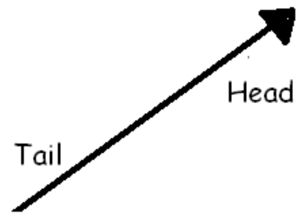
Virtual Lab – *Vectors & Vector Operations*

Setup

1. Make sure your calculator is set to degrees and not radians. Sign out a laptop and power cord. Plug in the laptop and leave it plugged in and on.
2. Do a Google search for "PhET" and then go to the PhET website.
   https://phet.colorado.edu/en/simulation/vector-addition
3. From the menu at the left, click "Math Tools" and then select the **Vector Addition** simulation.
4. Once you get to the **Vector Addition** page, there should be a green button below the picture that says "Run Now!" Click this button.

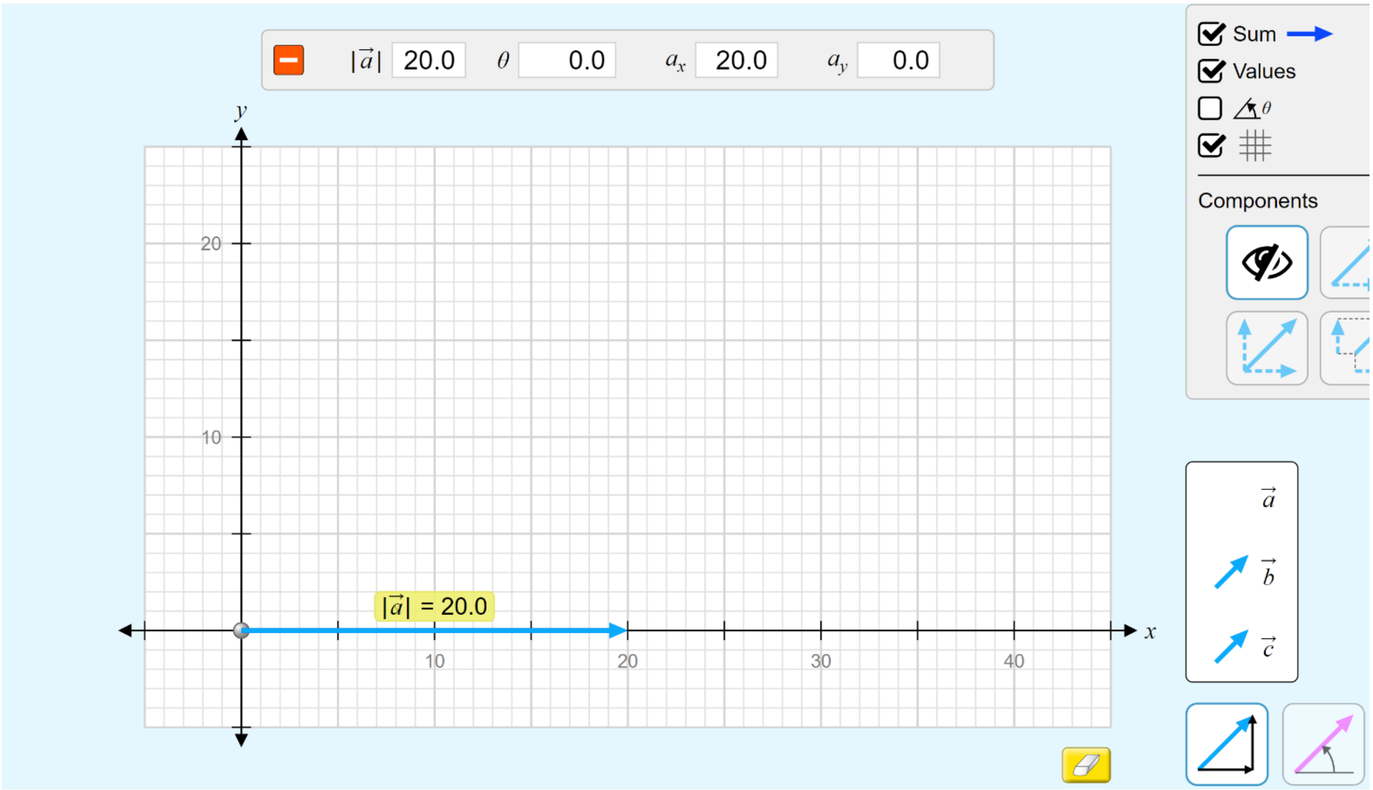


5. In the basket at the top right, you can drag out a vector arrow. If you ever want to get rid of a vector, drag it to the trash can at the bottom right. If you want to start over, click "Clear All."
6. You can adjust the direction and length of the arrow by click-dragging the arrow head. Play with this until you are comfortable.
7. 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

8. 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.
9. 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. a_x is called the **X-component** of the vector. This is the length of the vector in the X-direction only.
   d. a_y is called the **Y-component** of the vector. This is the length of the vector in the Y-+direction only.
10. For the first vector you dragged out, fill in the chart at right.
    Answer:

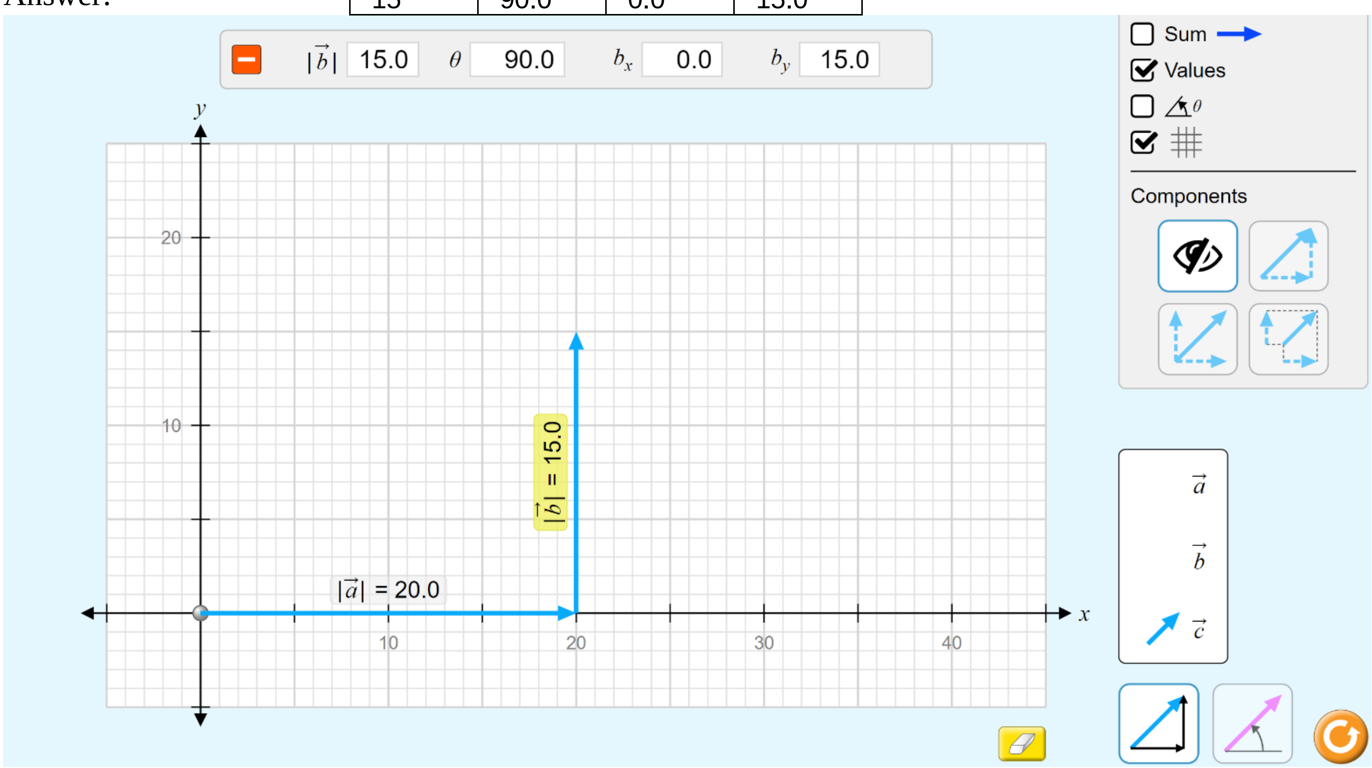
$\vec{a}$	θ	a_x	a_y
20	0	20	0



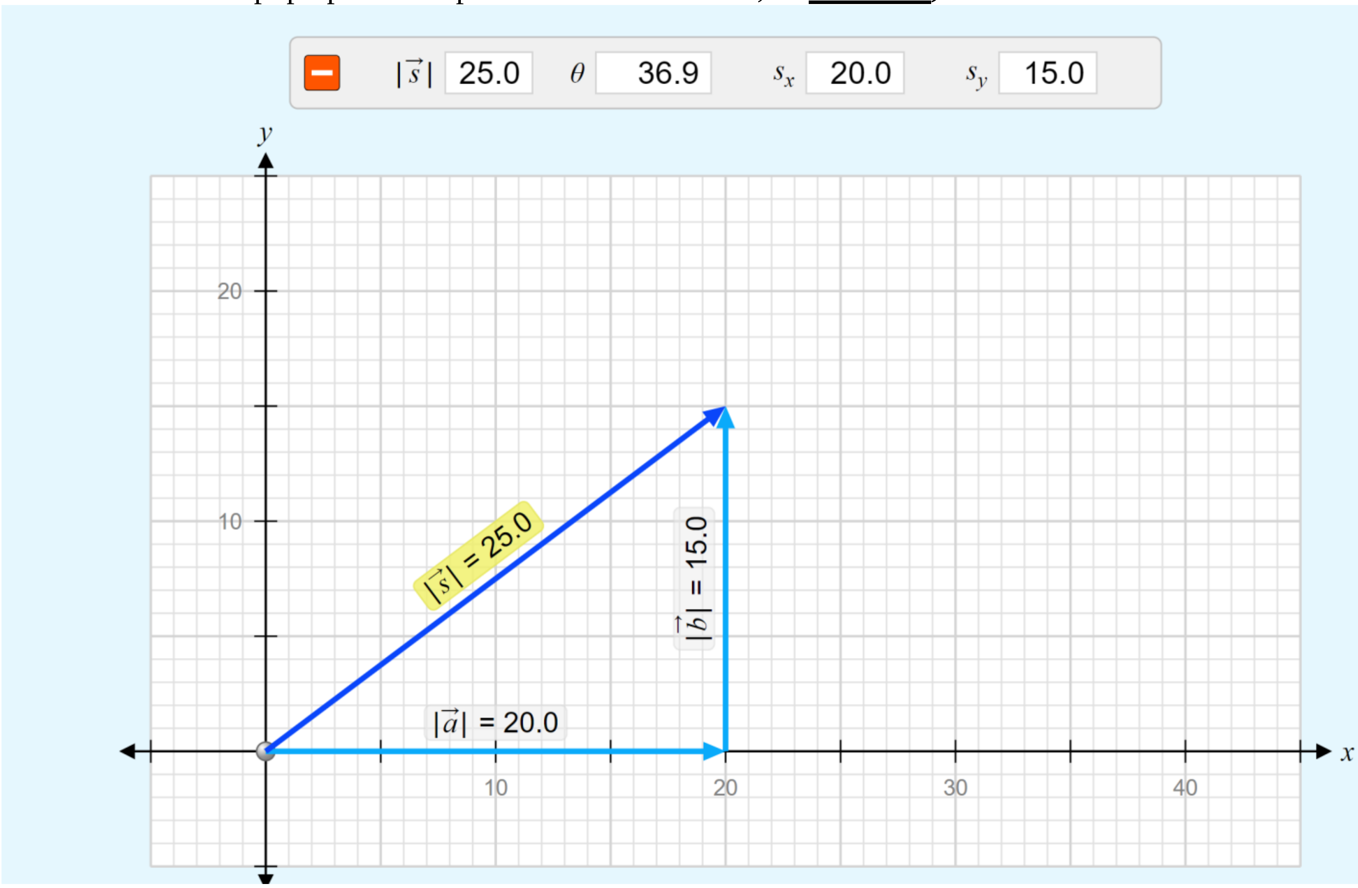
11. Now, drag out a second vector $\vec{b}$ and place its tail at the head of the first, as shown at right. Adjust this second vector until it points vertically upward and has a length of 15. Fill in the table for this vector here:

Answer:

$\vec{b}$	θ	b_x	b_y
15	90.0	0.0	15.0



12. 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 **<u>resultant</u>,** of the first two arrows.



13. 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	Sx	Sy
25	36.9	20.0	15.0

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

Answer: Their magnitude are the same:

Sx is 20 and Sy is 15, however we can see the resultant vector here vs no resultant vector in #10 and #11.

Part B: Single Vector, Magnitude 50

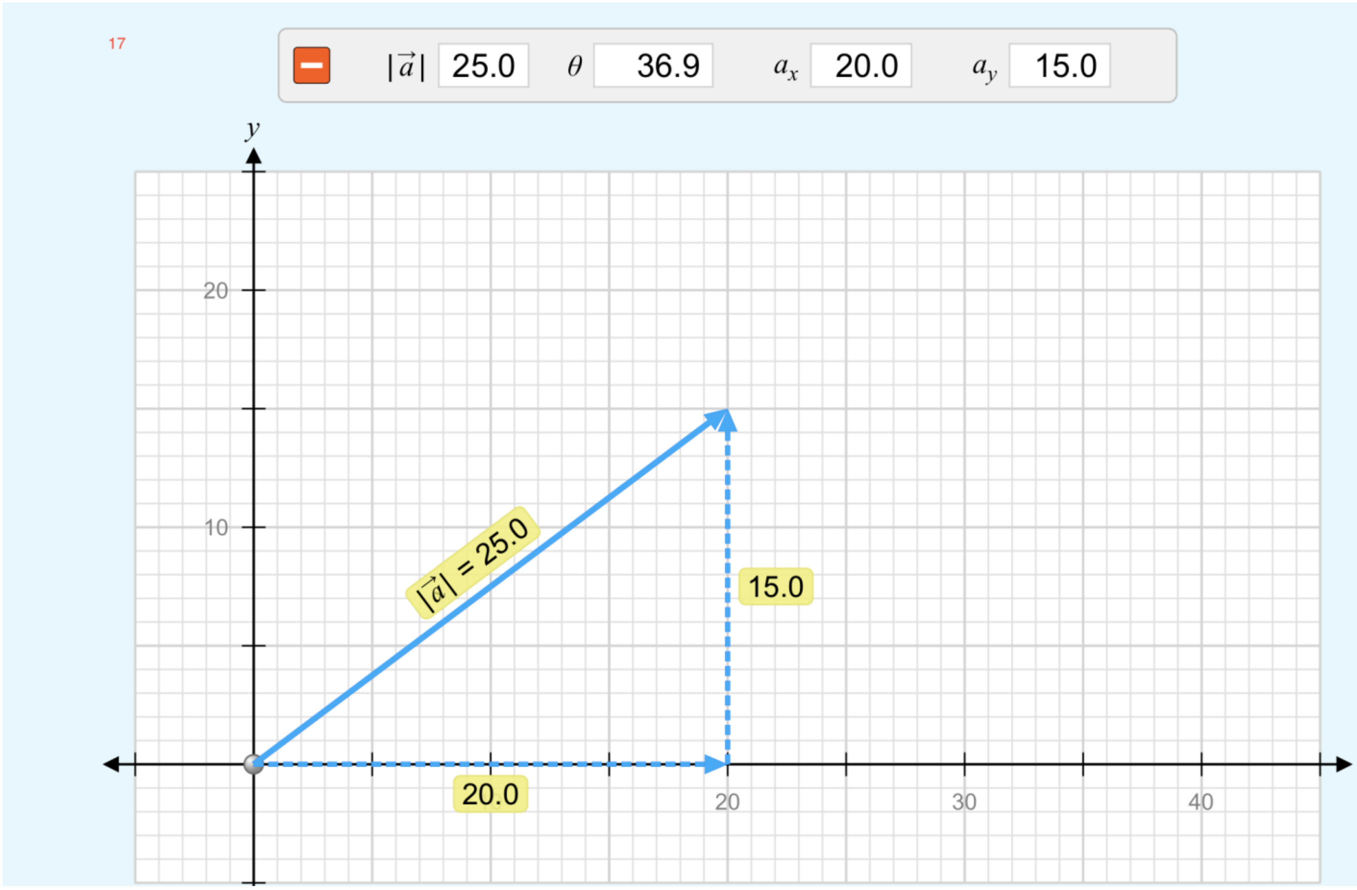
15. Hit the **Clear All** button to erase the screen. Next, create a new $\vec{a}$ vector with an a_x of 20 and an a_y of 15. Fill in the chart for this vector here:

$\vec{a}$	θ	a_x	a_y
25	36.9	20	15

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

Answer: the numerical values are the same however s is the resultant vector of a and b. But here in 16 we are directly drawing a of magnitude 25.

