UNDERSTANDING THE COSMOS

There are more things in Heaven and Earth, Horatio, than are dreamt of in your philosophies.

-- William Shakespeare, *Hamlet*

Math Basics 101

Every scientific measurement always consists of 2 parts:

a number (*which represents magnitude or size*)

a unit

Numbers in science are meaningless without units!

Units provide the reference point to which all **like** measurements are compared.

What are **like** measurements?

distance, time, mass, temperature…

Fundamental Properties

- Any physical property in the universe that can be measured can be described by using 1 of 4 fundamental physics properties or by some combination of the 4.

4 Fundamental Physics Properties:

Length (*a measure of the amount of space in a given direction*)

Mass (*a measure of the amount of matter an object contains*)

Time (*a measure of the interval between events*)

Charge

Examples

- What fundamental property would you use to describe the size of this room?

  Length ➔ area *or* volume

- What color is the sky?

  What fundamental property would you use to describe the color blue?

  Length or time ➔ wavelength *or* frequency

Different colors have different wavelengths or frequencies.

Units are extremely important because they will always be associated with a unique property or concept.

The units associated with a particular property depends on the choice of measurement system.

- 2 Types of Measurement Systems
  - Imperial (English/British) System
    - ft-lb-s
  - SI or Metric System
    - mks*
      - Length – meter (m)
      - Mass – kilogram (kg)
      - Time – seconds (s)

**standard*

Units of Convenience

Fundamental units can be combined with themselves or other fundamental units to help describe or represent other physical phenomena. Units formed by a combination of the fundamental SI units are called units of convenience or derived units.

Ex.

Area (*length* * *length*) → m*m = m^2

Volume (*length* * *length* * *length*) → m*m*m = m^3

??? Density (ρ) (*??? / Volume*)

mass density (ρ=m/V) → kg/m^3

Unit Conversions

At times, it may become necessary to switch between measurement systems for better clarity or understanding.

Ex. How much money was Jesus betrayed for?

30 pieces of silver (Matt. 26:15)

How much is that in todays money?

Depends on which type of silver coin was used:

Tyrian shekel - $355

Ptolemaic tetradrachm - $92

Athenian tetradrachm - $441

Unit Conversions

Ex. Length

English System mks

feet *meter*

But $1\ ft \neq 1\ m$

➔

$1\ ft = .3048\ m$ or $1\ m = 3.281\ ft$

- What is 34 *m* in *ft* ?
  - Write down what you start w/ followed by a set of big parenthesis w/ a line in them

$$34\ \text{m}\left(\frac{\quad}{\quad}\right)$$

  - Place the number 1 & the current unit on bottom & the destination unit on top

$$34\ \text{m}\left(\frac{\text{ft}}{1\ \text{m}}\right)$$

  - Insert the appropriate conversion factor on top & then multiply

$$34\ \text{m}\left(\frac{3.281\ \text{ft}}{1\ \text{m}}\right) = 111.554\ \text{ft}$$

What is 100 *km/hr* in *ft/s*?

$$100 \text{ km/hr} \left(\quad \right)$$

$$100 \text{ km/hr} \left(\frac{\text{ft/s}}{1 \text{ km/hr}} \right)$$

$$100 \text{ km/hr} \left(\frac{0.911 \text{ ft/s}}{1 \text{ km/hr}} \right) = 91.1 \text{ ft/s}$$

Conversion Factors

Mass

1 gram = 10^{-3} kg
1 kg = 1000 g (equivalent weight = 2.2 lb)
1 u = 1.66 x 10^{-24} g = 1.66 x 10^{-27} kg
1 lb = 0.4536 kg
1 kg = 2.2 lb

Length

1 cm = 10^{-2} m = 0.394 in
1 m = 10^{-3} km = 1.09 yd = 3.28 ft
= 39.4 in = 6.215 x 10^{-4} mi
1 km = 1000 m = 0.62 mi = 3280 ft
= 1093.33 yd
1 in = 2.54 cm = 2.54 x 10^{-2} m
1 ft = 12 in = 30.48 cm = 0.3048 m
= 0.3333 yd = 1.894 x 10^{-4} mi
1 yd = 3 ft = 0.914 m = 5.682 x 10^{-4} mi
= 9.146 x 10^{-4} km
1 mi = 5280 ft = 1609 m = 1.609 km
= 1760 yd
1 pc = 3.26 ly = 2.05 x 10^{5} AU
1 AU = 1.499 x 10^{11} m
1 ly = 9.461 x 10^{15} m
1 pc = 3.086 x 10^{16} m

