

Lecture 1

Introduction to Measurement - SI system

Dimensional Analysis / Unit Analysis

Unit Conversions

Vectors and Mathematics

International System of Units (SI)

→ Table 1.1, p.5

The Seven Base Units

What is cool about the metric system is that unit conversions are easy. You just have to move decimal places.

How many centimeters in a meter? $100 \text{ cm} = 1 \text{ m}$

The key there is looking at the prefix centi -

Table 1.2, p.6 \Rightarrow centi - $10^{-2} = 1/100$

Therefore, a centimeter is one-one hundredth of a meter.

Memorize the Table for the quiz Thursday, know prefix and multiple.

Dimensional Analysis / Unit Analysis

→ Table 1.3, p.10

You can see the difference between Dimensions and Units.

Let's try an example of Unit Analysis.

Your friend gives you this formula: $x=at$. You have to figure out if it's right using Unit Analysis.

$$x = at$$
$$[L] = \frac{[L]}{[t]^2} \times [t] = \frac{[L][t]}{[t][t]} = \frac{[L]}{[t]}$$

$$[L] \neq \frac{[L]}{[t]}$$

Just by using the dimensions we can see that the formula can't be correct!

Using Dimensional Analysis we can figure out the correct units of an answer.

For Example:

You're given the density of water to be 1000 kg/m^3 . Is this reasonable?

What are the units of density? The formula is: $\rho = \frac{m}{V}$

mass(m) has units of kg

volume(V) has units of $\text{m}^3 \Rightarrow$ density has units of kg/m^3

From this we can conclude that at least the units are reasonable.

Now for Unit Conversions:

How many inches in a foot?

How many inches in two feet?

You just did your first unit conversion.

$12 \frac{\text{in}}{\text{ft}} \Rightarrow$ this is your conversion factor

$2 \text{ ft} \Rightarrow \text{in}$

$$2 \text{ ft} \times \frac{12 \text{ in}}{\text{ft}} = 24 \text{ in}$$

Notice how you align the conversion factor so that the feet cancel and the inches take their place.

Significant Figures (p. 18)

When you do an experiment and take measurements, indicating the error of those measurements is very important. The significant figures in any measurement are the digits that are known with certainty plus one that is uncertain.

Measurement Demo:

Use a ruler to measure a pencil. We can measure the pencil down to the millimeter scale, so our measurement should have 3 or 4 significant figures. Take 3 measurements and do the average. Measure a second pencil and add the two measurements together to see how long they both are.

Significant Figures in Calculations:

1. When multiplying and dividing quantities, leave as many significant figures in the answer as there are in the quantity with the least number of significant figures.

2. When adding or subtracting quantities, leave the same number of decimal places (rounded) in the answer as there are in the quantity with the least number of decimal places.

There are also some rules for how to treat zeros in numbers. You'll be responsible for knowing the rules for significant figures - being careful on homework and exams.

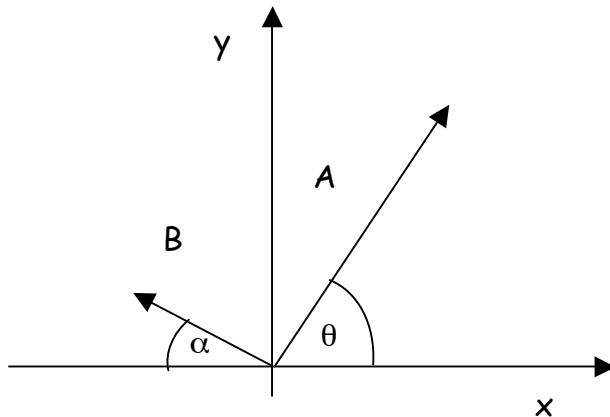
Practice with significant figures (5-10 min)