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

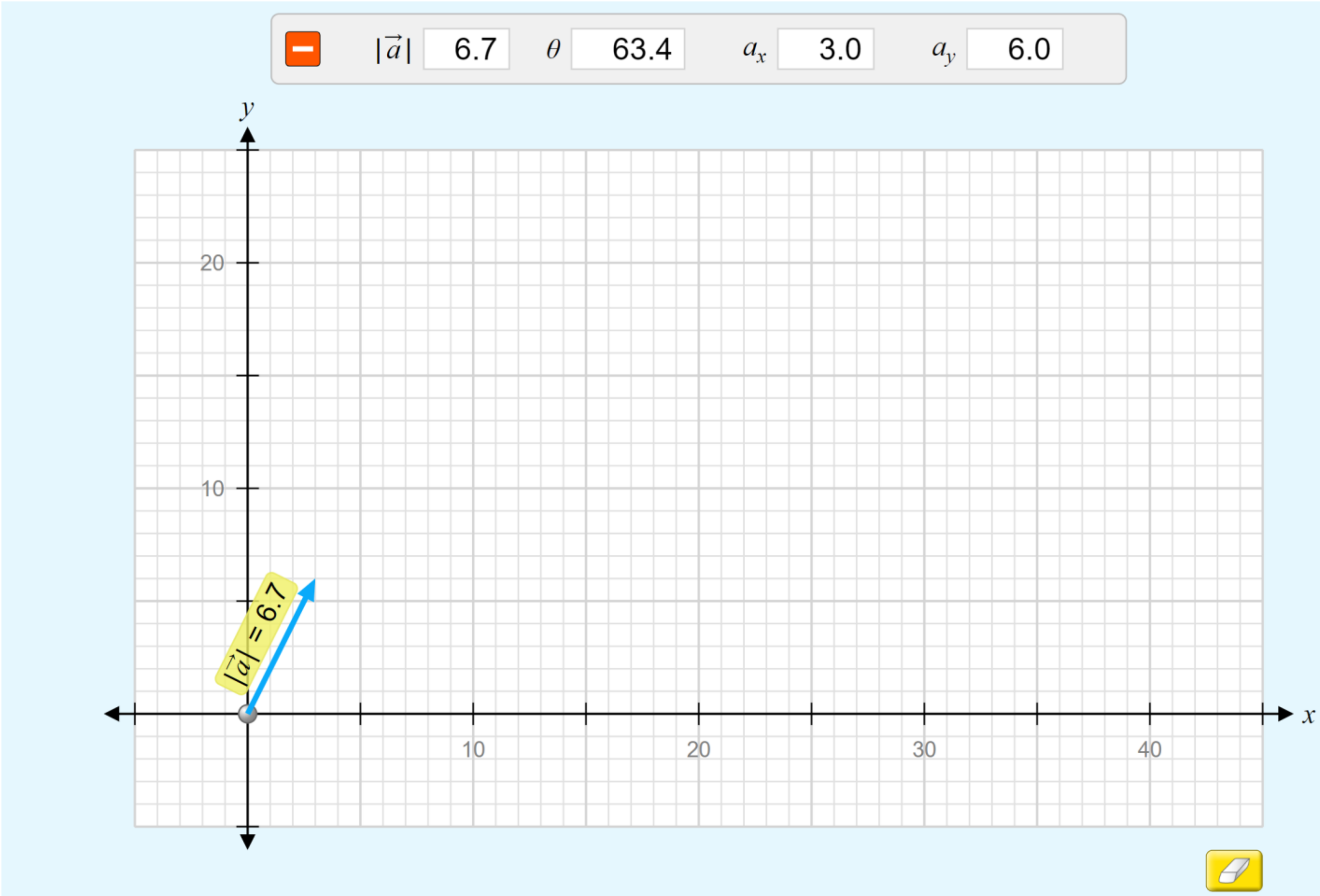


18. Adjust this vector until it has an a_x value of 15 and an a_y value of 30. Fill in the chart for this vector:

Answer:
Taking

$\vec{a}$	θ	a_x	a_y
6.7	63.4	3.0	6.0

ratio as the website has some limitation.

