Propagation of uncertainty using a linear approximation

Suppose we measure the mass to be 1.15 kg with an uncertainty of 0.02 kg.

$$m = (1.15 \pm 0.02)\,\mathrm{kg}$$

Also, we measured the force to be 20.3 N with an uncertainty of 0.5 N.

$$F = (20.3 \pm 0.5)\,\mathrm{N}$$

The average acceleration is $a = \dfrac{F}{m} = \dfrac{20.3\,\mathrm{N}}{1.15\,\mathrm{kg}} = 17.7\,\mathrm{m/s^2}$

The uncertainty is $|\Delta a|^2 = \left|(\Delta F)\dfrac{\partial a}{\partial F}\right|^2 + \left|(\Delta m)\dfrac{\partial a}{\partial m}\right|^2$

The uncertainty is calculated as $\Delta a = \sqrt{\left|\dfrac{\Delta F}{m}\right|^2 + \left|-\dfrac{F\,(\Delta m)}{m^2}\right|^2}$

which gives $\Delta a = \sqrt{\left[\dfrac{0.5\,\mathrm{N}}{1.15\,\mathrm{kg}}\right]^2 + \left[\dfrac{(20.3\,\mathrm{N})\,(0.02\,\mathrm{kg})}{(1.15\,\mathrm{kg})^2}\right]^2} = 0.5\,\mathrm{m/s^2}$

Thus, the acceleration of the system is $a = (17.7 \pm 0.5)\,\mathrm{m/s^2}$

Dimensional analysis

In physics, the word **dimension** means the physical nature of a quantity.

$$\begin{aligned} \text{Length} &= \text{L} \\ \text{Time} &= \text{T} \\ \text{Mass} &= \text{M} \end{aligned}$$

Quantity	Area (A)	Volume (V)	Speed (v)	Acceleration (a)
Dimensions	L^2	L^3	L/T	L/T^2
SI units	m^2	m^3	m/s	m/s^2
U.S. customary units	ft^2	ft^3	ft/s	ft/s^2

For constant acceleration from rest, we have the equation $x = \frac{1}{2}at^2$

We find that this equation is dimensionally consistent, where $\mathrm{L} = \frac{\mathrm{L}}{\cancel{\mathrm{T}^2}}\cancel{\mathrm{T}^2} = L$

Equations must be dimensionally consistent, but just being dimensionally consistent does not necessarily mean an equation is correct.

Vectors

A **vector** has both a *magnitude* and a *direction*

A **scalar** is described by only the *magnitude*

REMEMBER TO ALWAYS INCLUDE UNITS IN YOUR ANSWERS

Example

When a car is driving, it has a velocity (which is a vector) that is described by its speed (a magnitude) and the direction in which the car is traveling.

Is acceleration a vector?

A. Yes
B. No

Is density a vector?

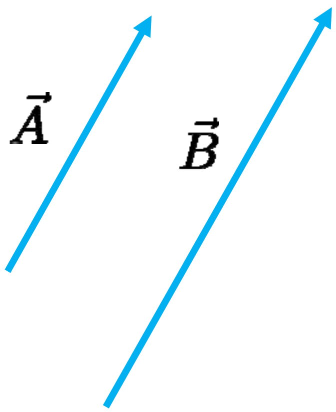
A. Yes
B. No

Is force a vector?

A. Yes
B. No

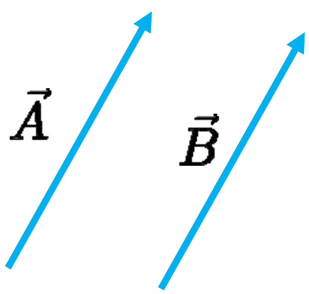
Properties of Vectors

If two vectors are parallel, then they have the same direction



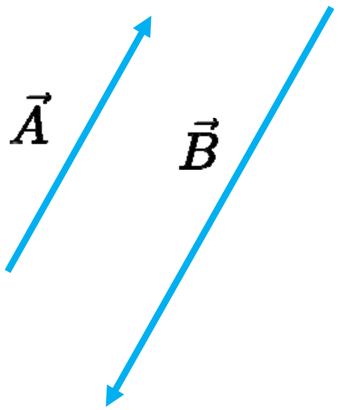
$\vec{B}$ is always parallel to $\vec{A}$ regardless of where $\vec{B}$ is located in space.

