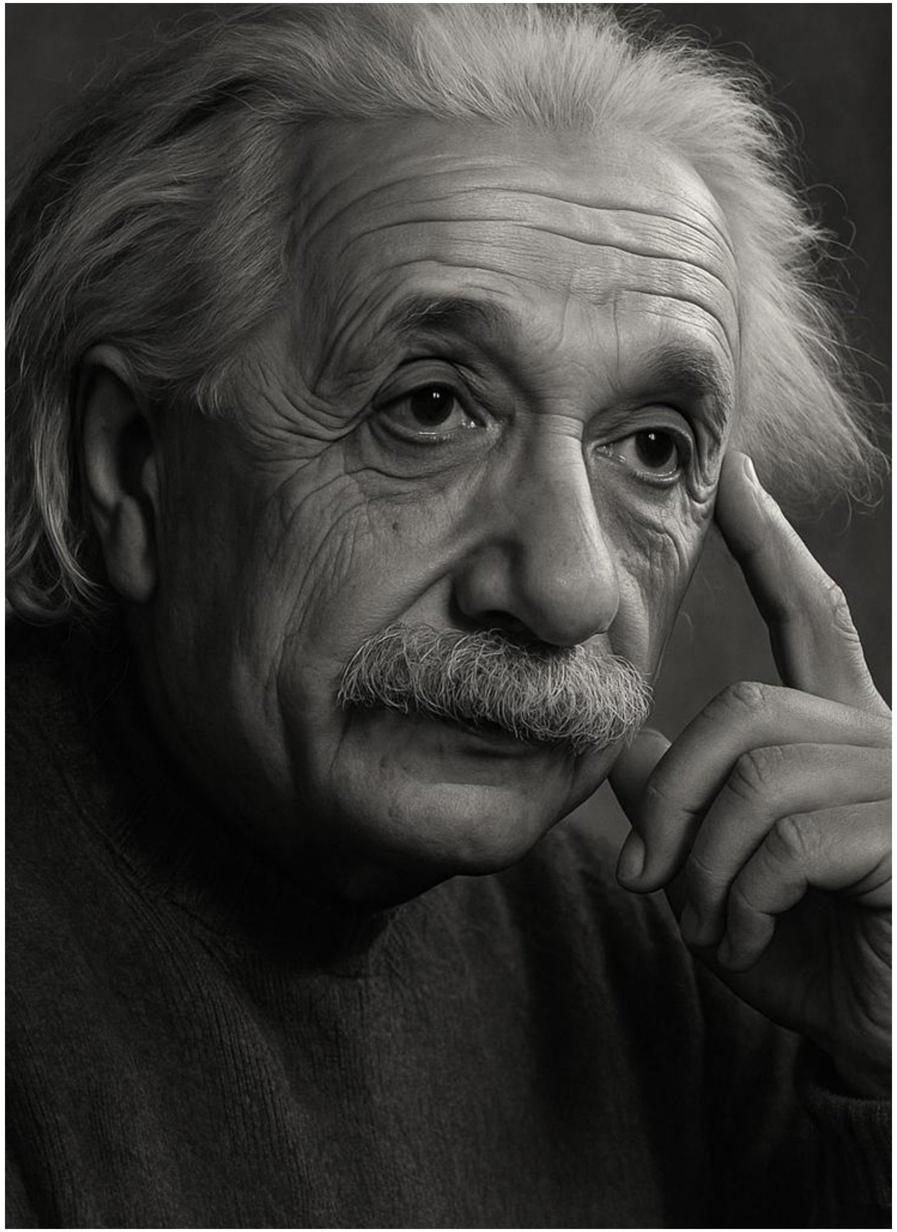
Introduction and Math Review

Chapter One

Welcome to Physics 201

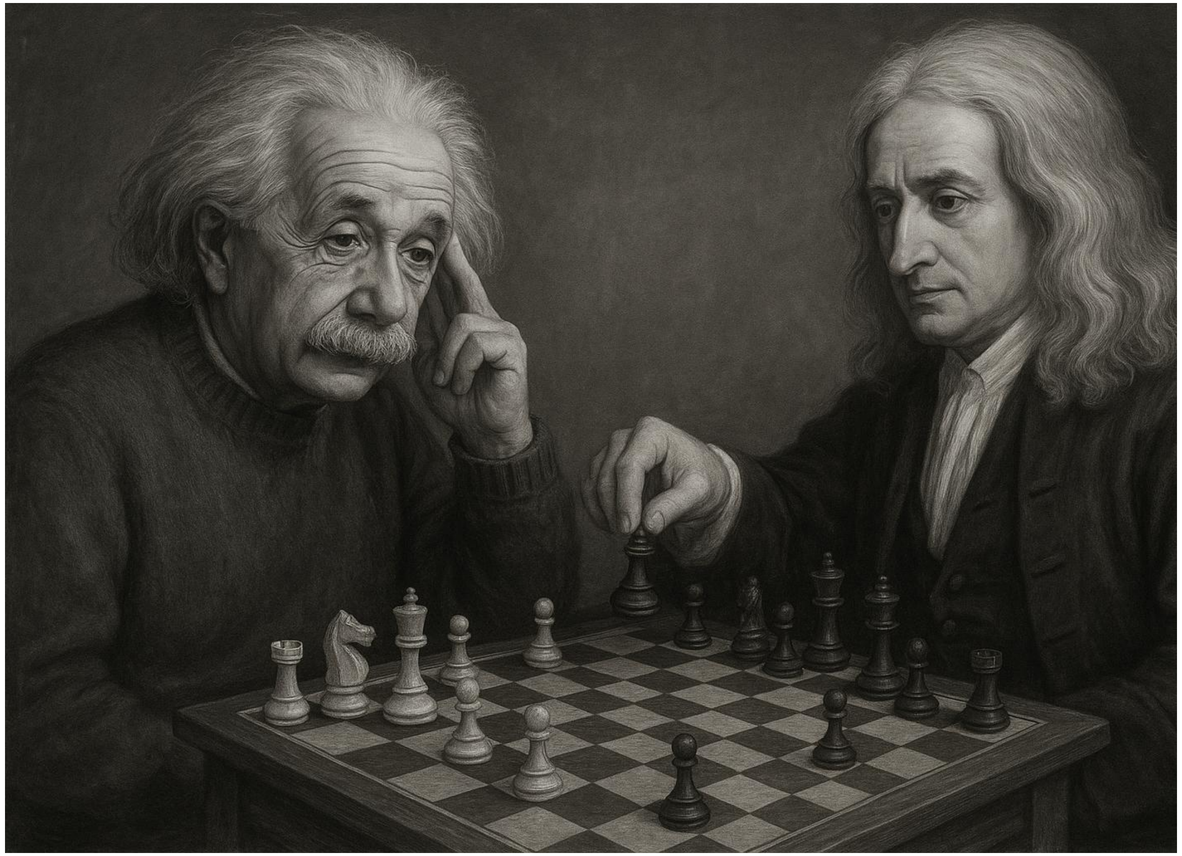
- Physics is the study of how the universe works — from falling apples to orbiting planets, from quarks to protons, from rocket launches to the expansion of the cosmos.
- In this course, we'll explore the laws that govern **motion, forces, energy, and gravity** — the same principles that explain how stars are born, how galaxies collide, and how the universe itself began.
- Physics is everywhere. It's not just equations — it's a way of seeing the world.
- Whether you're here for science, medicine, engineering, or just curiosity — welcome. Let's dive into the laws that shape reality.
- Before we can run, we must walk.