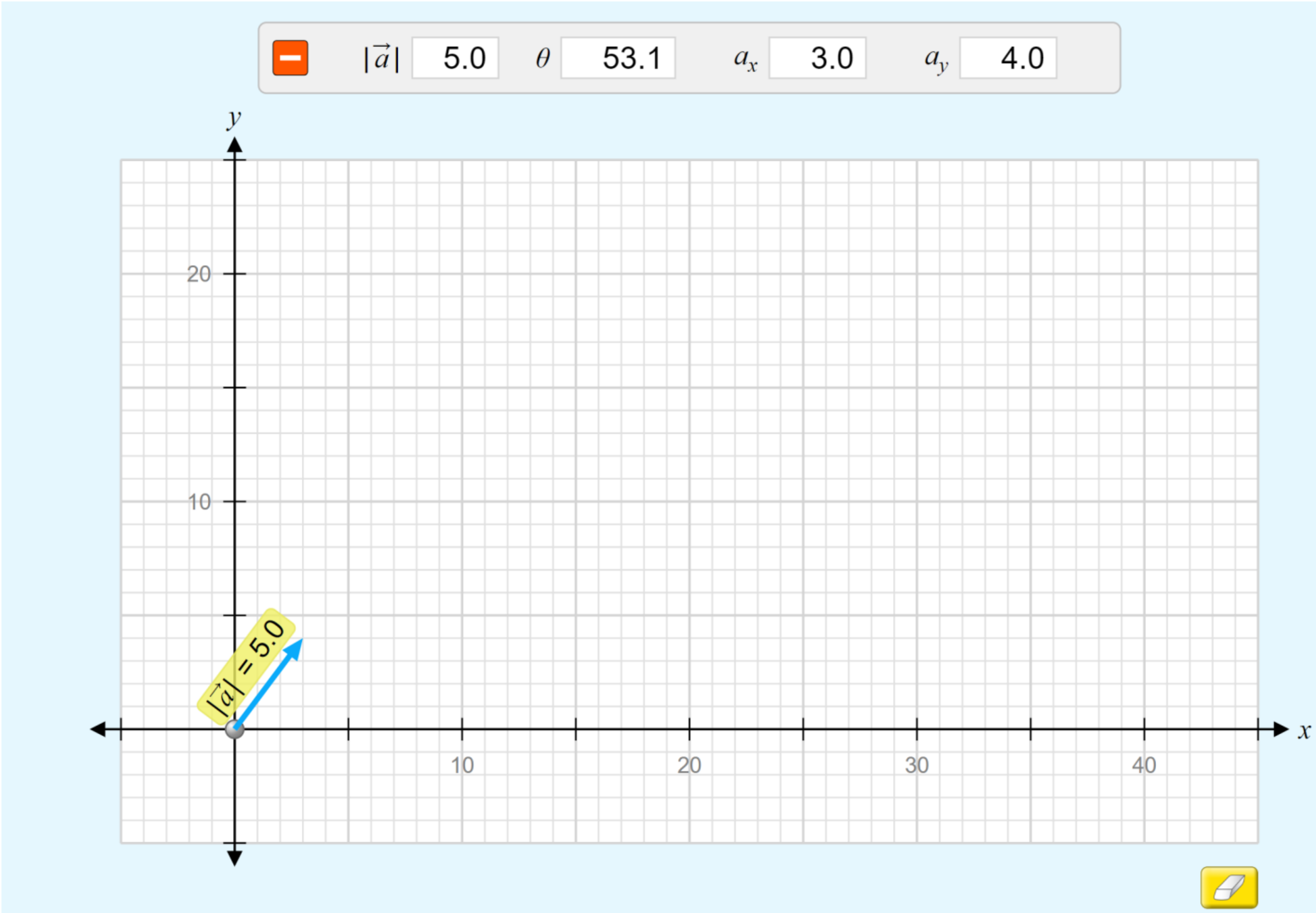


19. Has the **magnitude** of this vector changed, compared #15? If so, how?
Ans: Yes the magnitude has been changed, in 15 the magnitude was 25 and here its 14.1, which is again the resultant vector.

20. Has the **direction** (that is, θ) of this vector changed, compared to #15? If so, how?
Ans: yes the directions are also different, #5 has 36.9 vs #20 has 45 degree angle.

21. 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
5.0	53.1	3.0	4.0



22. Looking at this vector, it is easy to imagine a right triangle, made from a_x, a_y and $|\vec{a}|$. In this case, $|\vec{a}|$ would be the hypotenuse, and a_x & a_y would be the legs.

   a. Show, using the Pythagorean Theorem, that $|\vec{a}|^2 = a_x^2 + a_y^2$.

   Answer: The Pythagorean Theorem states:

|a⃗|2=ax2+ay2

6.7^2=3^2+6^2

44.89=45

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

   Answer:

   cosθ=ax/ $\vec{a}$|

   therefore $|\vec{a}| \cos \theta = a_x$

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

ay=|a|sinθ

Using the sine of the angle θ≈63.26∘

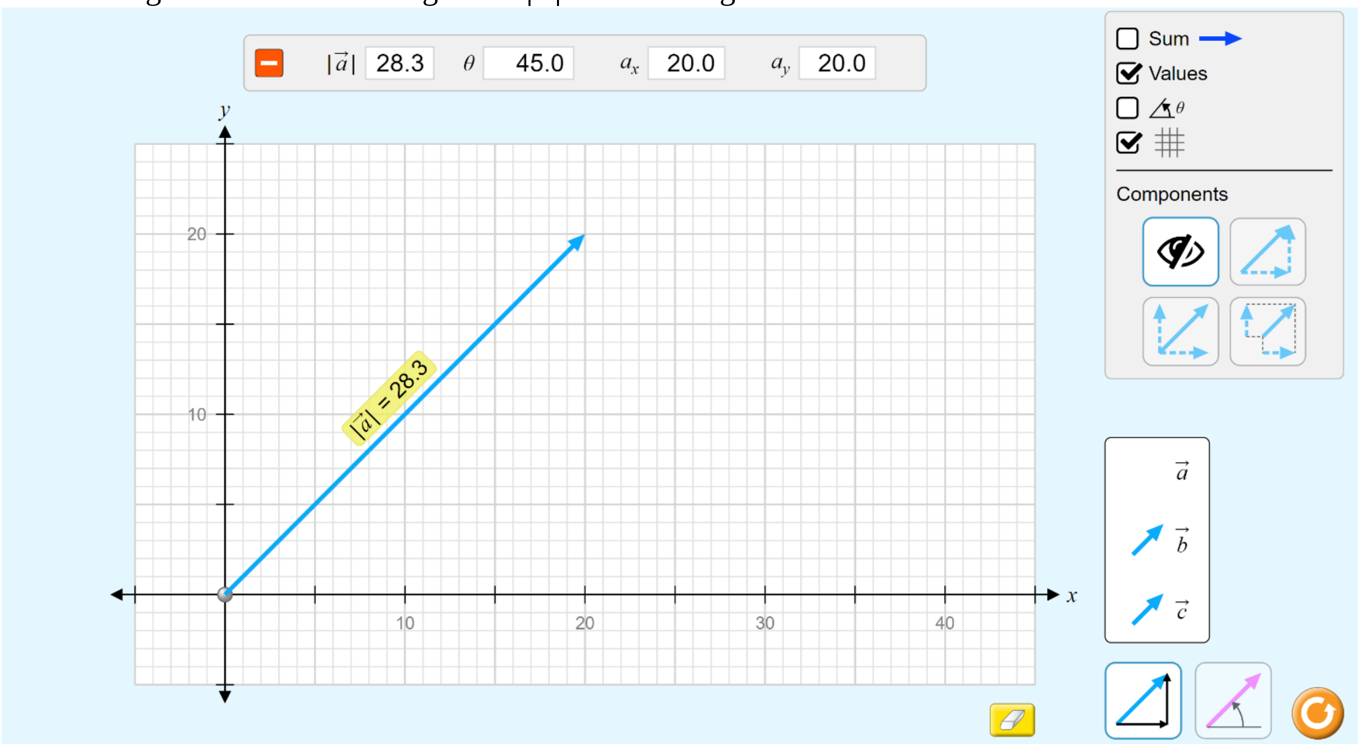
Sin 63.26∘≈0.8944

Now calculate ayay:

ay=6.7×0.8944≈6

This matches the given ay=6

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



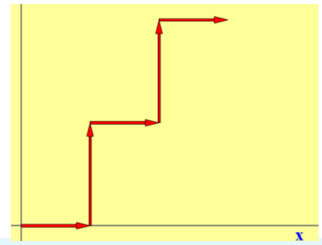
a. Use SOHCAHTOA to determine the X- And Y- components (that is, find a_x and a_y). Show your work to your instructor.
Answer:
Using pythagorus theorem,

ax= sqroot of (28.3^2 – 20^2) = 20 approx

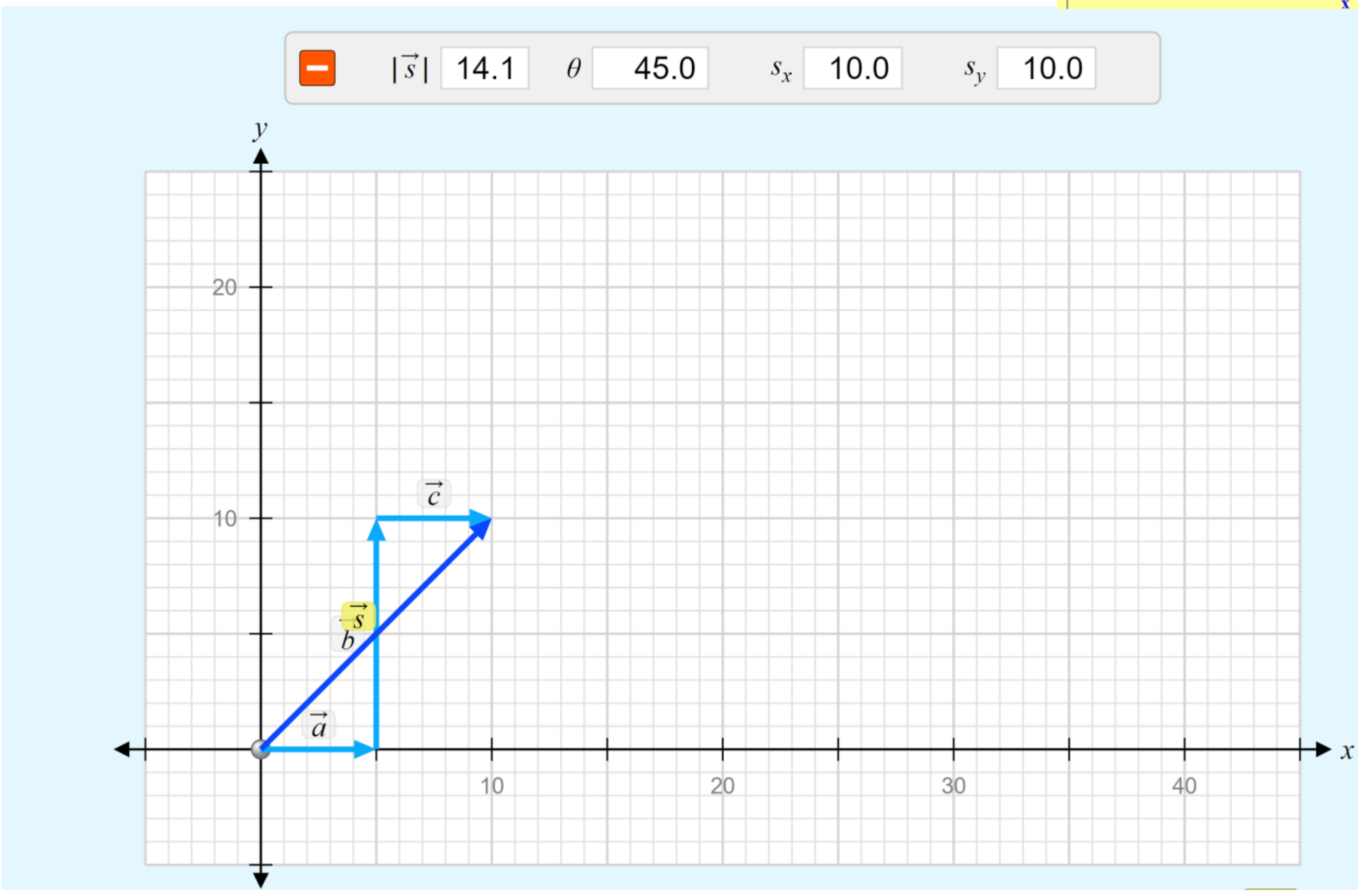
yx= sqroot of (28.3^2 – 20^2) = 20 approx

b. Check your answer by constructing this vector.