If two vectors have the same direction and magnitude then they are equal



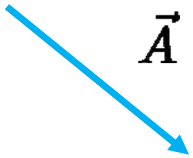
$$\vec{A} = \vec{B}$$

If two vectors are facing the opposite way, then they are called antiparallel.



$\vec{B}$ is always antiparallel to $\vec{A}$ regardless of where $\vec{B}$ is located in space.

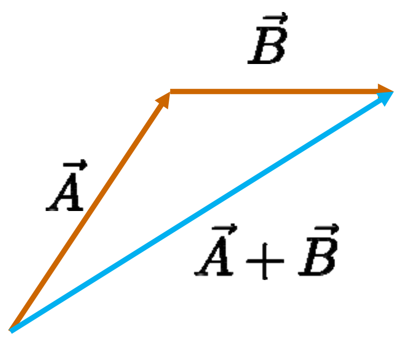
The absolute value of a vector is equal to the magnitude.

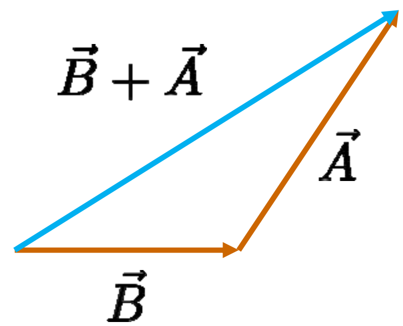


$$\left|\vec{A}\right| = A \neq \vec{A}$$

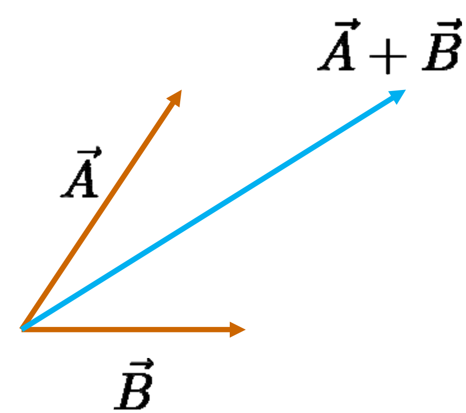
Adding Vectors

Vectors follow the commutative property of addition. $\vec{A}+\vec{B}=\vec{B}+\vec{A}$



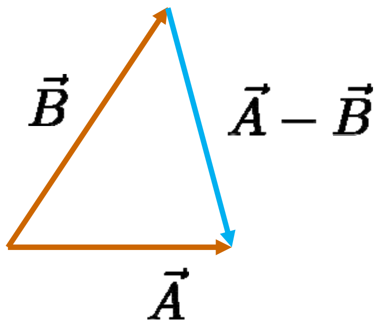


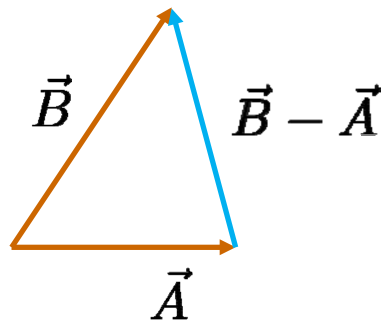
They also add like a parallelogram.



Subtracting Vectors

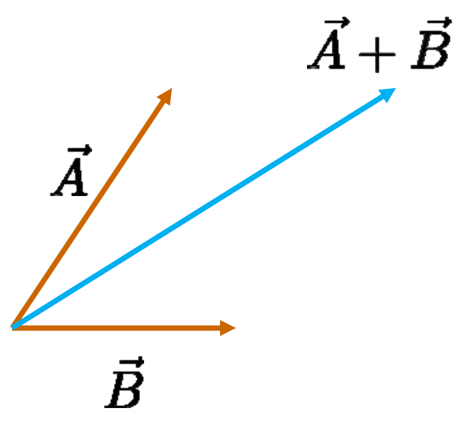
Vector subtraction is the same as adding a negative vector. $\vec{A} - \vec{B} = \vec{A} + (-\vec{B})$