Self Assessment

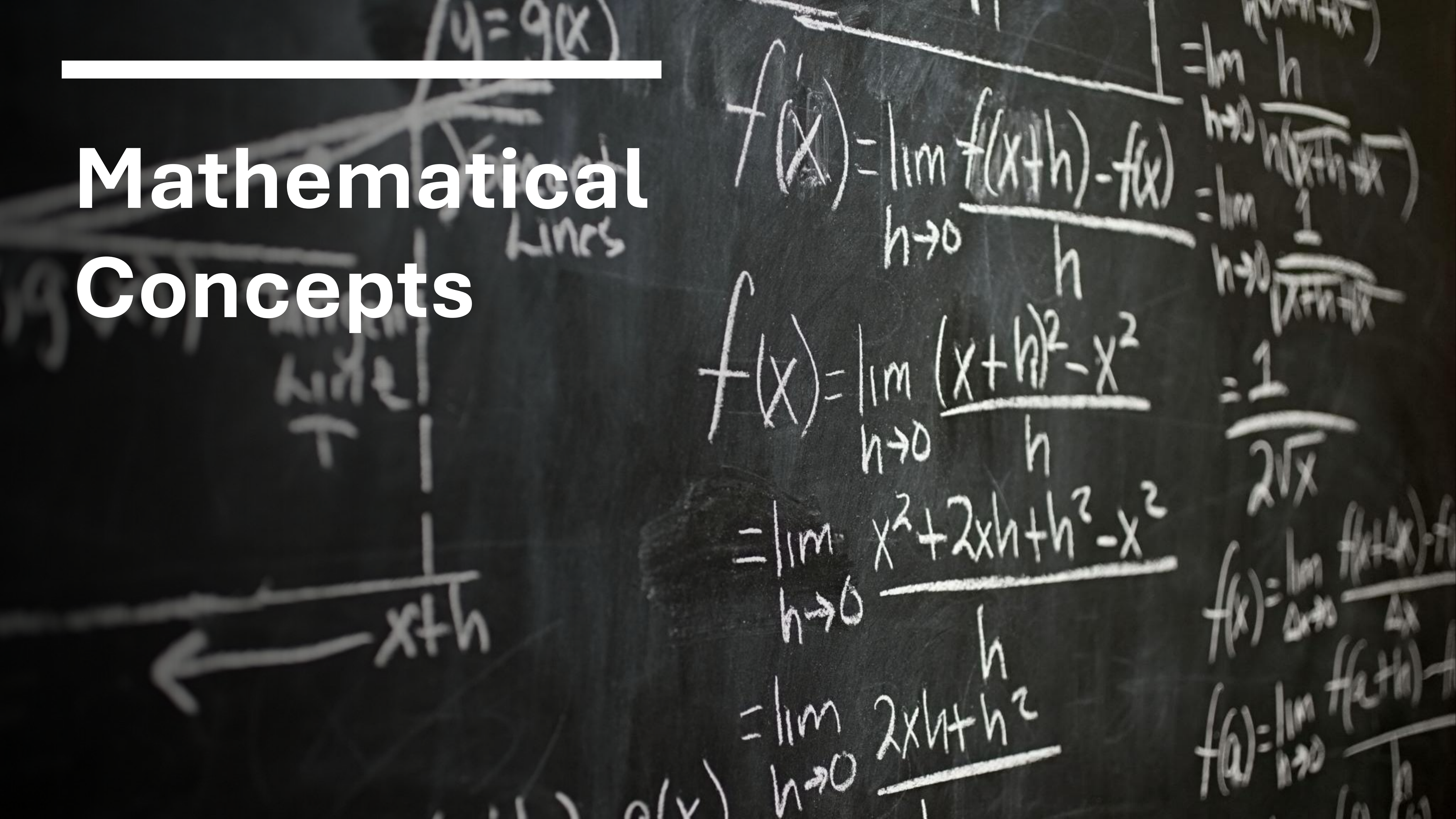
- While we will review fundamental units, scalars, vectors, and trigonometry today, basic algebra, and how to convert between units will not explicitly be reviewed.
- I added a self assessment on D2L so that you may gauge your skill in those subjects and prioritize what you want to review on your own.
- I am always around for questions/guidance
- “*There are no such thing as stupid questions, just stupid people afraid to ask stupid questions because they are afraid to look stupid*.” - Abraham Lincoln, probably

Teams



- You will pick teams and a team name.
- Throughout lecture, we will have group discussions, contests, exercises, and other activities where you and your team will work together.
- You will see a slide titled: Team Activity
  - This means its time for a team activity.
  - Assemble your team, listen to the challenge, and get to work.
- Not set in stone. Can change names, group compositions, meant to be fun.

Mathematical Concepts



Fundamental Units

Unit	System		
	SI	CGS	BE
Length	*Meter (m)*	*Centimeter (cm)*	*Foot (ft)*
Mass	*Kilogram (kg)*	*Gram (g)*	*Slug (s)*
Time	*Second (s)*	*Second (s)*	*Second (s)*

Prefix	Symbol	Factor
Giga	G	10^{9}
Mega	M	10^{6}
Kilo	k	10^{3}
Centi	c	10^{-2}
Milli	m	10^{-3}
Micro	μ	10^{-6}

More on table 1.2 in the textbook.

1kilogram = 10^{3} g = 1000g

How do we write 2970g in terms of kg?

$$2970g \times \frac{1kg}{1000g} = 2.970kg$$

How do we write $2970\mu g$ in terms of g?

$$2970\mu g \times \frac{1\mu g}{1000000g} = 0.002970g = 2.970 \times 10^{-3}g$$

Converting between Unit Systems

- In general, when U_2 is larger than U_1:

$$(X \cdot U_1) \times (Number\ of\ U_2\ in\ U_1)/U_1$$

  - For example, there are 5280 feet in a mile, to convert to 3 miles to feet

$$3\ mile \times \frac{5280\ ft}{1\ mile} = 3 \cdot 5280\ ft = 15{,}840\ ft$$

  - In the above example, X = 3, U_1=mile, Number of U_2 in U_1 was 5280 ft. Note that the unit "mile" divide out.

- When U_1 is larger than U_2:

$$(X \cdot U_1) \times (U_2\ )/(Number\ of\ U_2\ in\ U_1)$$

  - For example, convert 15,840 ft to miles,

$$15840\ ft \times \frac{1\ mile}{5280\ ft} = \frac{15840}{5280} mile = 3\ mile$$

- Note: There is really no difference between these expressions. For example, "Number of U_2 in U_1" could be smaller than on. For example, we could say, there are (1/5280) miles in a foot and do the second example using the first expression.

Team Activity 1.1

- There are 1.60×10^5 cm in a mile. Covert 480,000 cm to miles.

Units Built from Fundamental Units

You will describe motion with fundamental units

- Velocity: *m/s*
- Acceleration: m/s^2
- Torque: $kg \cdot m^2/s^2$
- Angular Velocity: *rad/s or 1/s*
- Force: $kg \cdot m/s^2$

You will encounter new named units using fundamental units

- Newtons (N): $kg \cdot m/s^2$
- Joule (J): $N \cdot m$
- Watts (W): *J/s*
- Pascal (Pa): N/m^2

Notice that Newtons describe something called "Force". Knowing that, can we write "Torque" in terms of Newtons?

Hold up? Isn't Torque represented by Joules? No. While they involve the same units, torque is something called a **vector** and joules represent something called Energy which is called a **scalar**.

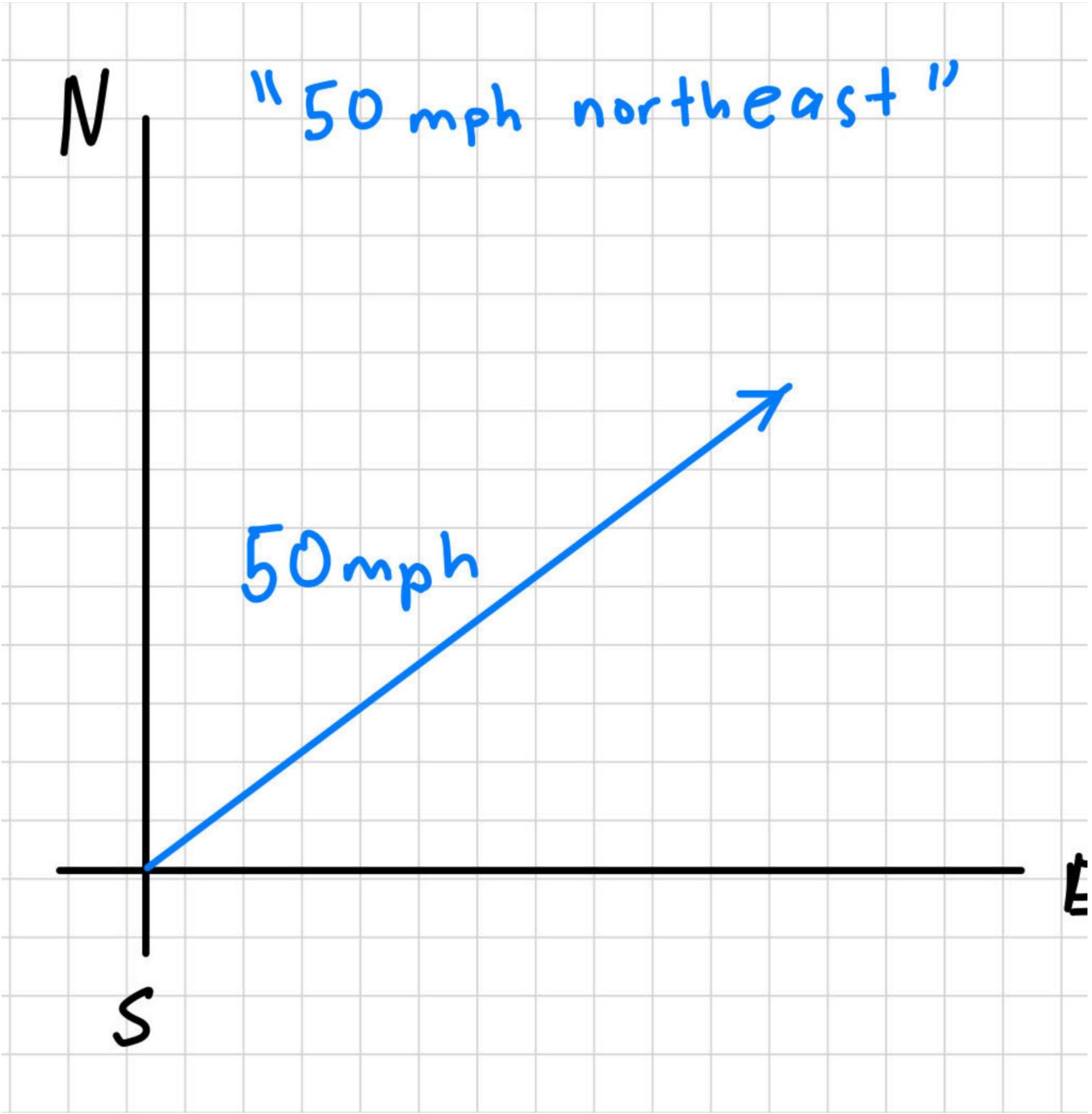
Scalars

- Many physical quantities such as time, temperature, mass, speed, energy can be described completely with a number and a unit.
  - 5 seconds, 5^{o} C, 5 kg, 5 m/s, 5 Joules
- Scalars have no information about direction.
- Scalars are the building blocks of physical descriptions—used in calculations like kinetic energy, power, and total time.

