Physics Notes

Week of Aug 6-10

The Nature of Science

What is science?

What is science?

A method for increasing our knowledge about the physical world.

- Characterized by its reliance on experimental evidence and its openness to revision in light of new evidence
- Best method we have to increase *physical* knowledge
- Not the *only* source of knowledge

Old Model: "The Scientific Method"

The Scientific Method is an outdated way of describing the process of science

Science & Engineering Practices

Experimental Design

How do we make an experiment that gives us trustworthy results?

Experimental Design

Two students are investigating whether fertilizer will make a certain type of plant grow faster

Student A prepares two garden pots. One is given fertilizer and the other is not. Other than that, the two pots are kept the same (same amount of water, sunlight, etc.)

Student B prepares two pots, one with fertilizer and the other without. The pots also get different amounts of water and sunlight.

Experimental Design

- To test a hypothesis or answer an investigation question, we must know what is causing the effects of an experiment
- We do this using a **controlled experiement**

Experimental Variables

- An experimental variable is any characteristic of an experiment set up that can be *varied*, or changed

- They come in three categories

Experimental Design

- When designing a controlled experiment, you need to have one **independent variable** that you vary. As the independent variable changes, you measure the resulting change in the **dependent variable**. All other variables are **controlled variables**, meaning they stay the same.

Independent Variable

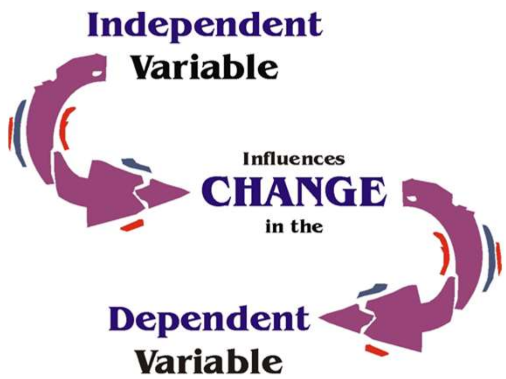
- The variable that you vary during the experiment
- You decide what values the independent variable will take
- There should only be one in your experiment!

- In our example experiment, the independent variable was the amount of fertilizer each pot received

Dependent Variable

- The variable that you observe to see how it changes as you change the independent variable
- Called dependent variable because its value will *depend* on the value of the independent variable
- There should only be one in your experiment

- In our example experiment, the dependent variable was the height of the plants

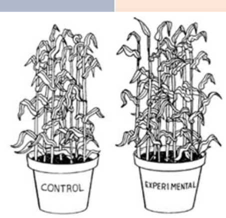


Controlled Variables

- If we vary other variables besides the independent variable, we will have no way to know what is causing the change of the dependent variable
- Therefore, all other variables besides the independent variable should be kept constant (or controlled)

- In our example experiment, Student A controlled these variables: amount of sunlight, amount of water, etc.

Control group	Experimental group
• 5 plants • 100 grams soil in each pot • 20 grams of water each day • Plants get 12 hours of light and 12 hours of dark • No fertilizer added	• 5 plants • 100 grams soil in each pot • 20 grams of water each day • Plants get 12 hours of light and 12 hours of dark • 5 grams of fertilizer added



Another Example

Question: Will a football filled with helium travel farther than a football filled with just air?

- Independent: the type of gas in the football
- Dependent: how far the football travels
- Controlled: the air pressure in the ball, mechanical throwing device (same throw each time), both tests done at the same altitude

Measurement Errors

Why do we perform multiple trials in experiments?

Measurement Errors

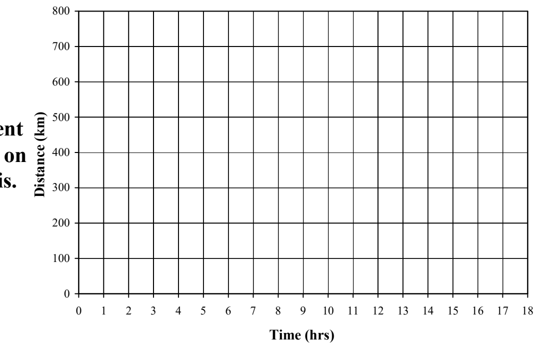
- Every individual measurement will have some amount of error
- Performing multiple measurements (trials) and averaging the values reduces the error and gives us a more accurate result

Accuracy vs. Precision

Graphing

Independent variable ("cause") is on the x-axis. Dependent variable ("effect" or response) is on the y-axis. X causes Y

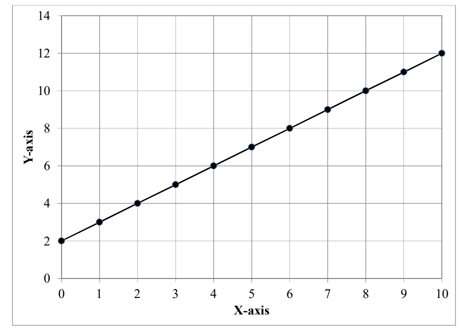
Dependent variable on the y-axis.



