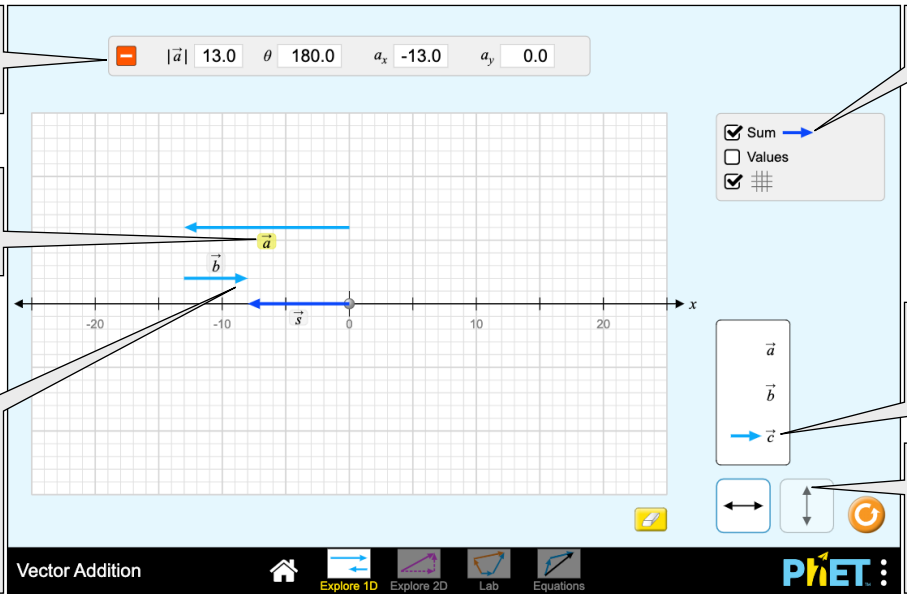
PhET Tips for Teachers

Vector Addition

Explore 1D Screen

Explore vectors in 1D and discover how vectors add together.



SHOW/HIDE vector data

SELECT a vector to inspect

GRAB vector head to change magnitude or orientation

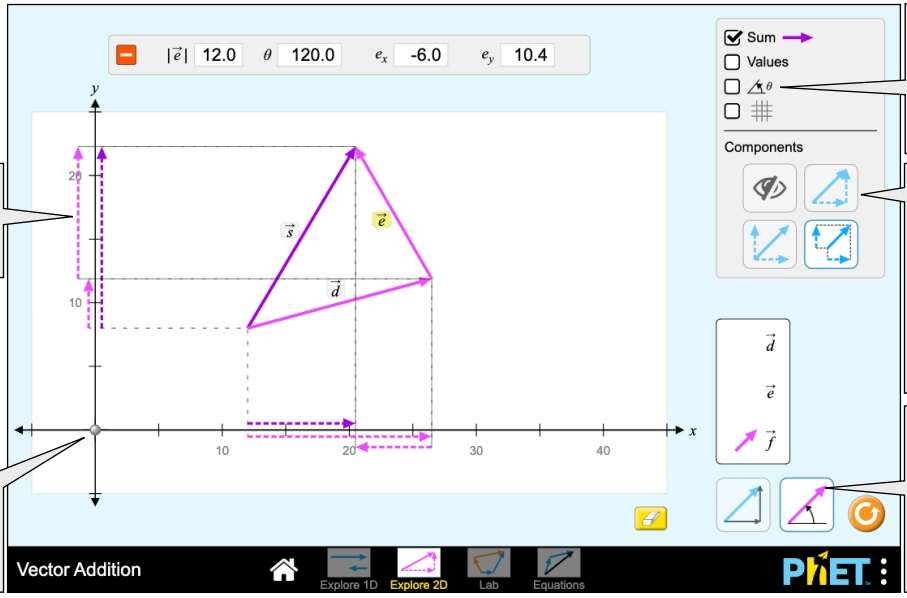
SHOW the sum

DRAG vectors into the graph

EXPERIMENT with vertical or horizontal vectors

Explore 2D Screen

Experiment with vector addition in 2D. Specify vectors in Cartesian or polar coordinates, and see the magnitude, angle, and components of each vector.