- How long did it take?
  - 1 hour
- How far is it?
  - 10 miles
- How fast were you going?
  - 60 mph
- What is the temperature outside?
  - 72 degrees F

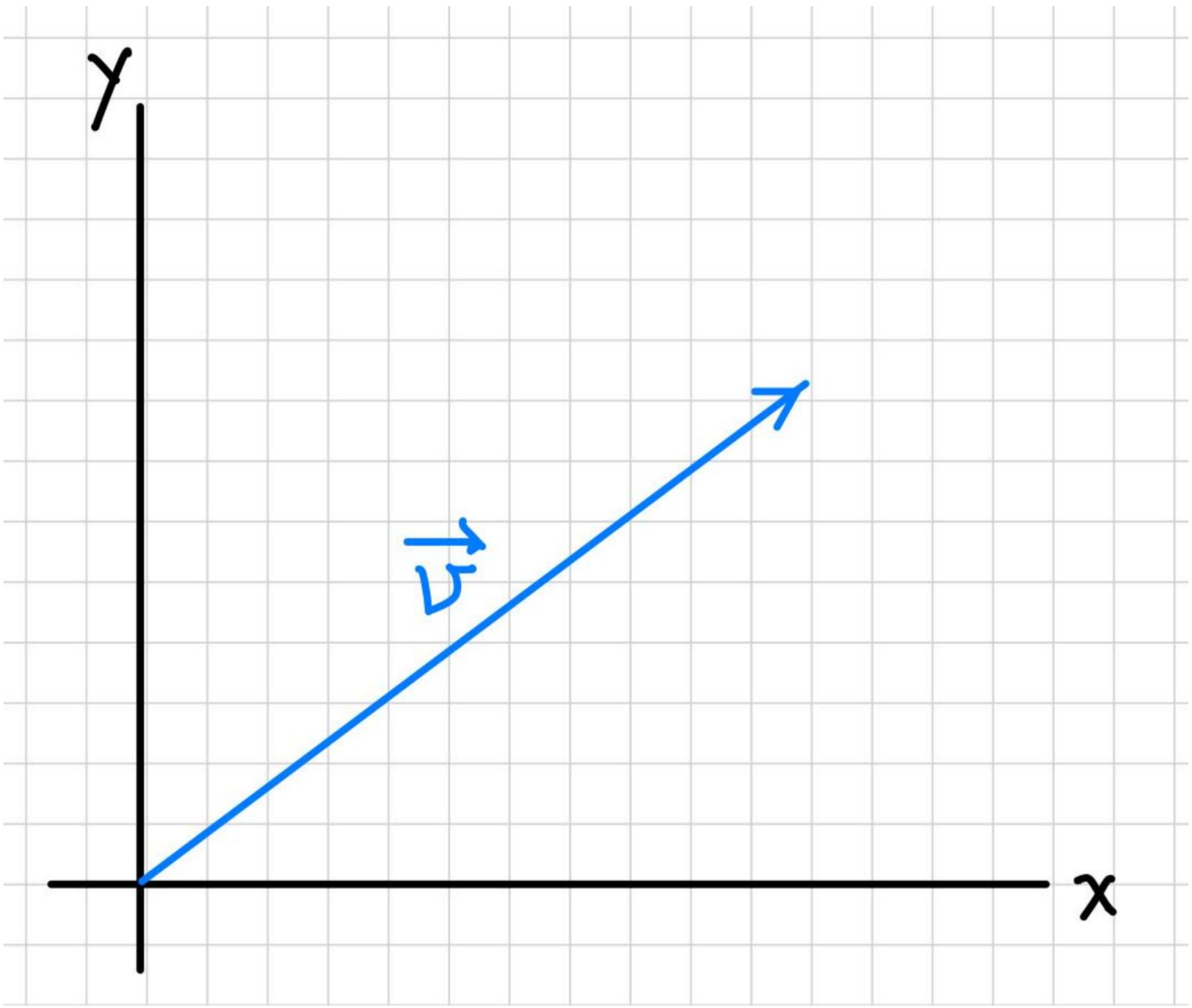
What is a vector?

- A vector is a number that has a direction.
- Recall speed is a scalar, but what if I told you my speed but also that I was driving northeast?
- In the plot,
  - Magnitude: 50 mph
  - Direction: Northeast



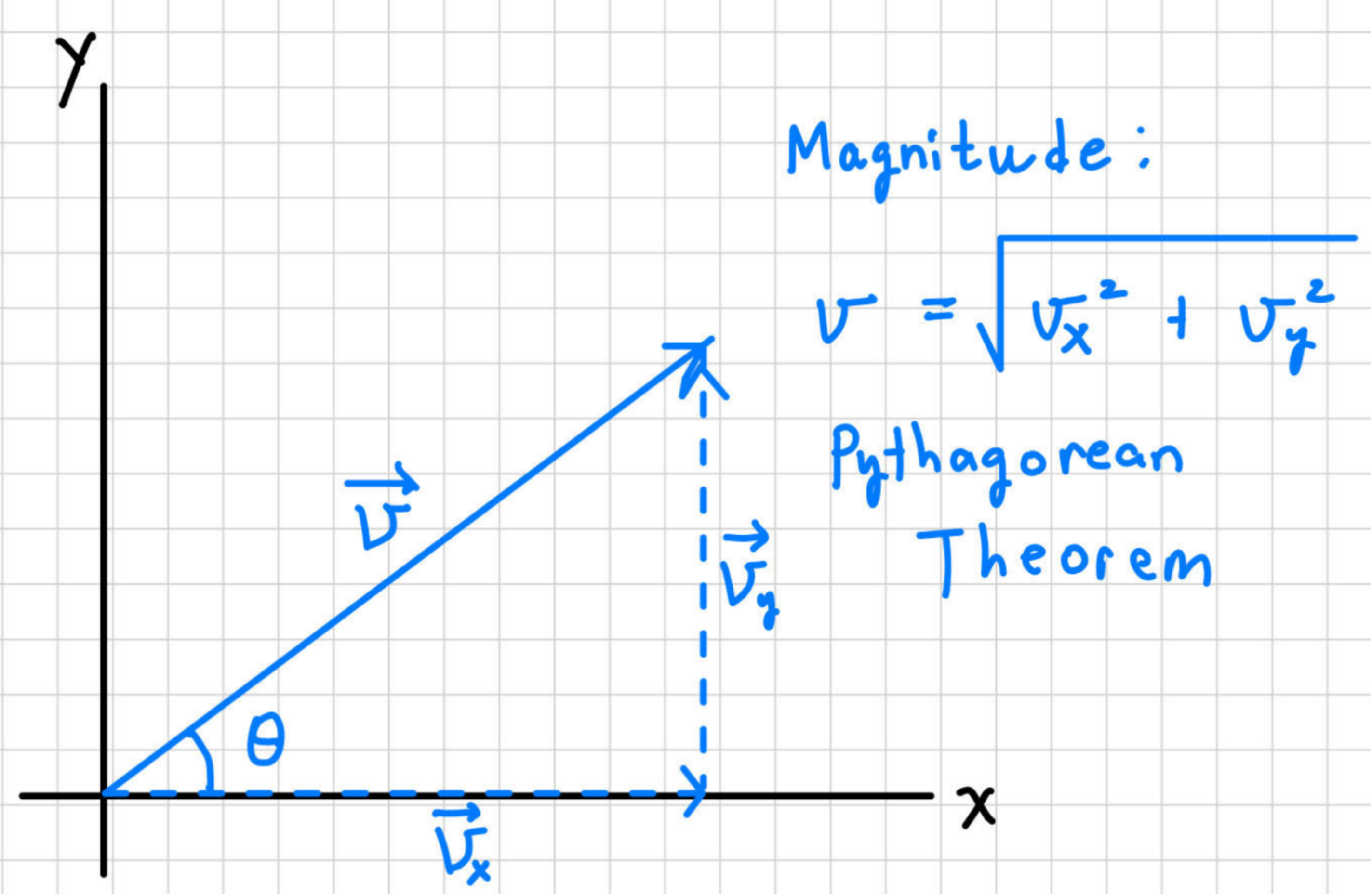
Vectors

- Generalize to x and y
  - Could be N, S, E, W
  - Could be up, down, left, right
- Vectors are often represented $\vec{v}$ or **v**
- Magnitude:
  - |**v**|, v, $|\vec{v}|$