Vectors

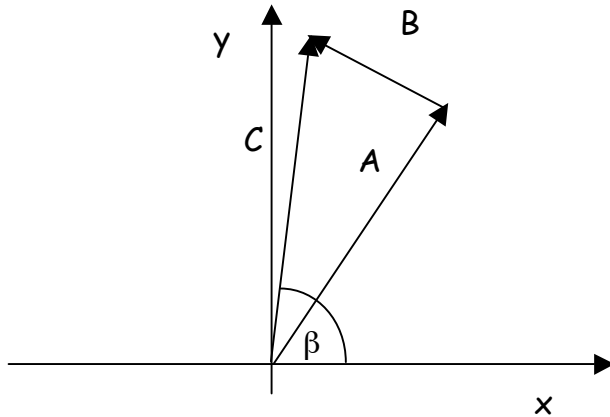


In physics, we have quantities that have both a magnitude and direction, like velocity. When we talk about a velocity, we have to specify how big it is and which direction it has. For instance, 30mph to the north. We can specify this velocity with a directed arrow. The length of the arrow represents the size of the velocity (30 mph) and the orientation indicates the direction (North).

One way to add vectors is graphically:



If we want to find $\mathbf{B} + \mathbf{A}$, we need to make a vector chain. Let's call the resultant vector \mathbf{C} .

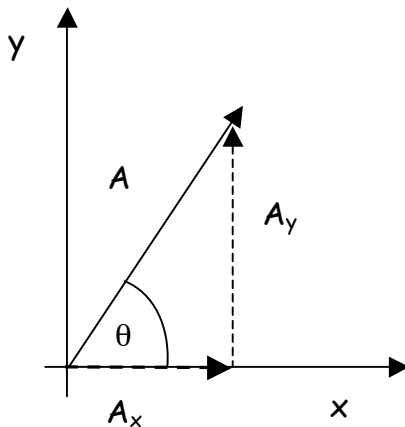


You draw the resultant vector from the tail of the first vector to the head of the last vector. Then you can just take a ruler and measure how long the vector **C** is and measure the angle with respect to the x-axis.

Again the steps are:

- 1) Make a vector chain.
- 2) Draw the resultant vector from the tail of the first to the head of the last.
- 3) Measure the length and angle of the resultant vector.

Sometimes we want to add vectors, and there are several ways to do this. Another way to add vectors is by using components. For this we need to specify an xy coordinate system.



We start with a vector **A**. Notice the notation, capital letter with arrow over it. This is important. What we can do with the vector is break it down into components parallel to the y-axis and x-axis. If we look at this like a right triangle, we can use trig functions to find these components.

Let's recall the trig functions we'll need:

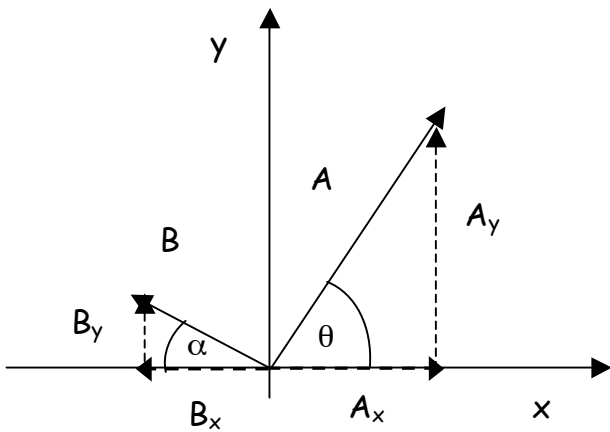
$$\sin \theta = \frac{\textit{opposite}}{\textit{hypotanuse}} \quad \cos \theta = \frac{\textit{adjacent}}{\textit{hypotanuse}} \quad \tan \theta = \frac{\textit{opposite}}{\textit{adjacent}}$$

Now we can find the components:

$$\sin \theta = \frac{A_y}{|A|} \Rightarrow A_y = |A| \sin \theta$$

$$\cos \theta = \frac{A_x}{|A|} \Rightarrow A_x = |A| \cos \theta$$

So let's try to add another vector to **A**.