VIEW vector components

DRAG origin to shift quadrant

VIEW angles

SELECT component style: right triangle, parallelogram, or projection-like

SNAP to integer coordinates <*x, y*> (left) or <*r, θ*> (right)

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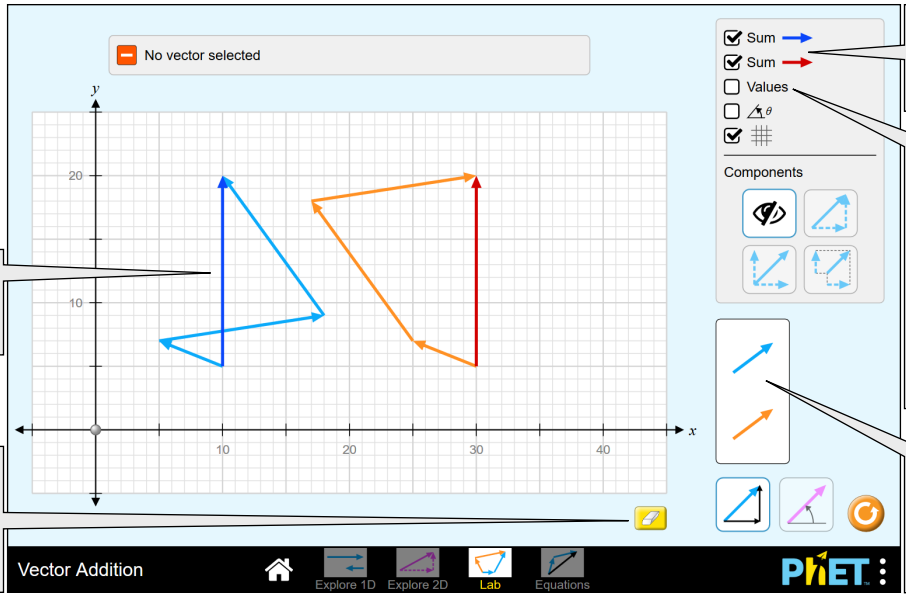
Lab Screen

Play with two sets of vectors and compare their sums. Add up to 10 vectors of the same type.

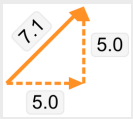


COMPARE two sets of vectors

CLEAR all vectors from the graph

TOGGLE sums individually

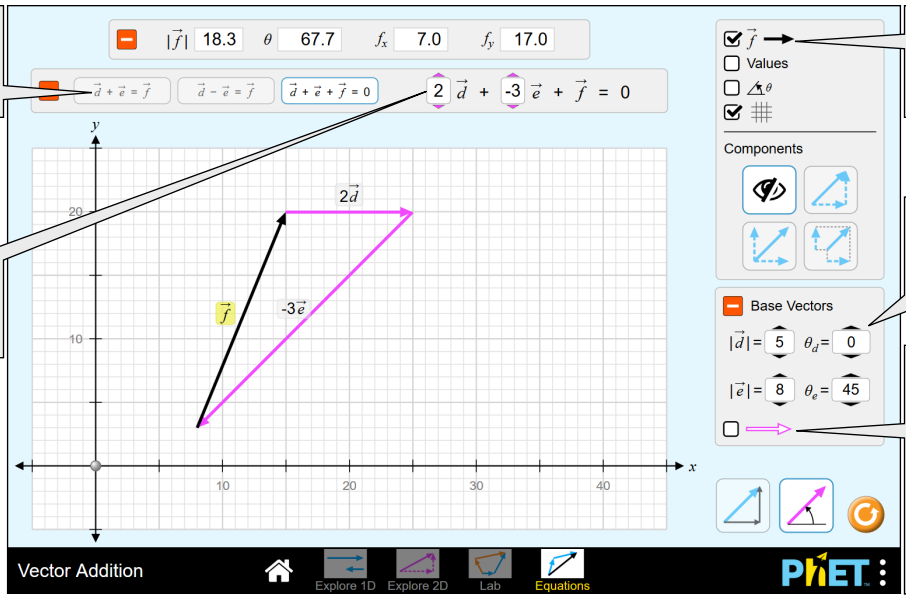
SEE magnitude of vector and components



EXPERIMENT with up to 10 of each vector type

Equations Screen

Experiment with vector equations and compare vector sums and differences. Customize the base vectors or explore scalar multiplication by adjusting the coefficients in equation.