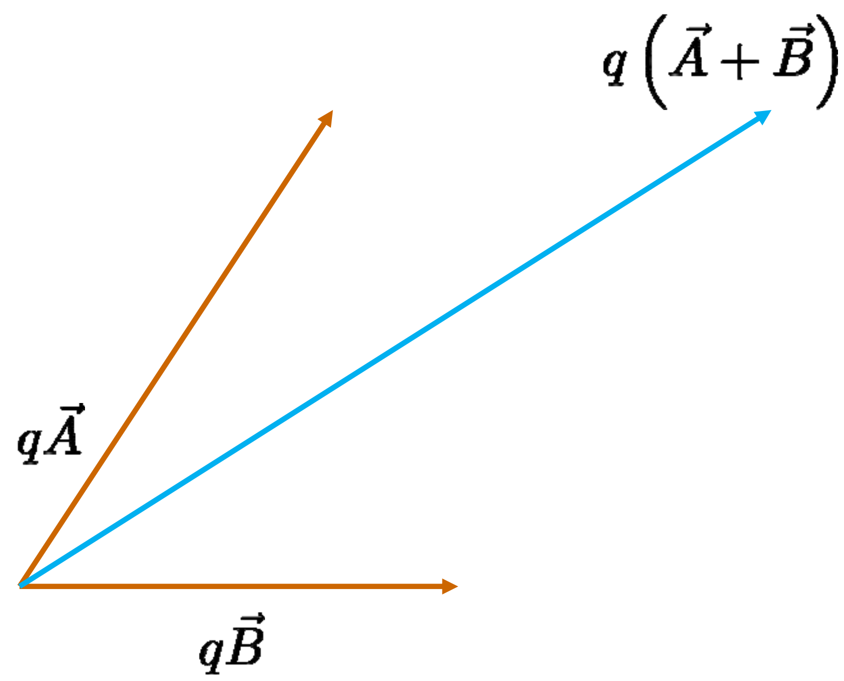




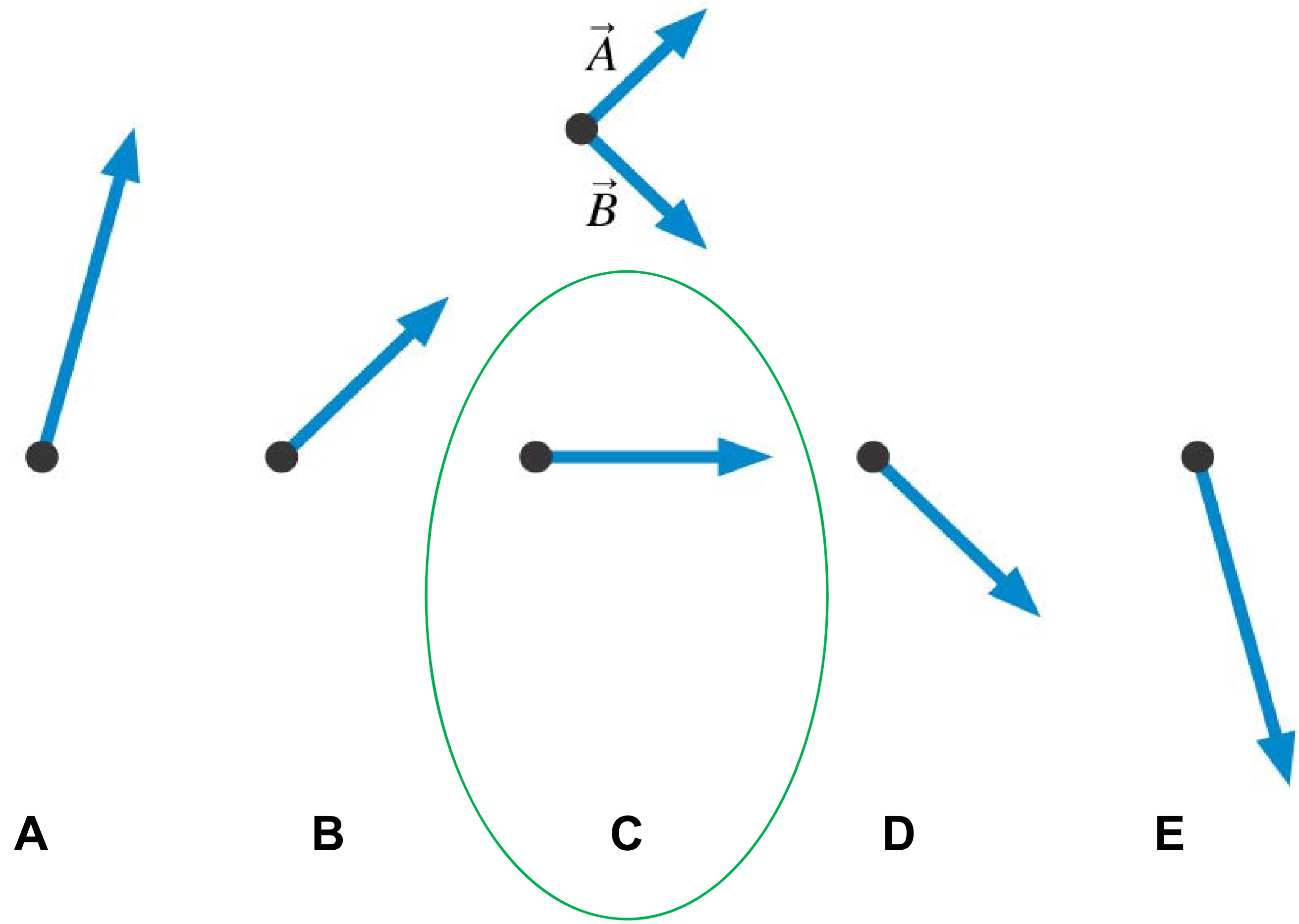
Multiplying a vector by a scalar

Multiplying a vector by a scalar changes the magnitude but not the direction. In other words, it “scales” the vector.