Independent variable on x-axis.

GRAPHS

- **Visual representations of data.**
- **Determine trends (changes, patterns)**



Relationships Between Variables

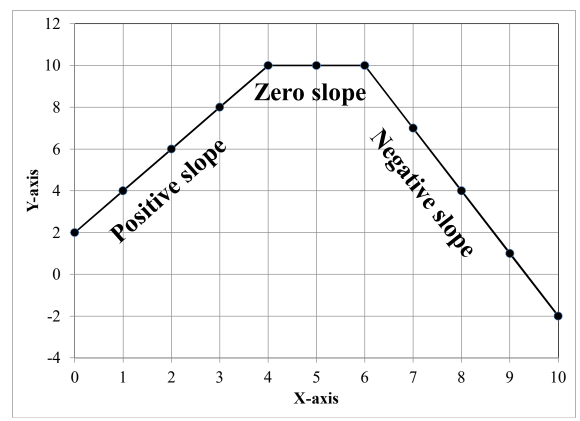
Proportional relationship: both variables change in the same direction

- As *x* increases, *y* increases
- As *x* decreases, *y* decreases

Inversely proportional relationship: the variables change in opposite directions

- As *x* increases, *y* decreases
- As *x* decreases, *y* increases

Identifying Slopes

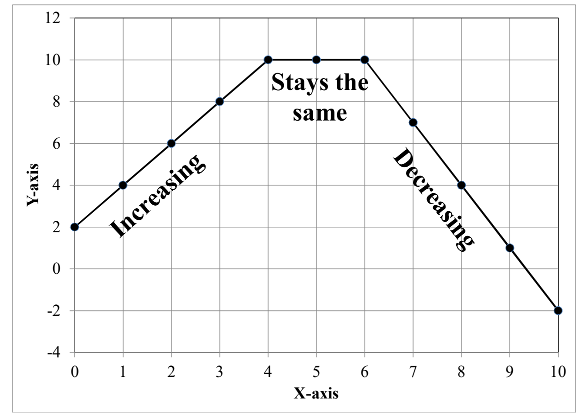


Positive slope: values of x increase, values of y increase.

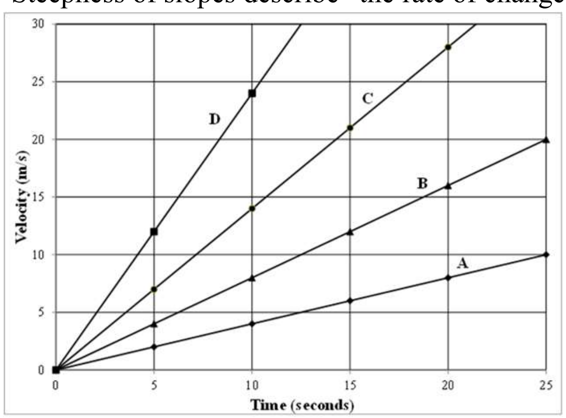
Negative slope: values of x increase, values of y decrease.

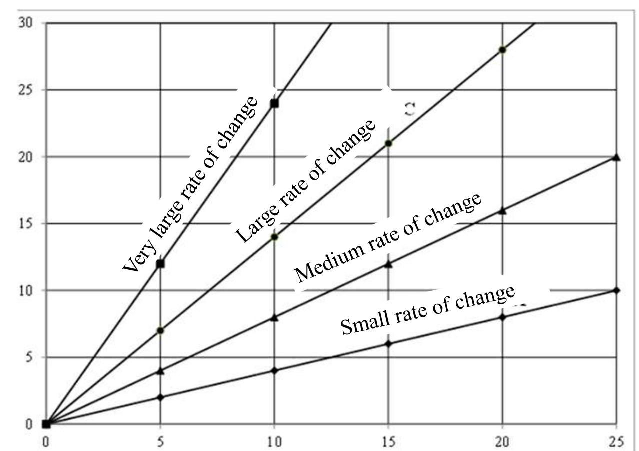
Slope of zero: values of x increase, values of y remain constant.

Identifying Slopes



Steepness of slopes describe “the rate of change”





Units & Unit Conversion

How do we describe our measurements?

What is a unit standard?