Volume

1 m^3 = 1000 L = 264 gal
1 L = 10^{-3} m^3 = 1.06 qt = 0.264 gal
1 ft^3 = 7.48 gal = 0.0283 m^3 = 28.3 L
1 qt = 2 pt = 0.946 L = 946 mL
1 gal = 4 qt = 3.785 L

Energy

1 joule = 0.738 ft-lb = 0.239 cal
= 9.48 x 10^{-4} Btu = 6.24 x 10^{18} eV
1 kcal = 4186 J = 3.97 Btu
= 0.00116 kWh
1 Btu = 1055 J = 778 ft-lb = 0.252 kcal
1 cal = 4.186 J = 3.97 x 10^{-3} Btu
= 3.09 ft-lb
1 ft-lb = 1.36 J = 1.29 x 10^{-3} Btu
1 eV = 1.60 x 10^{-19} J
1 kWh = 3.60 x 10^{6} J = 3413 Btu
= 860 kcal

Speed

1 m/s = 3.6 km/h = 3.28 ft/s
= 2.24 mi/h
1 km/h = 0.278 m/s = 0.621 mi/h
= 0.911 ft/s
1 ft/s = 0.682 mi/h = 0.305 m/s
= 1.10 km/h
1 mi/h = 1.467 ft/s = 1.609 km/h
= 0.447 m/s

Force

1 N = 0.225 lb
1 lb = 4.45 N
[Equivalent weight of 1 kg mass = 2.20 lb
or 9.80 N]

Pressure

1 atm = 14.7 lb/in^2 = 1.031 x 10^{5} N/m^2
= 30 in Hg = 76 cm Hg
1 bar = 100,000 Pa
1 millibar = 100 Pa
1 Pa = 1 N/m^2 = 10^{-2} millibar

Power

1 watt = 0.738 ft-lb/s = 1.34 x 10^{-3} hp
= 3.41 Btu/h
1 ft-lb/s = 1.36 W = 1.82 x 10^{-3} hp
1 hp = 550 ft-lb = 745.7 watts
= 2545 Btu/h

Time

1 h = 60 min = 3600 s
1 day = 24 hr = 1440 min = 8.64 x 10^{4}s
1 year = 365 days = 8.76 x 10^{3} hr
= 5.26 x 10^{5} min = 3.16 x 10^{7} s

The Dangers of Incorrect Measurements or Conversions

- [Magnitude]

  Ex. Prescription Drugs

  How much of a cancer curing pill would you take if more than 750 *mg* was fatal?

  100.0 *mg*

  1000 *mg*

  Magnitudes are important!

- [Units]

  Ex. Salary

  Suppose you are to be paid 100,000 a month. Would you rather be paid:

  100,000 *cents*

  100,000 *dollars*

  Missing units create confusion!

Symbols

Symbols stand for or represent a very specific property or concept

Ex.

π - the ratio of the circumference of a circle to its diameter

Vectors PPT [pdf]

Subscripts on symbols or letters can also be used to help identify or label a particular quantity

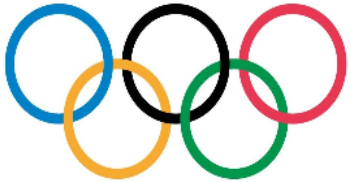
Ex. Time

t = time

t_i = (i)nitial time

t_f = (f)inal time

Identifiable Symbols



Average vs. Instantaneous Values

Average **[Big Picture]**

Average ??? – total quantity divided by the total elapsed time

** Average values tell us ***nothing*** about fluctuations or values at specific points in time (*unless the value was constant the whole time*)

Ex. Class Test Grades

The class test average tells how the class did as a whole, but does not indicate how any one individual did on the test.