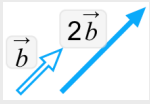
CHOOSE equation type

ADJUST coefficients

SHOW/HIDE derived vector

SET base vector values

SEE base vectors in the graph



Insights into Student Use

- The difference between the Cartesian and polar coordinate modes is subtle, and some students may not pick up on the difference on their own.
- If students are given opportunity to explore the sim without explicit directions, they will discover which vector representation makes the most sense for them. They may use different representations for different problems.

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Customization Options

Query parameters allow for customization of the simulation, and can be added by appending a '`?`' to the sim URL, and separating each query parameter with a '`&`'. The general URL pattern is:
`…html?queryParameter1&queryParameter2&queryParameter3`

For example, in Vector Addition, if you only want to include the 1st and 2nd screens (`screens=1,2`), with the 2nd screen open by default (`initialScreen=2`) use:
https://phet.colorado.edu/sims/html/vector-addition/latest/vector-addition_all.html?screens=1,2&initialScreen=2

To run this in Spanish (`locale=es`), the URL would become:
https://phet.colorado.edu/sims/html/vector-addition/latest/vector-addition_all.html?locale=es&screens=1,2&initialScreen=2

⚙ Indicates this customization can be accessed from the Preferences menu within the simulation.

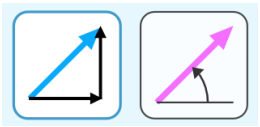
Query Parameter and Description	Example Links

`screens` - specifies which screens are included in the sim and their order. Each screen should be separated by a comma. For more information, visit the Help Center.	`screens=1`
	
	`screens=2,1`

`initialScreen` - opens the sim directly to the specified screen, bypassing the home screen.	`initialScreen=1` `initialScreen=3`
⚙ `locale` - specify the language of the simulation using ISO 639-1 codes. Available locales can be found on the simulation page on the Translations tab. Note: this only works if the simulation URL ends in "_all.html".	`locale=es` (Spanish) `locale=fr` (French)
`allowLinks` - when `false`, disables links that take students to an external URL. Default is `true`.	`allowLinks=false`
`supportsPanAndZoom` - when `false`, disables panning and zooming using pinch-to-zoom or browser zoom controls. Default is `true`.	`supportsPanAndZoom=false`

Complex Controls

- To translate a vector, grab its body. To stretch or rotate a vector, grab its tip.
- There are two snapping modes — Cartesian (left) and polar (right). In Cartesian mode, the vectors snap to integer $<x, y>$ values. In polar mode, the vectors snap to integer $<r, \theta>$ values with the angle adjusting in steps of 5°.



Model Simplifications

- The tail of the vector is restricted to the bounds of the graph. To prevent overly large vectors, the tip of the vector cannot be stretched beyond the bounds of the graph. However, the tip of the vector is allowed to escape the graph when translating the vector.

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- The model allows 180° to have a positive or negative sign. In polar mode, the sign will depend on the direction of approach — positive if rotating counterclockwise, negative if rotating clockwise. To change the sign, click the vector head and move the cursor slightly up or down. In Cartesian mode,180° will always be positive due to the way the y-coordinate snaps to zero.
- The vector labels are grabbable and can be used to translate the vectors within the graph. This may be particularly useful for touch devices with smaller screens.
- The goal of the projection-style component view is to collect the components along the axes. It is not meant to show true projection onto the axes.
- On the Equations screen, vectors **c** and **f** are always calculated from the values of the other vectors in the equation.