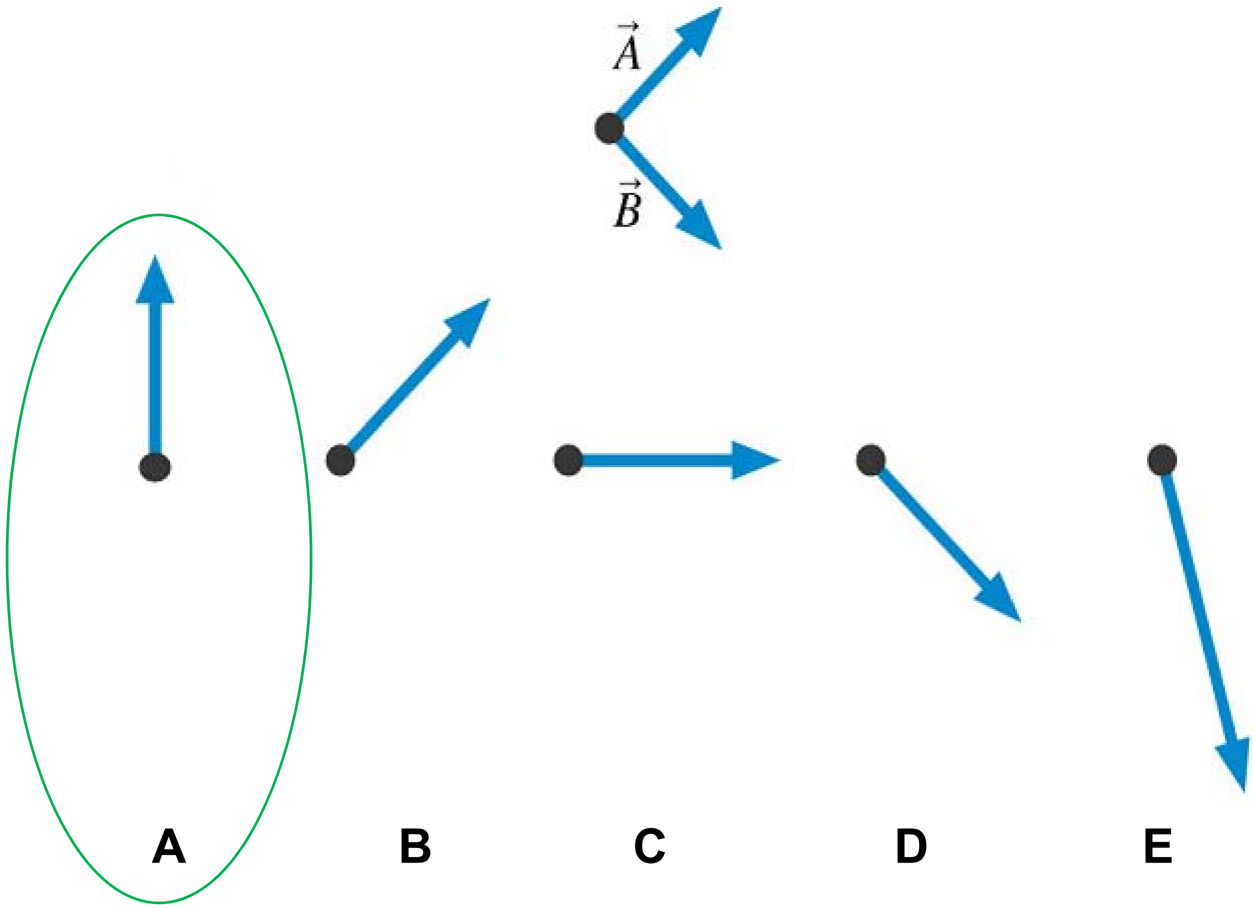