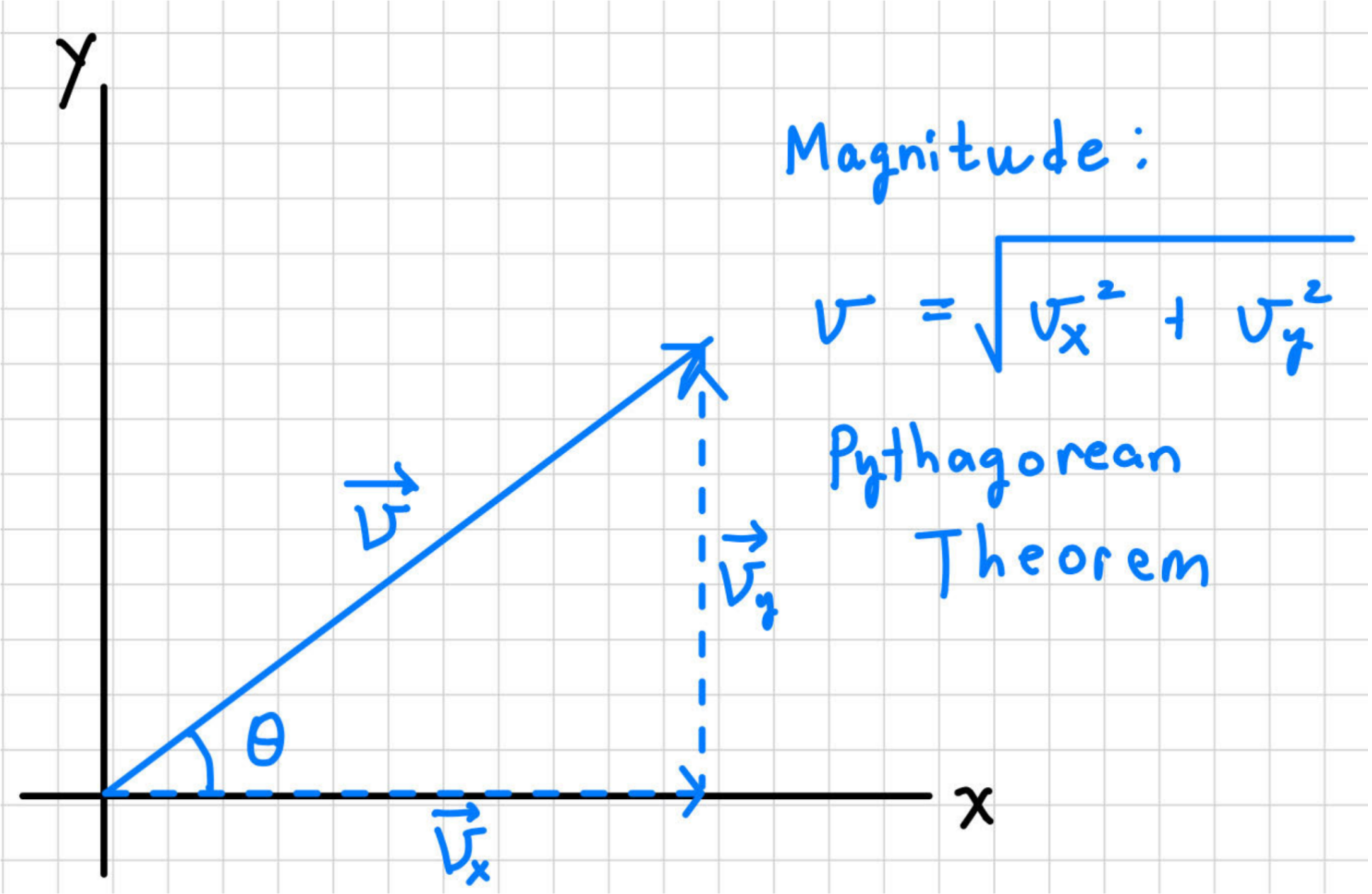
Vector Decomposition and Magnitude

- We can decompose a vector into its x and y components. We notate those with the subscripts x or y.
- Notice that the components are also vectors – they have magnitude and direction!
- They form a triangle – so using Pythagorean theorem we can find the magnitude, v.
- What if you knew that someone had a velocity in the x direction of 5 mph and in the y direction also 5 mph?



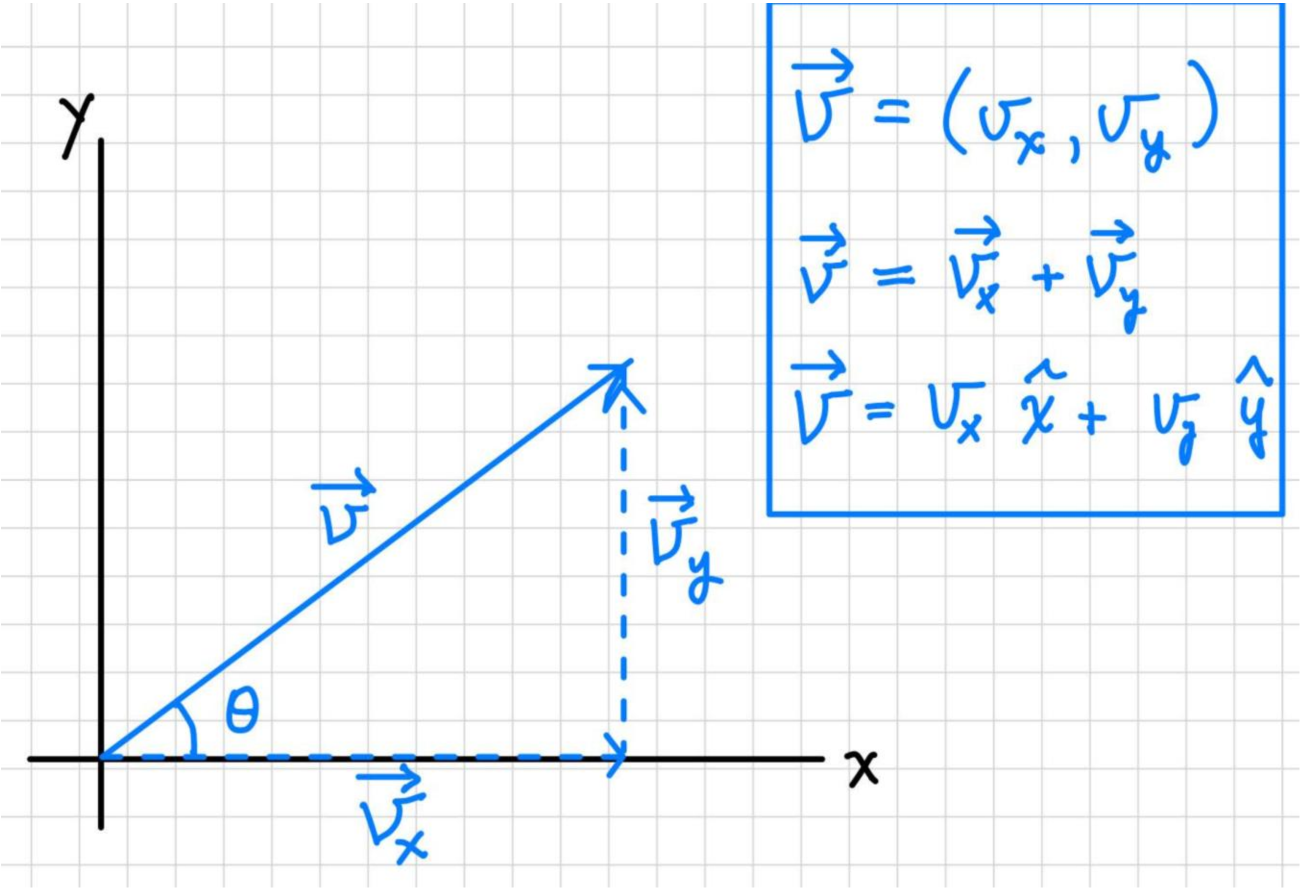
Team Activity 1.2

- What is the magnitude of a vector with x and y components of 5 m/s and 16 m/s respectively?



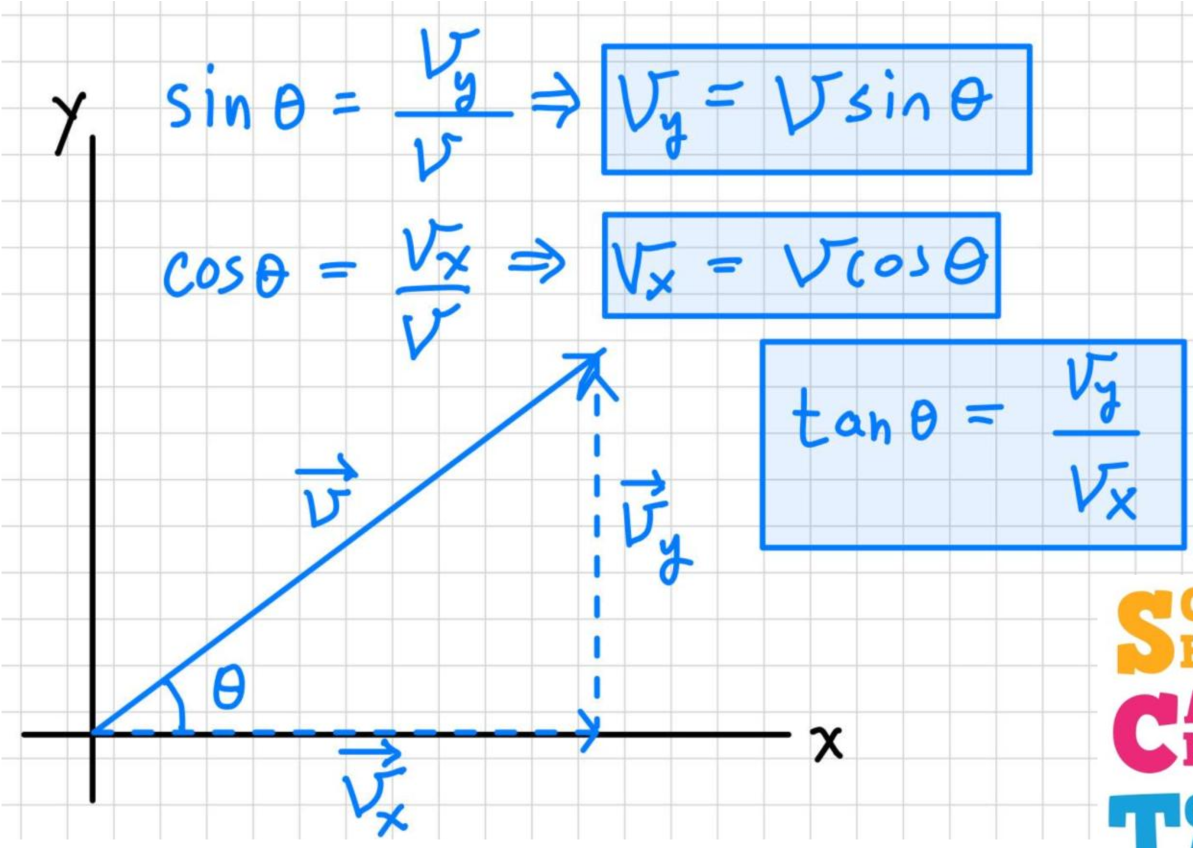
Vector Expressed As Components

- There are a variety of ways that you might see a vector expressed components.
    - As coordinates $\vec{v} = (v_x, v_y)$
    - As a sum $\vec{v} = \vec{v}_x + \vec{v}_y$
    - Or as a sum with direction encoded with new notation, $\vec{v} = v_x\hat{x} + v_y\hat{y}$, where $\hat{x}$ and $\hat{y}$ represent the x direction and y direction respectively.