We'll add **B** to **A** by finding the components of **B** and adding them to the components of **A**.

$$\sin \alpha = \frac{B_y}{|B|} \Rightarrow B_y = |B| \sin \alpha$$

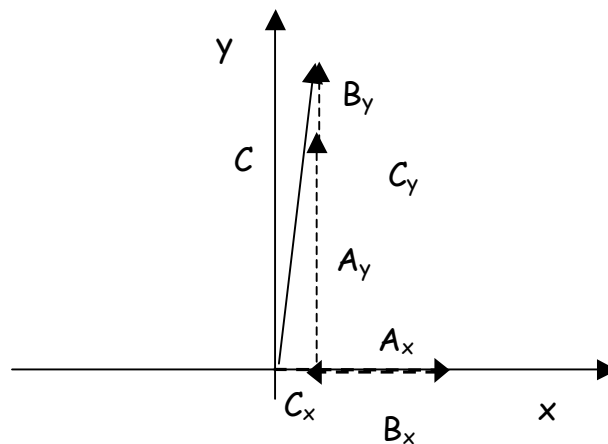
$$\cos \alpha = \frac{B_x}{|B|} \Rightarrow B_x = -|B| \cos \alpha$$

Notice the negative sign on **B_x**. The **B** vector points in the negative x direction, so its x-component is negative.

Now we can add the components to get **A+B**. Call this vector **C**.

$$C_y = A \sin \theta + B \sin \alpha$$

$$C_x = A \cos \theta - B \cos \alpha$$



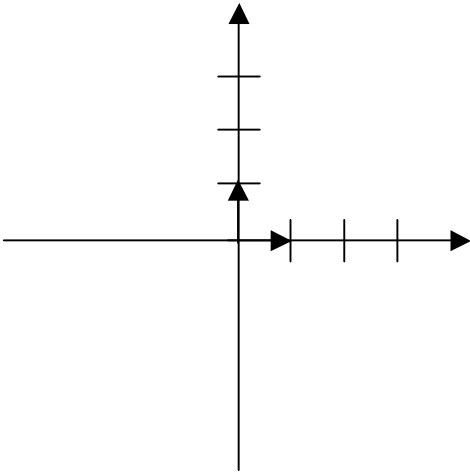
Finally we can figure out the magnitude and direction of **C**.

$$|C| = \sqrt{C_x^2 + C_y^2}$$

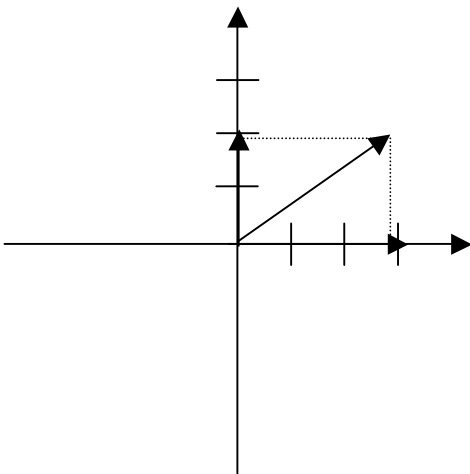
$$\beta = \tan^{-1}\left(\frac{C_y}{C_x}\right)$$

This first formula comes from the Pythagorean Theorem. Recall that for a right triangle the two legs squared and added together equal the hypotenuse squared. The second comes from the definition of tangent - $\tan = \text{opposite over adjacent}$.

There's one other way to express vectors. Using unit vectors: \hat{x} and \hat{y} . These are vectors that are each 1 unit long and point in the x direction and y direction respectively.



You can express a vector in terms of these vectors. For instance we can draw the vector $3\hat{x} + 2\hat{y}$ and figure out its magnitude and direction.



$$\text{magnitude} = \sqrt{3^2 + 2^2} = 3.61$$

$$\text{direction} = \tan^{-1}\left(\frac{2}{3}\right) = 33.7^\circ \text{ wrt } x\text{-axis}$$

Vector Practice Worksheet (20~30 min.)