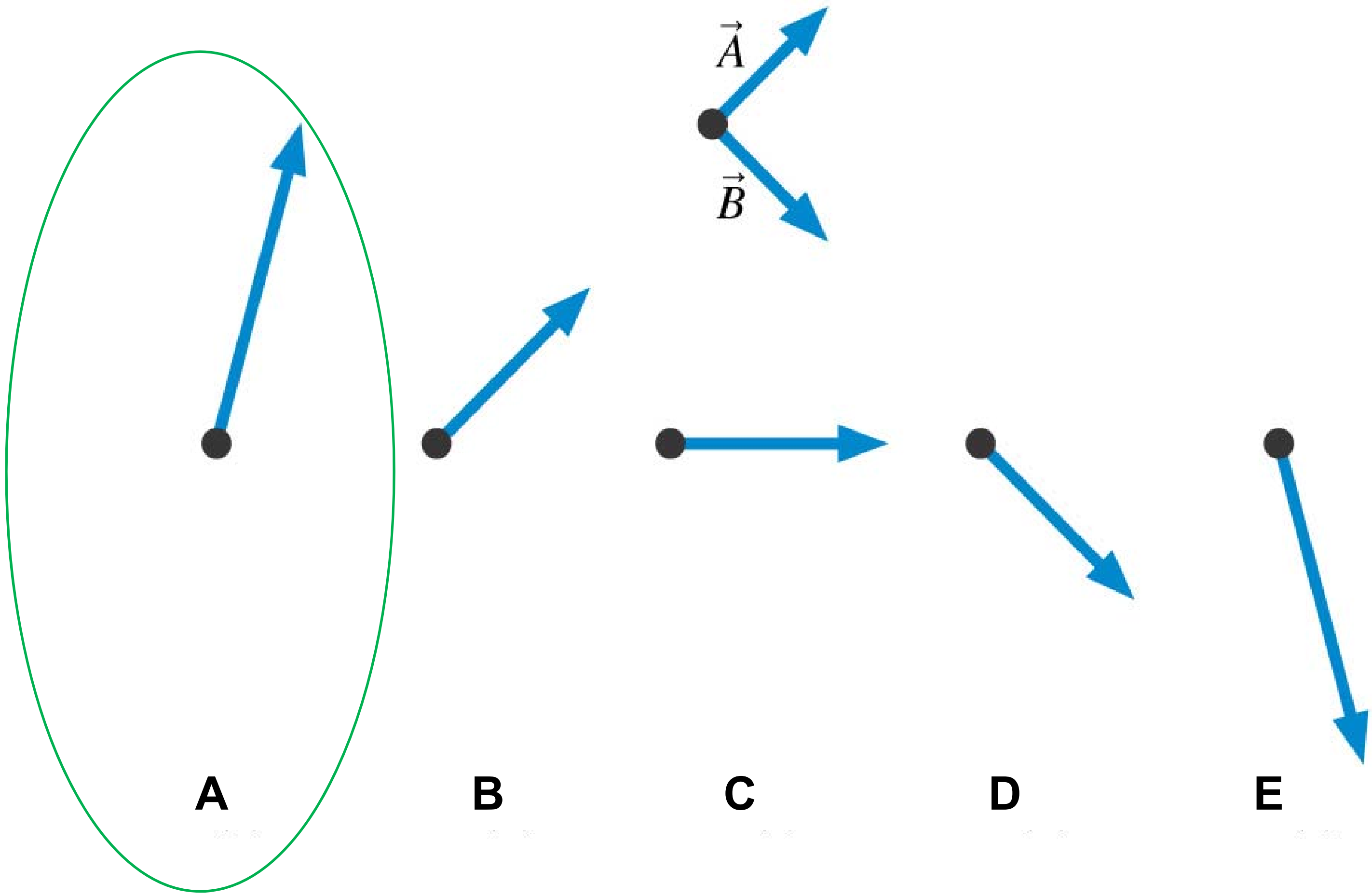
Which figure shows $\vec{A} + \vec{B}$?