- A set of units of measurement that a group of people agree to use
- Allows them to communicate measurements to each other accurately

SI System

- Almost the entire world uses the **SI (*Systeme Internationale*) System**
  - Also known as the metric system
- ALL scientists use the SI System

What unit do we use to measure…

- …mass?
  - Kilogram (kg)
- …distance?
  - Meter (m)
- …time?
  - Second (s)

Prefixes

Prefix	Symbol	Scientific Notation	Decimal	Common Word
tera	T	10^{12}	1000000000000	trillion
giga	G	10^{9}	1000000000	billion
mega	M	10^{6}	1000000	million
kilo	k	10^{3}	1000	thousand
		10^{0}	1	one
milli	m	10^{-3}	0.001	thousandth
micro	µ	10^{-6}	0.000001	millionth
nano	n	10^{-9}	0.000000001	billionth
pico	p	10^{-12}	0.000000000001	trillionth

How to Convert Units

Called a **conversion factor**

1. Know the unit equivalence
2. Write the starting number and unit
3. Multiply by a fraction
   - Unit converting from goes on bottom
   - Unit converting to goes on top
4. Fill in the numbers in the fraction using the unit equivalence (step 1)
5. Do the multiplication to get your answer

How to convert units

Starting number & unit **x** Conversion factor = Final number & unit

- Conversion factor is a fraction.
- The fraction must be oriented where the **numerator has the units being converted *to*** and the **denominator has the units being converted *from***
- The starting units must cancel out with the denominator units in the conversion factor.

Convert 300 seconds into minutes.

- Converting from → seconds
- Converting to → minutes
- Conversion: 1 min = 60 seconds

Starting number & unit **x** Conversion factor = Final number & unit

$$300\,\text{s} \times \frac{1\,\text{min}}{60\ \text{s}} = 5.0\,\text{min}$$

Scalars & Vectors

Scalars & Vectors

In physics, we deal with two kinds of quantities: scalars and vectors

1. **Scalars**: only have magnitude
2. **Vectors**: have magnitude AND direction

Magnitude = size, amount, how much

Scalars

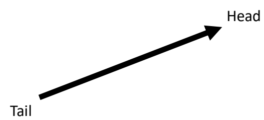
- Only have magnitude
- For example:
  - Temperature
  - Mass
  - Density
  - Time

Vectors

- Have magnitude AND direction
- For example:
  - Velocity
  - Acceleration
  - Force

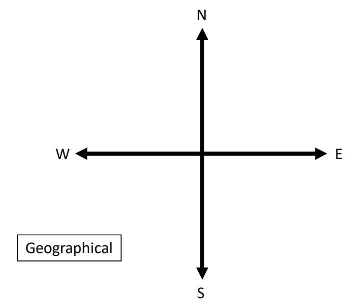
How do we represent vectors?

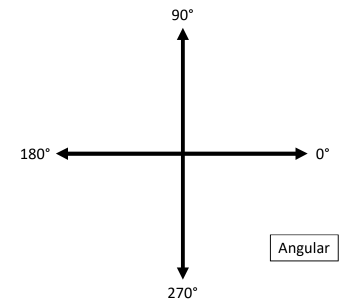
- In writing:
  - A bold letter: **v**
  - A letter with an arrow over it: $\vec{v}$
- Visually:



The length of the vector arrow corresponds to the magnitude of the vector

Frames of Reference





Signs

By convention, certain directions are considered positive (+) and others are considered negative (-)

Positive (+)
- North, East, up, right, 0°, 90°

Negative (-)
- South, West, down, left, 180°, 270°

Writing a Vector

- Give the magnitude (number and unit) AND the direction relative to a frame of reference
- For example:
  - 5 meters, N
  - 2 meters/second, 180°
  - 10 Newtons, SE

Adding Vectors (Along One Line)

To add two or more vectors that are directed along the same line (for example, North-South or East-West):

1. Give each vector's magnitude the proper (+) or (-) sign depending on the vector's direction
2. Add the magnitudes and signs together

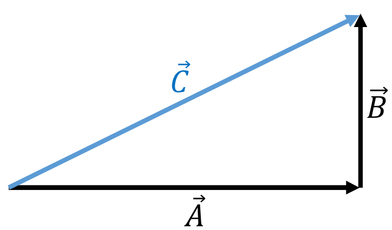
The sign of the sum tells you the direction of the resulting vector sum

Adding Vectors (In Perpendicular Directions)

To add two vectors that point in perpendicular directions (for example, one is East and the other is North), you must use the Pythagorean Theorem.

The two vectors you are adding make up the legs of a right triangle. The vector sum is the hypotenuse of the right triangle. Calculate the magnitude with

$$C = \sqrt{A^2 + B^2}$$



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

$$C = \sqrt{A^2 + B^2}$$