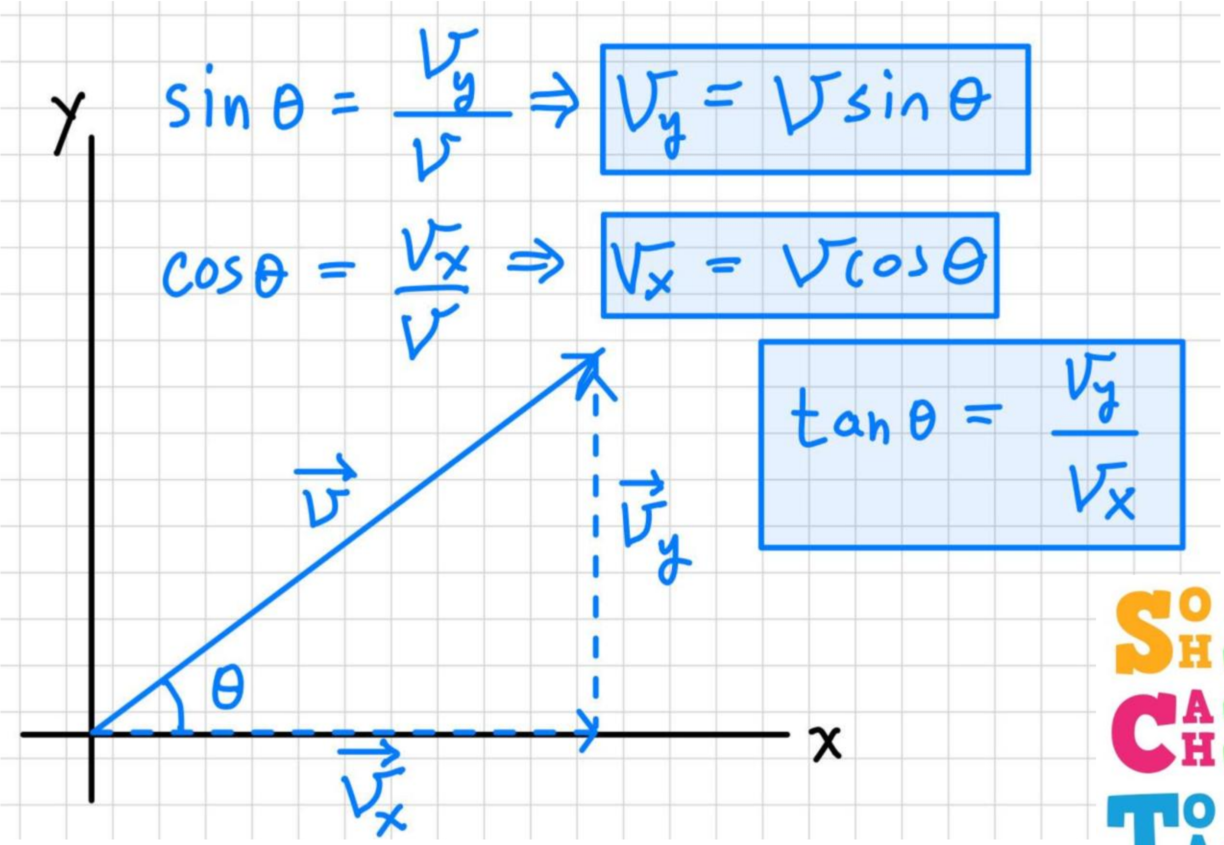
Direction of a Vector

- Earlier we gave an example of a vector, 50 mph northeast.
  - This is rather vague as there are 90 degrees of northeast.
  - Instead let's represent direction as an angle from the x axis.
- In the triangle in the diagram,
  - the hypotenuse is $\vec{v}$
  - Opposite to the angle, is $\vec{v}_y$
  - Adjacent to the angle is $\vec{v}_x$



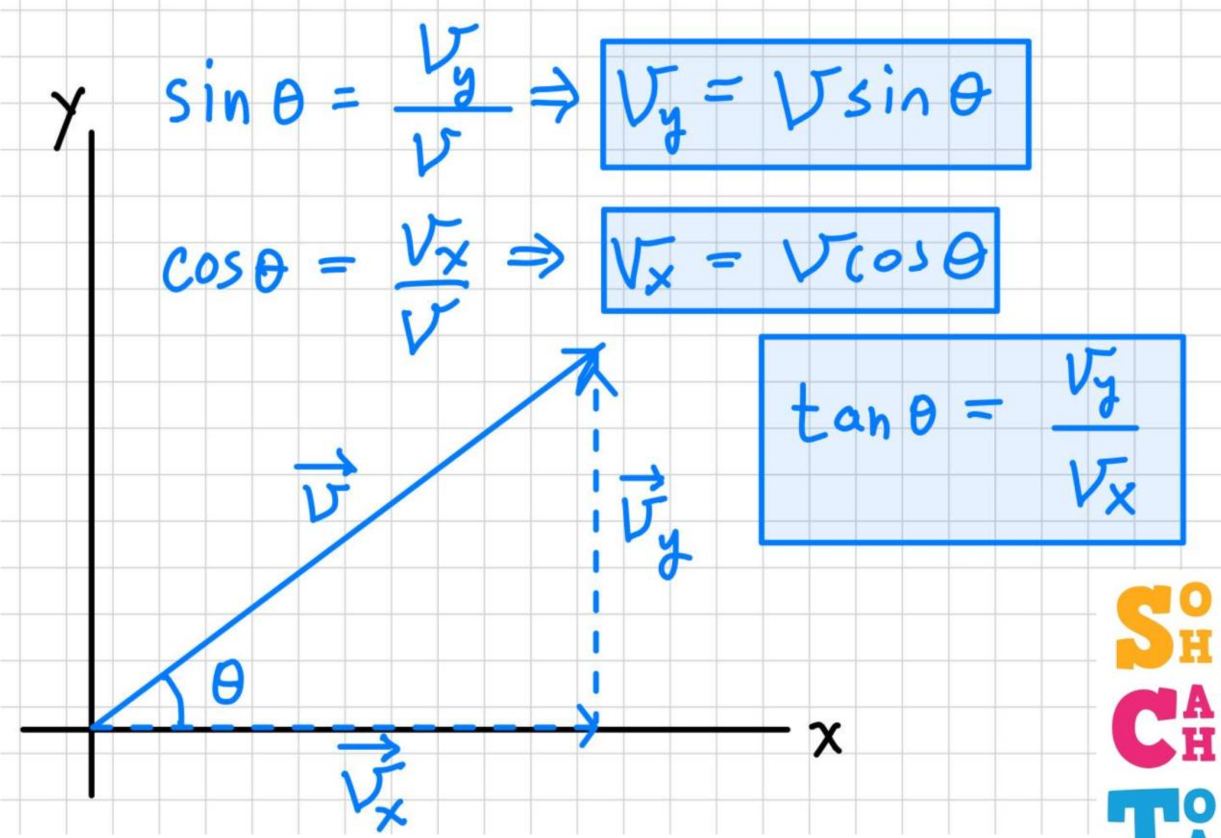
Team Activity 1.3

- Sally is travelling northeast. Her speed is 50 mph at an angle of 45 degrees from the east axis. What are the x and y components of her speed?



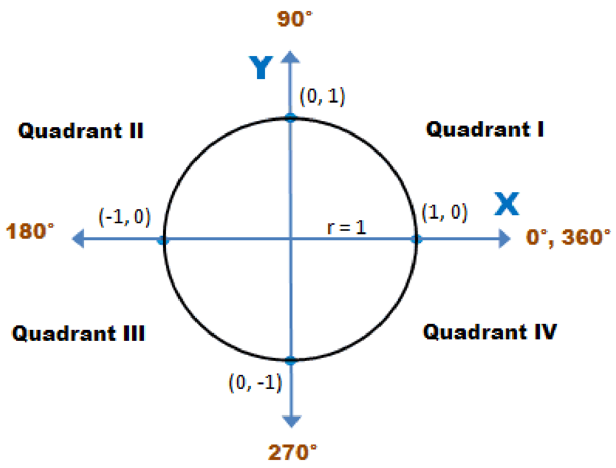
Team Activity 1.4

- Sally is travelling northeast. The x component of her speed is 10 mph and the y component is 20 mph. What angle from the x axis is her direction?