Suggestions for Use

Sample Challenge Prompts

- Describe a vector in your own words.
- Explain a method to add vectors.
- Compare and contrast the component styles.
- Decompose a vector into components.
- Describe what happens to a vector when it is multiplied by a scalar.
- Arrange vectors graphically to represent vector addition or subtraction.

See all published activities for Vector Addition here.
For more tips on using PhET sims with your students, see Tips for Using PhET.

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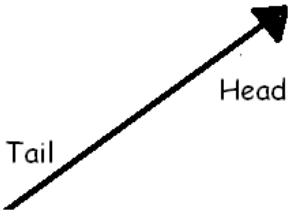
Name, Date, Period_____

Virtual Lab – *Vectors & Vector Operations*

Setup

1. Find the website called PhET, and within this site find the simulation called "Vector Addition."
2. From the bin at the right, you can drag out a vector arrow. If you ever want to get rid of a vector, drag it back into the bin. If you want to start over, click the eraser at the bottom.
3. You can adjust the direction and length of the arrow by click-dragging the arrow head. Play with this until you are comfortable.
4. Check all the boxes at the top right except for "sum." (these will show grid, vector length, and angles)



Part A: 3-4-5 Triangle

5. Drag out a vector, and move it until the tail is located at the origin. Click on the head of the vector, and drag it until it is completely horizontal, points to the right, and has a magnitude ($\vec{a}$) of 20.
6. Look at the chart at the top of the page. Here is an explanation of what each number represents:
   a. $\vec{a}$ represents the length of the arrow. This is usually called the **magnitude** of the vector.
   b. **Θ** represents the direction the arrow points. This is simply called the **direction** of the vector. The magnitude AND direction will completely define a vector.
   c. $\mathbf{a_x}$ is called the **X-component** of the vector. This is the length of the vector in the X-direction only.
   d. $\mathbf{a_y}$ is called the **Y-component** of the vector. This is the length of the vector in the Y-direction only.
7. For the first vector you dragged out, fill in the chart at right.

$\vec{a}$	θ	a_x	a_y

8. Now, drag out a second vector $\vec{b}$ and place its tail at the head of the first, as shown at right. Adjust this second vector until it points vertically upward and has a length of 15. Fill in the table for this vector here:

$\vec{b}$	θ	b_x	b_y

9. As you saw in the previous activity, if you were to walk this path, at the end you would be 25 units away from the origin. You can show this by clicking the button that says **Sum**. A new dark blue vector $\vec{s}$ should pop up. This represents the vector sum, or **resultant,** of the first two arrows.

10. Drag this vector over so that the tail is at the origin, and use it to form the hypotenuse of a right triangle. Notice that the head of this vector ends exactly where the second vector ends. Click on the dark blue vector and fill in the chart for this vector here:

$\|s\|$	θ	s_x	s_y

11. ۞ Compare the s_x and s_y values to the values from questions #10 and #11. What do you notice about these values?

Part B: Single Vector, Magnitude 50

12. Hit the **Clear All** button to erase the screen. Next, create a new $\vec{a}$ vector with an a_x of 20 and an a_y of 15. Fill in the chart for this vector here:

$\vec{a}$	θ	a_x	a_y

13. ⌬ Compare the chart values of this vector to those of the dark blue $\vec{s}$ vector from #13. How do these values compare?

14. Next, click the  button on the "Components" menu. This is a way to visualize any vector as a sum of horizontal and vertical components.

15. Adjust this vector until it has an a_x value of 15 and an a_y value of 30. Fill in the chart for this vector:

$\vec{a}$	θ	a_x	a_y

16. ⌬ Has the **magnitude** of this vector changed, compared #15? If so, how?

17. ⌬ Has the **direction** (that is, θ) of this vector changed, compared to #15? If so, how?

18. ◯ Figure out a way to adjust the magnitude and direction of this vector until it has a magnitude of 25, just like before, but points in a *different* direction from the first two tries. Fill in the chart for this vector, and **show your vector to your instructor**.