Which figure shows $\vec{A} - \vec{B}$?

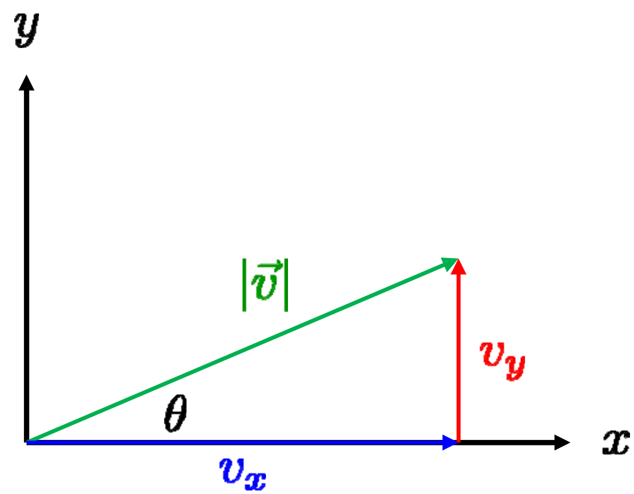


Which figure shows $2\vec{A} - \vec{B}$?



Two-dimensional vectors and components

A component of a vector is the length of the vector projected on an axis.



Remember that $\cos\theta = \dfrac{\text{adj}}{\text{hyp}}$ and $\sin\theta = \dfrac{\text{opp}}{\text{hyp}}$

Therefore, $\cos\theta = \dfrac{v_x}{|\vec{v}|}$ and $\sin\theta = \dfrac{v_y}{|\vec{v}|}$

Two-dimensional vectors and components

Displacement and velocity are vectors. Therefore we can break them into components. The components are commonly represented by the magnitude of the vector and the angle sweeping counterclockwise from the +x axis.

(note that you may not always be given an angle defined in this way)

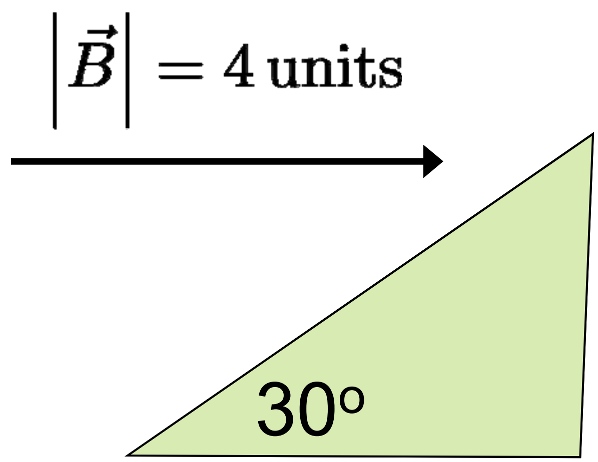
Starting from the origin (x=0, y=0)

$$
\begin{aligned}
x &= r\cos\theta \\
y &= r\sin\theta
\end{aligned}
\qquad
\begin{aligned}
v_x &= |\vec{v}|\cos\theta \\
v_y &= |\vec{v}|\sin\theta
\end{aligned}
$$