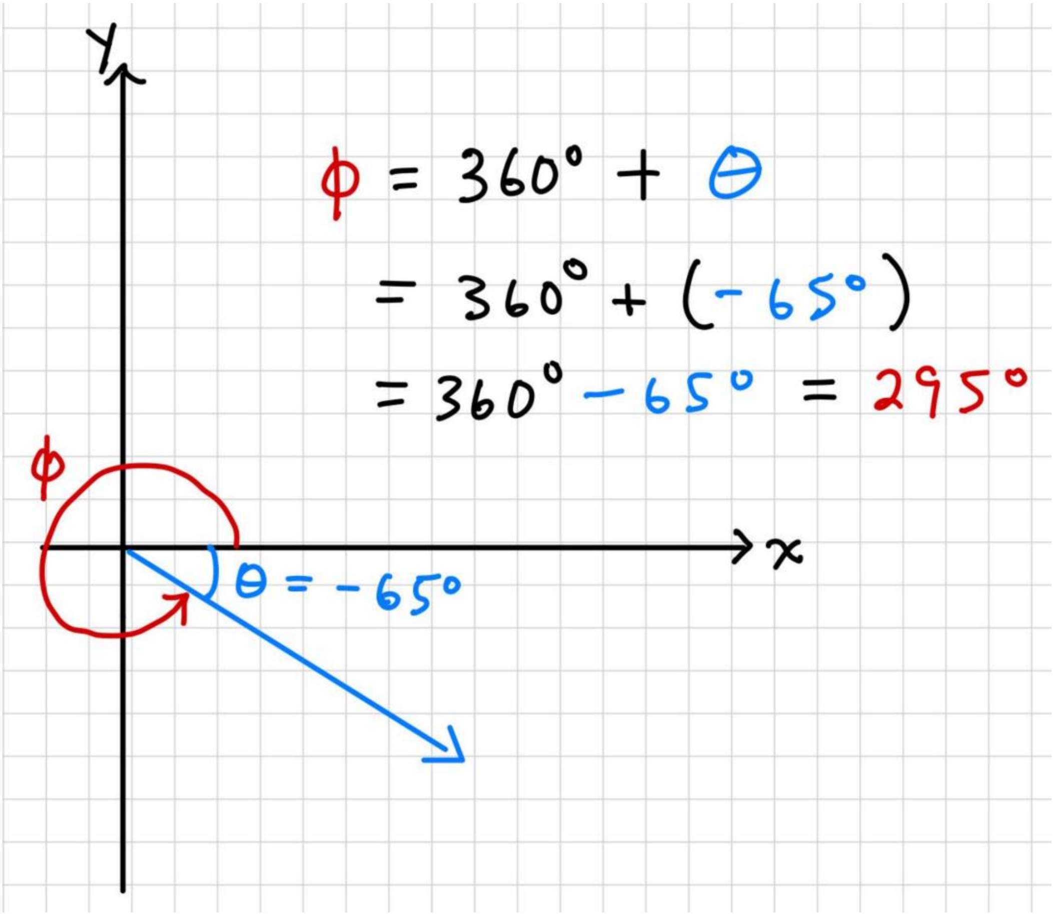


Angle Measurement Depends on Reference Direction

- Sometimes you might encounter a problem that tells you that the direction of a vector is 65 degrees below the x axis or -65 degrees.
- To represent that as an angle that is measured from the axis in the normal counterclockwise direction,
    - $\varphi = 360^o + \theta$

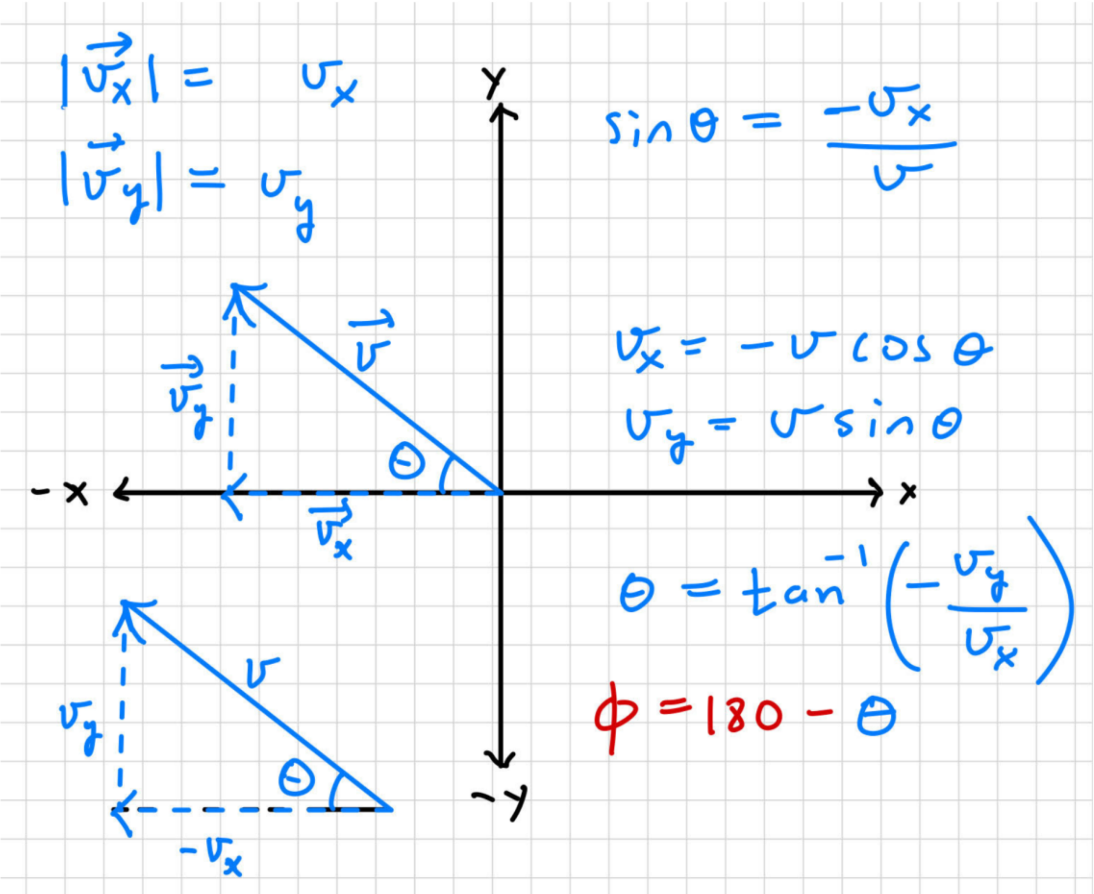


- **Why 360 degrees?** It's the smallest angle, measured counterclockwise from the x-axis, that is greater than ϕ.
- What would ϕ if my vector was in quadrant III measured from -y?
- Quadrant II measured from -x?



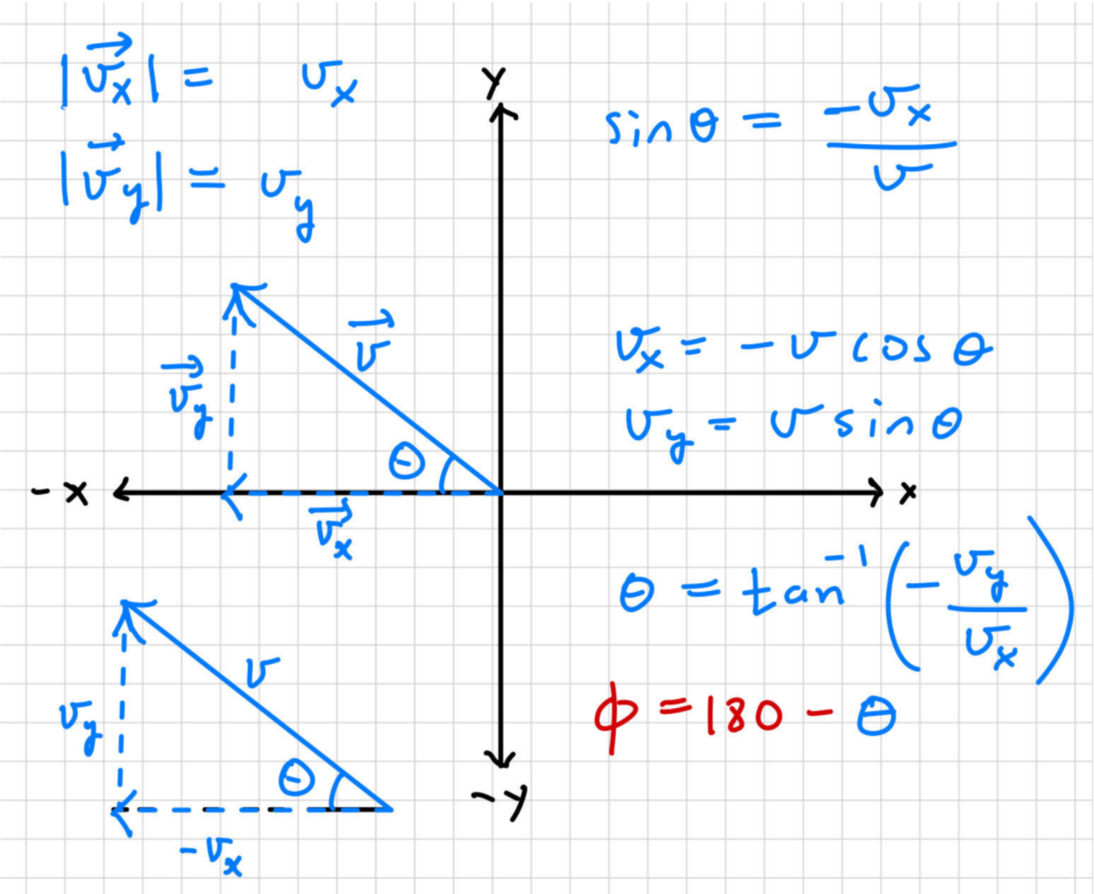
The Almighty Triangle

- Rather than try to use trigonometric identities by converting our angle as on the previous slide
  - First construct your vector decomposition triangle with the given angle.
  - For example, the vector to the right has an x component of velocity that points toward negative x.
    - We construct our triangle knowing that $\vec{v}_x = -v_x\hat{x}$
    - We use our trigonometric identities but now with $-v_x$
    - And once done, if necessary, give our angle from the positive x axis in the counterclockwise direction