$\vec{a}$	θ	a_x	a_y

19. Looking at this vector, it is easy to imagine a right triangle, made from a_x, a_y and $\overrightarrow{|a|}$. In this case, $\overrightarrow{|a|}$ would be the hypotenuse, and a_x & a_y would be the legs.
    a. Show, using the Pythagorean Theorem, that $|\vec{a}|^2 = a_x^2 + a_y^2$.

    b. Show, using SOHCAHTOA, that $a_x = |\vec{a}| \cos\theta$.

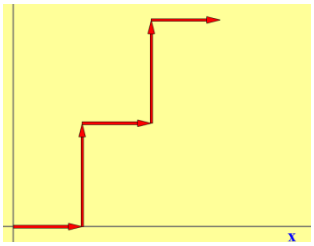
    c. Show, using SOHCAHTOA, that $a_y = |\vec{a}| \sin\theta$.

20. Clear All. Imagine a vector with magnitude $|\vec{a}| = 28$ and angle $\theta = 45^o$.

    a. ◯ Use SOHCAHTOA to determine the X- And Y- components (that is, find a_x and a_y). Show your work to your instructor.

    b. Check your answer by constructing this vector.

Part C – Several Vectors (Switch to "Lab" version of sim)



21. Re-open the vector sim, but this time choose the "lab" version. Create 5 vectors of the same color, as shown at right. The length of each of the horizontal vectors should be 5, and the length of the vertical vectors should be 10.

22. Click on the "Show Sum" button. Fill in the chart for this resultant, or sum, vector.

$\vec{s}$	θ	s_x	s_y

23. ◯ A useful way to keep track of vector sums is to create a chart. Complete the chart below, using the 5 vectors you've constructed, and then add the columns to get the sums. Show your instructor when finished.

Vector #	v_x	v_y
1	5	0
2		
3		
4		
5		
SUM		

24. ⬡ How do the v_x and v_y sums from the previous chart compare to the s_x and s_y values from question #25?

25. ◯ Using the Pythagorean Theorem, determine the resultant $|\vec{s}|$ value, which is the hypotenuse of a triangle with s_x and s_y as its legs. Compare this number to the $|\vec{s}|$ value from #25. Show instructor when finished.

26. ***Clear All***. Construct the following 4 vectors and add them with the "head-to-tail" method:
- $\vec{v} = 10$, $\theta = 0^o$ (start this one at the origin)
- $\vec{v} = 10$, $\theta = 90^o$
- $\vec{v} = 10$, $\theta = 180^o$ (or -180^o)
- $\vec{v} = 10$, $\theta = 270^o$ (or -90^o)

27. What is the sum (or resultant) of these vectors?

$\vec{s}$	θ	s_x	s_y

28. What is the sum of these vectors if the first vector is 5 units long rather than 10?

$\vec{s}$	θ	s_x	s_y

29. Answer extension questions on the next page.

Extension Questions

1. A student, following instructions on her treasure map, starts at the origin and walks the following routes:
   → 18 meters North ($\theta = 90^o$)
   → 5 meters West ($\theta = 180^o$)
   → 9 meters South ($\theta = 270^o$ or -90^o)
   → 17 meters East ($\theta = 0^o$)

   a. Fill in the chart below, which represents the horizontal and vertical components of the routes. Also determine the X and Y sums.

Vector #	v_x	v_y
1	0	18
2		
3		
4		
SUM		

   b. After the student has finished walking, what is her horizontal displacement? (v_x sum)

   c. What is her vertical displacement? (v_y sum)

   d. Using the Pythagorean Theorem, and your answers from (b) and (c), how far is she from the origin? (In other words, what is her resultant |R|?)

   e. Using SOHCAHTOA, what is her direction, as measured from the origin? (In other words, what is θ?)

2. A model airplane is flying North with a velocity of 15 m/s. A strong wind is blowing East at 12 m/s.

   a. What is the airplane's resultant ***speed*** (magnitude of velocity vector)?

   b. What is the airplane's ***heading*** (direction of velocity vector)?