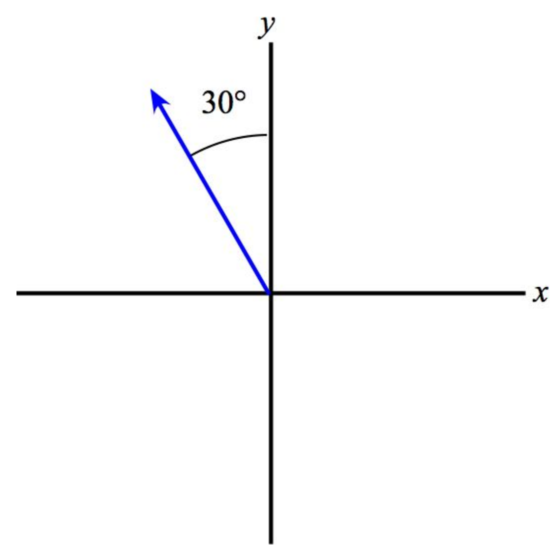
Likewise, the magnitude and angle can be represented by the components. For velocity, this gives

$$
\begin{aligned}
|\vec{v}| &= \sqrt{v_x^2 + v_y^2} \\
\theta &= \tan^{-1}\left(\frac{v_y}{v_x}\right) \text{ for } -\frac{\pi}{2} \leq \theta \leq \frac{\pi}{2}
\end{aligned}
$$

What are the components of $\vec{B}$ parallel and perpendicular to the sloped surface?



The following vector has length 4.0 units.
What are the *x*- and *y*-components of this vector?



A. 3.5, 2.0
B. –2.0, 3.5
C. –3.5, 2.0
D. 2.0, –3.5
E. –3.5, –2.0

Unit vectors

Unit vectors have a magnitude of 1 and point in a given direction.

We use the hat symbol to denote a unit vector.

In cartesian coordinates, unit vectors along the axes are commonly given using the conventions, $\hat{i}\,,\hat{j}\,,\hat{k}$ or $\hat{x}\,,\hat{y}\,,\hat{z}$

As an example, suppose we had a velocity in two dimensions with components $v_x = 5\,\mathrm{m/s}$ and $v_y = -7\,\mathrm{m/s}$.

We can write this in vector form as $\vec{v} = (5\,\mathrm{m/s})\,\hat{i} - (7\,\mathrm{m/s})\,\hat{j}$

Multiplying vectors (Dot product)

Vectors may be multiplied in various ways. The scalar product (or dot product) multiplies two vectors together to return a scalar.

Consider the vectors
$$\begin{cases} \vec{A} = A_x\hat{i} + A_y\hat{j} + A_z\hat{k} \\ \vec{B} = B_x\hat{i} + B_y\hat{j} + B_z\hat{k} \end{cases}$$

Knowing that
$$\begin{cases} \hat{i}\cdot\hat{i} = 1 & \text{(same)} \\ \hat{i}\cdot\hat{j} = 0 & \text{(different)} \end{cases}$$

The dot product is $\vec{A}\cdot\vec{B} = A_xB_x + A_yB_y + A_zB_z$

If we know the magnitudes and directions of the vectors, then the dot product is the product of the magnitudes times the cosine of the angle between the two vectors.

$$\vec{A}\cdot\vec{B} = AB\cos\theta$$

Multiplying vectors (Cross product)

The vector product (or cross product) multiplies two vectors together and returns another vector.

The resultant vector is in the direction normal to the plane made by the two vectors being multiplied.

Consider the vectors
$$\begin{cases} \vec{A} = A_x\hat{i} + A_y\hat{j} + A_z\hat{k} \\ \vec{B} = B_x\hat{i} + B_y\hat{j} + B_z\hat{k} \end{cases}$$

The cross product may be calculated by taking the determinant of a matrix.

$$\vec{A} \times \vec{B} = \det \begin{bmatrix} \hat{i} & \hat{j} & \hat{k} \\ A_x & A_y & A_z \\ B_x & B_y & B_z \end{bmatrix}$$

If we know the magnitudes and directions of the vectors, then the **magnitude** of the cross product's resultant vector is the product of the magnitudes times the sine of the angle between the two vectors.

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

Example problems for vectors

Consider the dimensionless vectors
$$\begin{cases} \vec{A} = 3\hat{i} - 2\hat{j} \\ \vec{B} = \hat{i} + 4\hat{j} \\ \vec{C} = -\hat{i} + 2\hat{j} + 3\hat{k} \end{cases}$$

(a) Calculate the quantity $\left(\vec{B} + \vec{C}\right) \cdot \vec{A}$

(b) Calculate the quantity $\left(\vec{A} \times \vec{B}\right) \cdot \vec{C}$