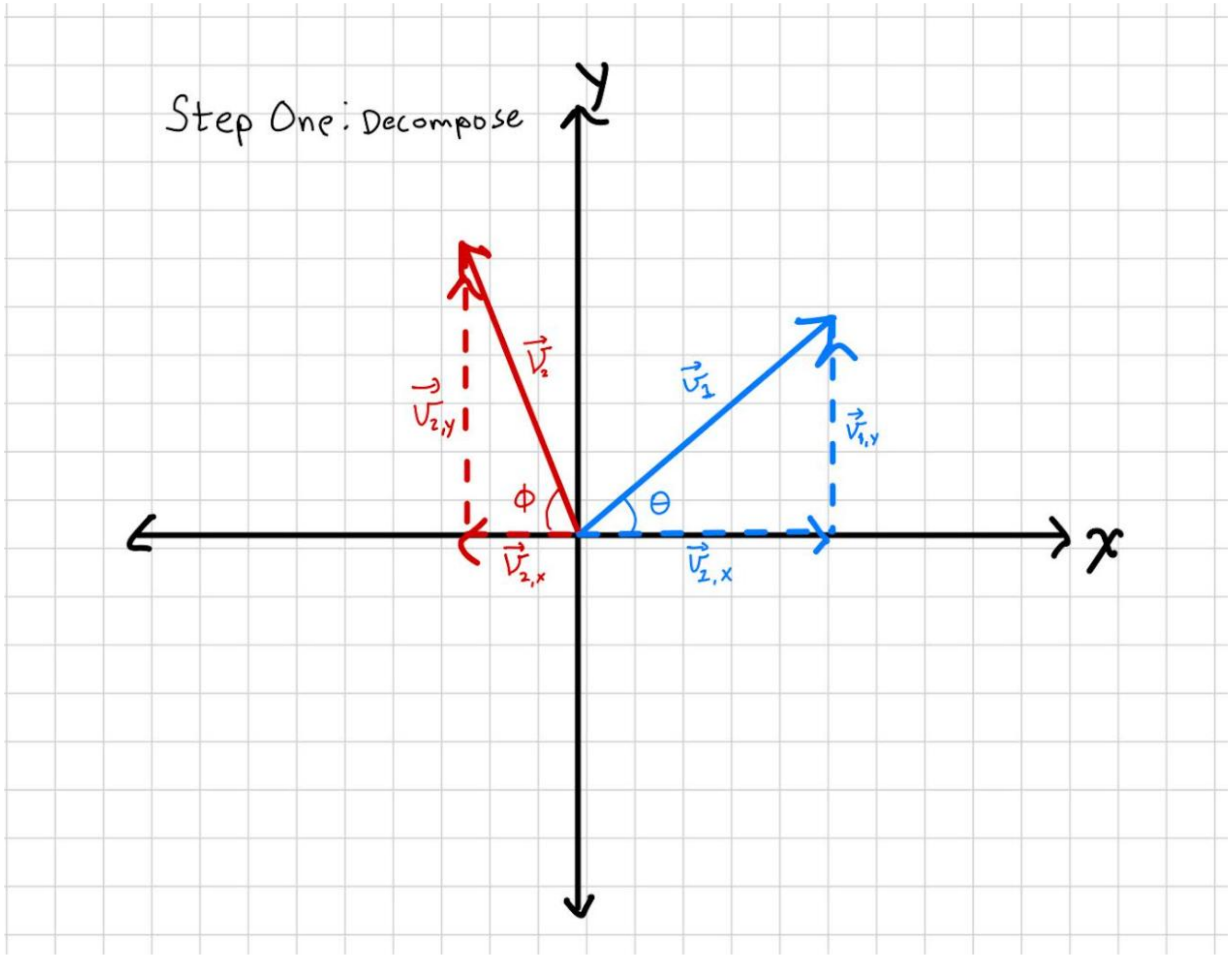
Team Activity 1.5

- Sally is driving 50 mph in the northwest direction. Given her angle from the westward direction as 45 degrees, what are the x and y components of her velocity, and her angle as measured from the eastward axis. Use a coordinate system where North is positive y, South is negative y, East is positive x, and West is negative x.



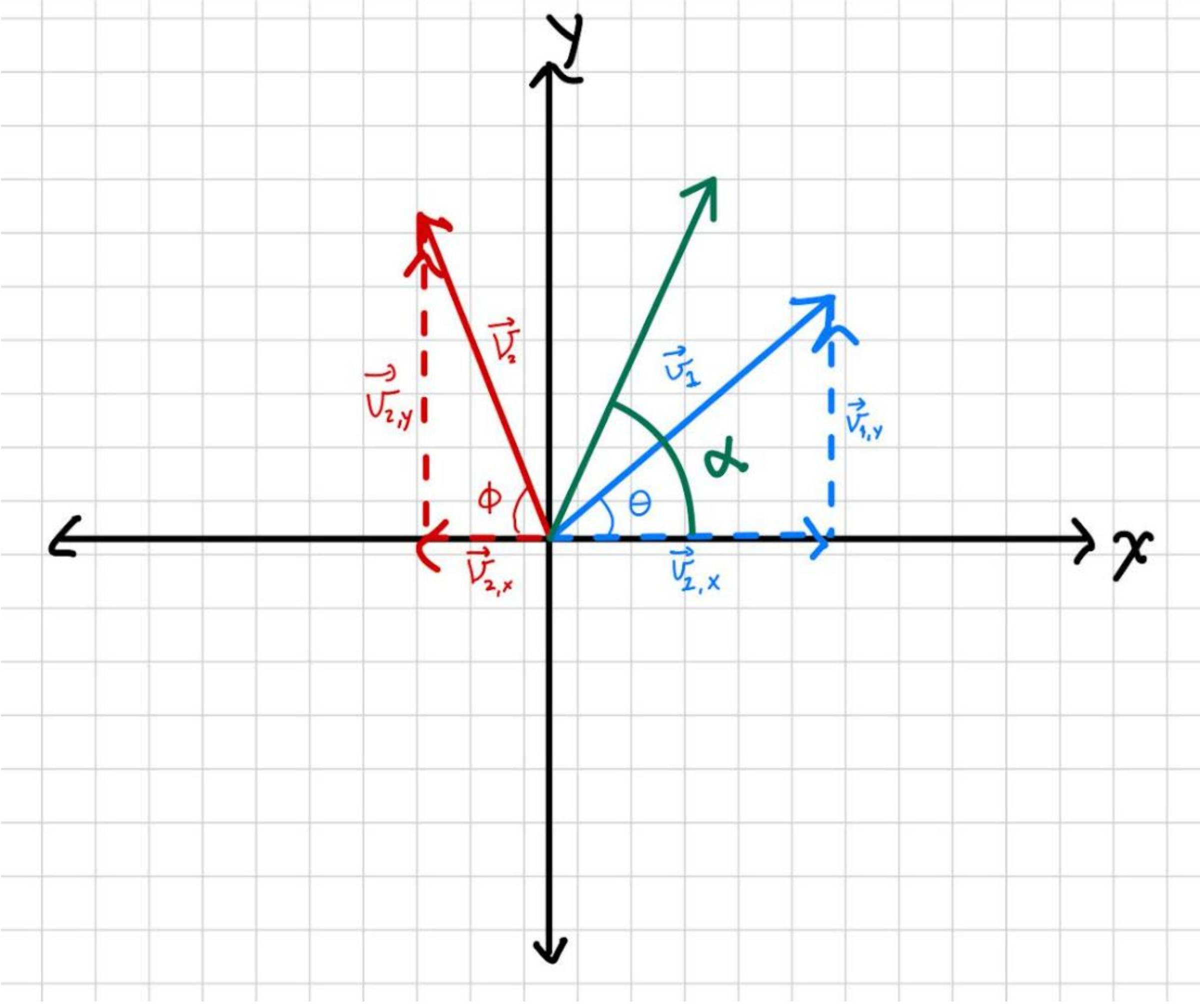
Vector Addition

- Usually, we will have more than one vector, and we will want to find the resultant vector – that is the vector that results from adding the two vectors together.
- Each vector has its own magnitude, direction, and angle.
- The first step is to decompose the vectors into their x and y components.