<u>Part C – Several Vectors</u> (Switch to "Lab" version of sim)



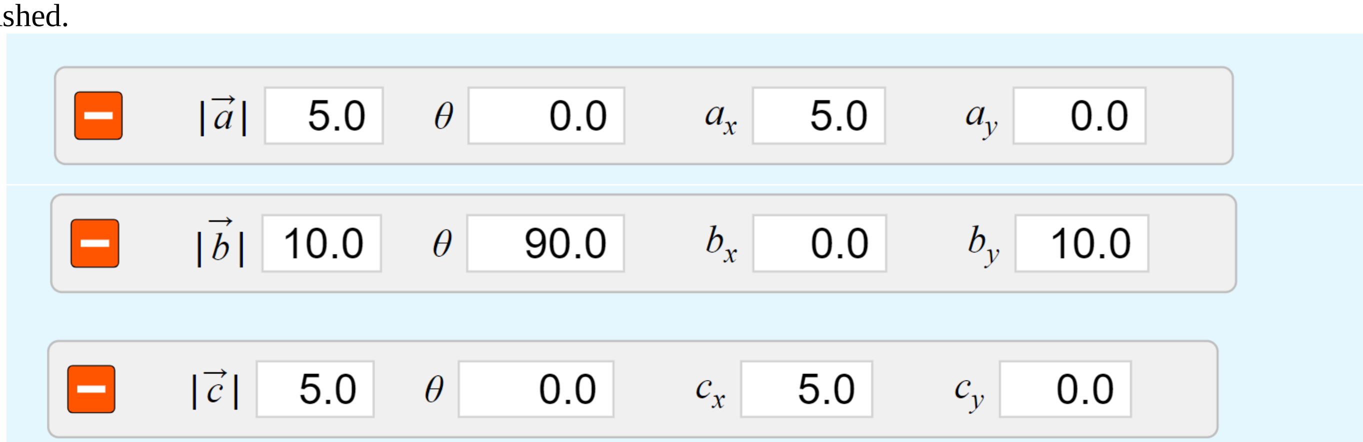
24. Re-open the vector sim, but this time choose the "lab" version. Create 5 vectors of the same color, as shown at right. The length of each of the horizontal vectors should be 5, and the length of the vertical vectors should be 10.



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

$\vec{s}$	θ	S_x	S_y
14.1	45	10.0	10.0

26. ◌ 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	0	10
3	5	0
4		
5		
SUM	10	10

27. 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?

Answer: question #25 takes resultant vector values whereas in question #27 we add individual magnitudes of x and y component.

28. 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.
    - For vector $\vec{v}1=(5,0)$, the resultant magnitude s1=5s.
    - For vector $\vec{v}2=(0,10)$, the resultant magnitude s2=10s.
    - For vector $\vec{v}3=(5,0)$, the resultant magnitude s3=5s.

29. ***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)

- 

  For each vector, we'll use the following equations to find the components:

  $v_x=v\cos$

  $v_y=v\sin\theta$

- **Vector $\vec{v}_1 v_1$**

  $v_{1x}=10\cos 0^\circ=10$

  $v_{1y}=10\sin 0^\circ=0$

- **Vector $\vec{v}_2 v_2$**

  $v_{2x}=10\cos 90^\circ=0$

  $v_{2y}=10\sin 90^\circ=10$

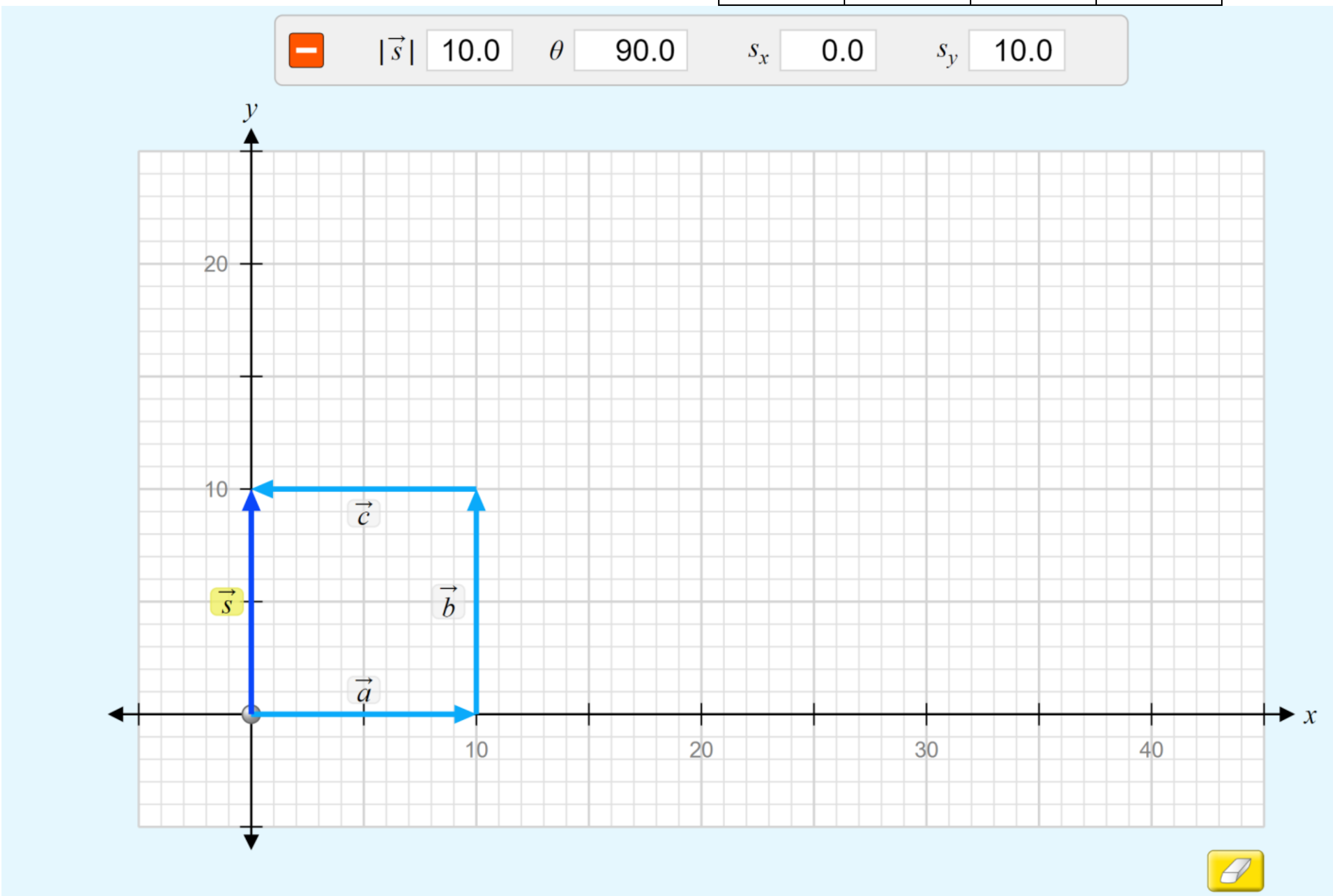
- **Vector $\vec{v}_3 v_3$**

  $v_{3x}=10\cos 180^\circ=-10$

  $v_{3y}=10\sin 180^\circ=0$

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

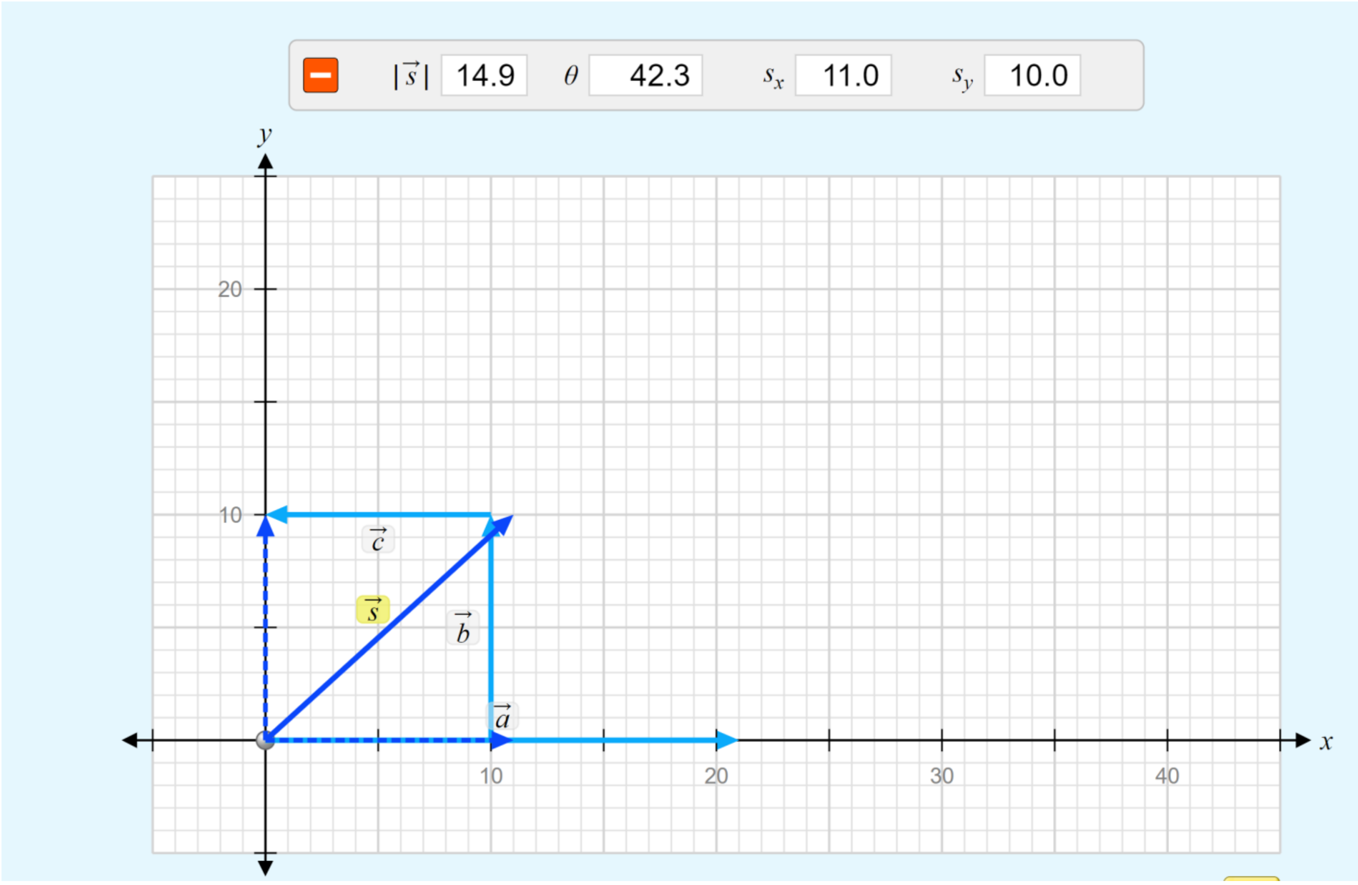
$\vec{s}$	θ	Sx	Sy
10.0	90	0	10



31. What is the sum of these vectors if the first vector is 10 units long rather than 20?

Answer: the first vector is already 10 units longer, extending it 10units further, we get

$\vec{s}$	θ	Sx	Sy



32. 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	0	-9
3	-5	0
4	17	0
SUM	12	9

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

Answer- 12m

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

Answer- 9m

   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|?)

Answer- R = sqroot {(12)^2 + (9)^2} = 15

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

Answer- theta = tan^-1(0.75)
Therefore, the direction of the resultant vector is approximately 36.87° north of east.

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)?

Answer- ∣vresultant∣=vplane2+vwind2

∣$\vec{v}$resultant∣= sqroot (15^2+12^2) ≈19.2m/s

b. What is the airplane’s ***<u>heading</u>*** (direction of velocity vector)?

$\theta=\tan-1(vplane/vwind)$

$\theta=\tan\text{^}-1(12/15)$

$\theta=\tan\text{^}-1(0.8)$

Using a calculator:

$\theta\approx38.66\circ\theta\approx38.66\circ$