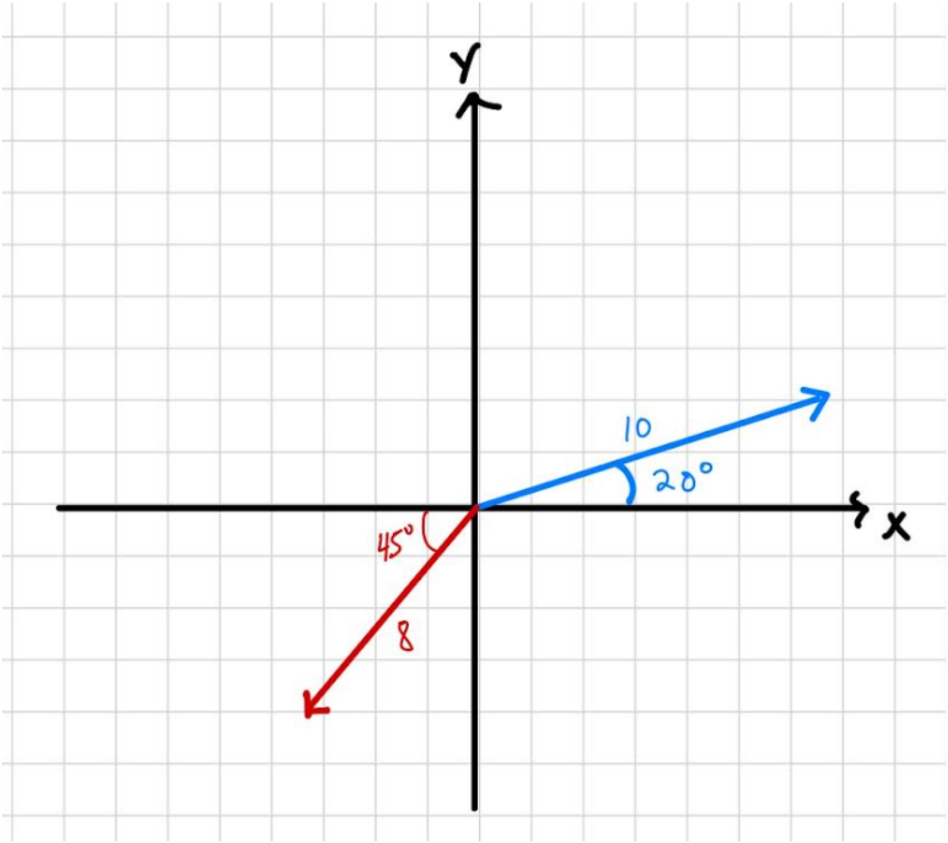
Vector Addition

- Now we consider each triangle separately. Use the trig identities to figure out what each component is.
  - Red Vector
    - $\sin\varphi = \frac{v_{2,y}}{v_2} \rightarrow v_{2,y} = v_2 \sin\varphi$
    - $\cos\varphi = \frac{v_{2,x}}{v_2} \rightarrow v_{2,x} = -v_2 \cos\varphi$
  - Blue Vector
    - $\sin\theta = \frac{v_{1,y}}{v_1} \rightarrow v_{1,y} = v_1 \sin\theta$
    - $\cos\theta = \frac{v_{1,x}}{v_1} \rightarrow v_{1,x} = v_1 \cos\theta$
- Now we can just add the components together, once for x and once for y.
  - $\hat{x}$: $v_x = v_{1,x} + v_{2,x} = v_1\cos\theta - v_2\cos\varphi$
  - $\hat{y}$: $v_y = v_{1,y} + v_{2,y} = v_1\sin\theta + v_2\sin\varphi$
- Now use the Pythagorean theorem to get the magnitude
  - $v = \sqrt{(v_1\cos\theta - v_2\cos\varphi)^2 + (v_1\sin\theta + v_2\sin\varphi)^2}$
- Now find the resultant angle: $\alpha = \tan^{-1}\left(\frac{v_y}{v_x}\right)$



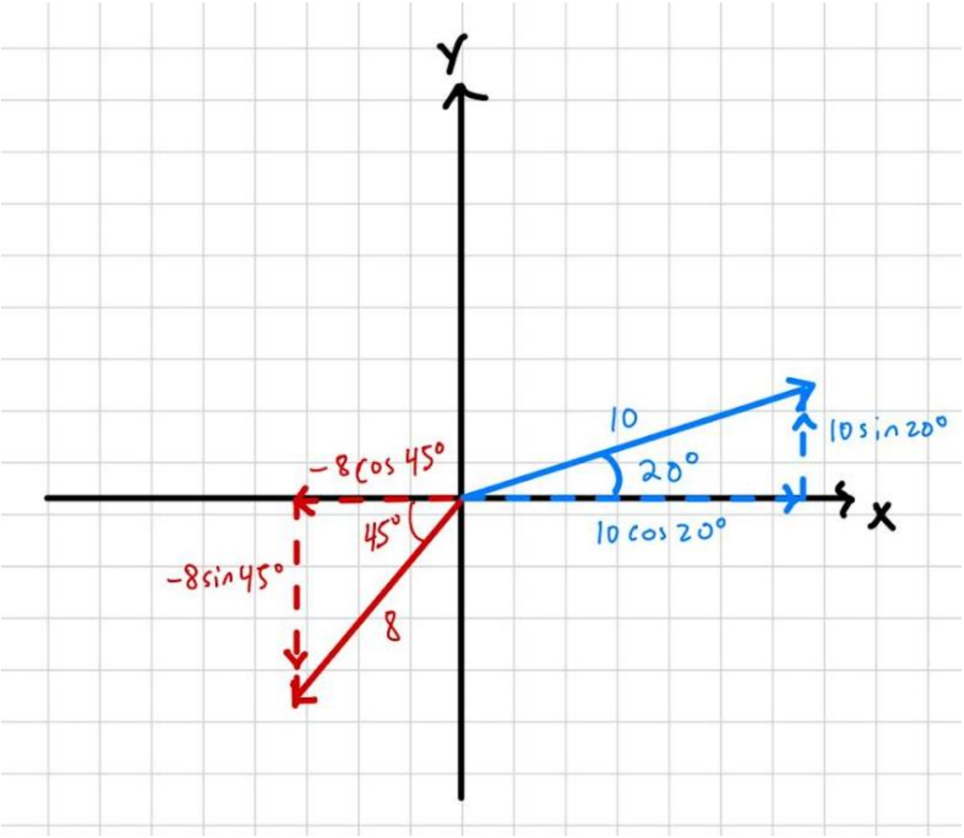
Example: Vector Addition 1/3

- Two vectors,
  - Vector 1: magnitude 10, 20 degrees counterclockwise from x.
  - Vector 2: magnitude 8, 45 degrees counterclockwise from negative x.
- The task: Find the resultant vector!



Example: Vector Addition 2/3

- Step One: Decompose into x and y components
  - Notice that x and y components of the red vector are negative.



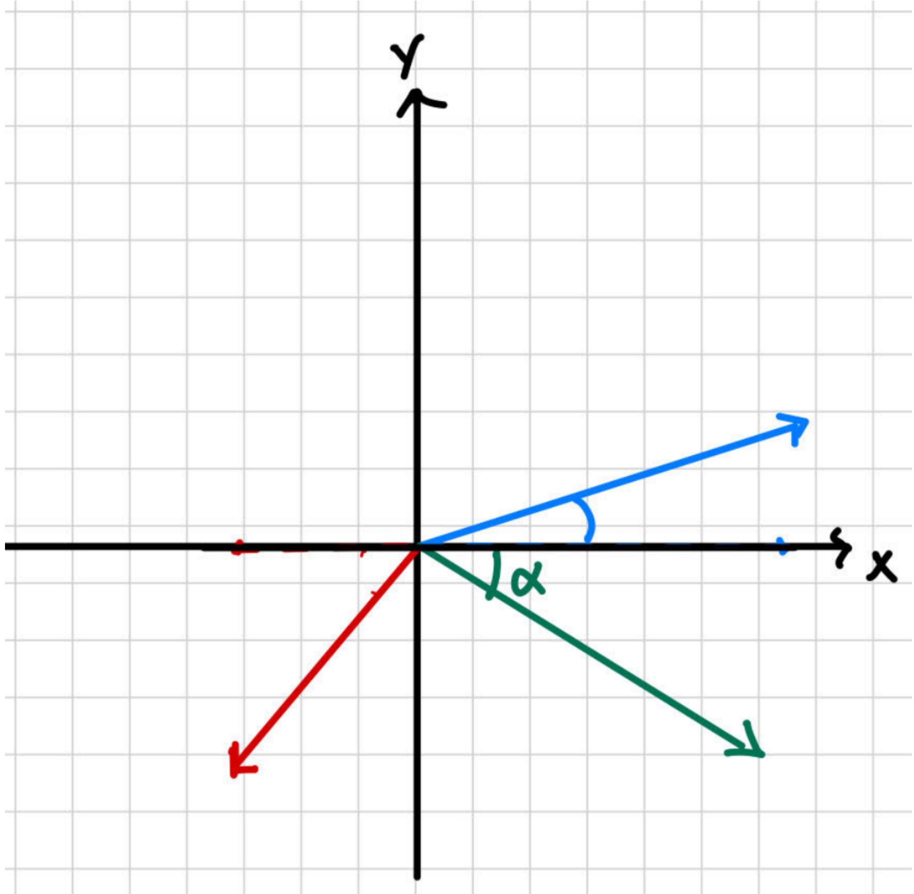
Example: Vector Addition 3/3

- Step One: Decompose into x and y components
  - Notice that x and y components of the red vector are negative.
- Step Two: Add your x and y components
  - X: $v_x = 10\cos 20^o - 8\cos 45^0 = 3.740$
  - Y: $v_y = 10\sin 20^o - 8\sin 45^o = -2.237$
- Step Three: Find the magnitude of the resultant vector.
  - $v = \sqrt{v_x^2 + v_y^2} = \sqrt{3.740^2 + 2.237^2} = 4.36$
- Step Four: Direction
  - First figure out which quadrant it is in. Positive x and negative y means that it is quadrant IV. So, the angle is measured from the positive x axis in the clockwise direction.

$$\alpha = \tan^{-1}\frac{v_y}{v_x} = \tan^{-1}\left(\frac{-2.237}{3.740}\right) = -31^o$$

Or

$$\vartheta = 360^0 - 31^o = 329^O$$



Team Challenge

- Given the two vectors shown in the plot,
  - Draw the component vectors for each vector.
  - Use trigonometry to find the magnitudes of the components for each vector.
  - Find the x and y components of the resultant vector.
  - Find the magnitude of the resultant vector.
  - Which quadrant is the resultant vector in?
  - Find the resultant angle and indicate which axis it is measured from.
  - Check your answer with me.
  - Feel free to go home after, and then come back for lab at 1pm.