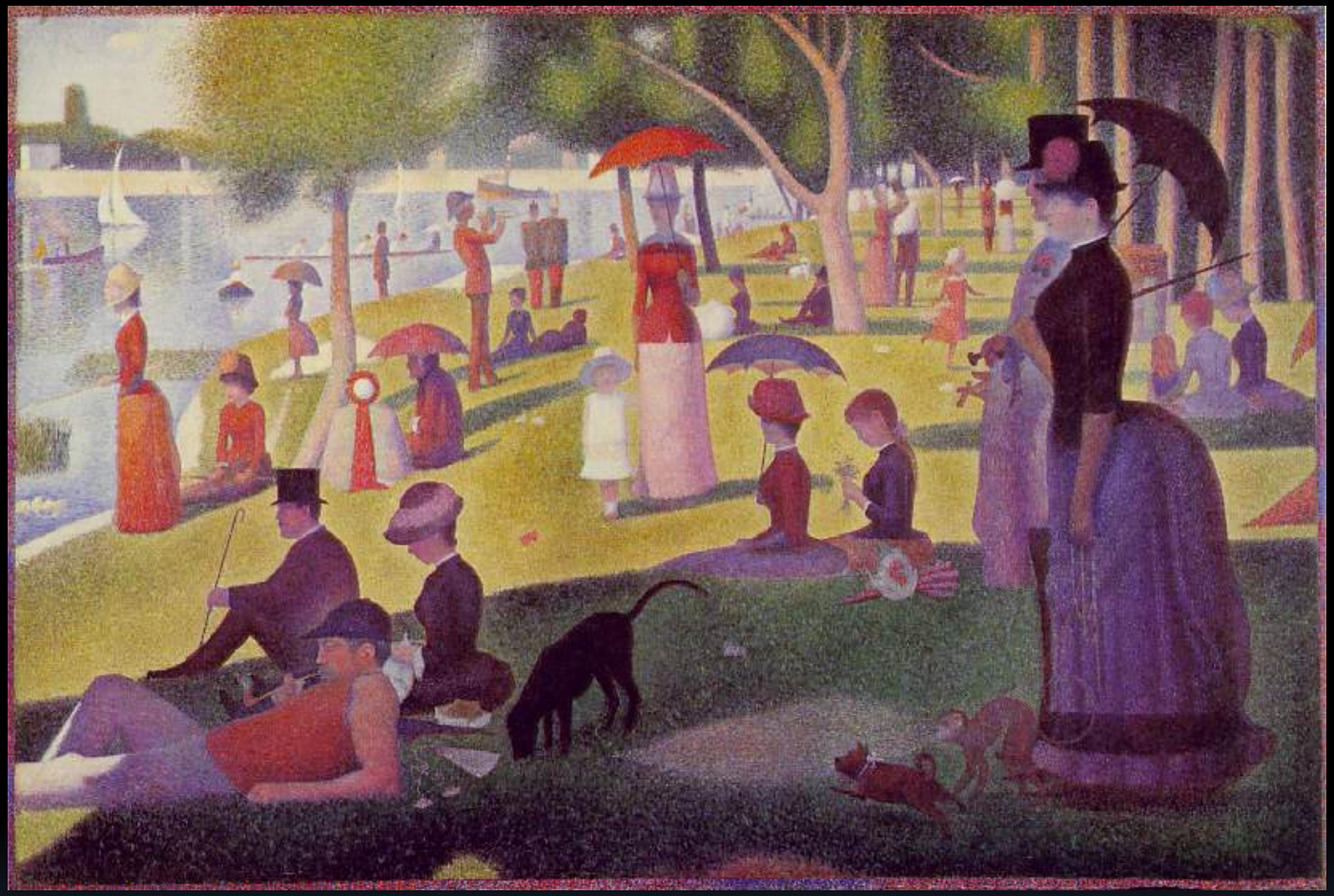
Instantaneous [Snap Shot]

Instantaneous ??? – value of a quantity at a specific instant in time

** Instantaneous values tell us ***nothing*** about general trends or the total process over time (*unless the value was constant the whole time*)

Ex. Individual Test Grades

An individual test grade tells how a student did on the test, but does not indicate how they did compared to the rest of the class.



Georges Seurat's *A Sunday Afternoon on the Island of La Grande Jatte*

Dangers of interchanging Avg. and Inst. Values

*When information from one type of time measurement is extended to gain information about the other, chances are it **will be** wrong!*

Ex.

The average daily temp. in Hawaii is 84^{o}

➔ Today it will be 84^{o} in Hawaii

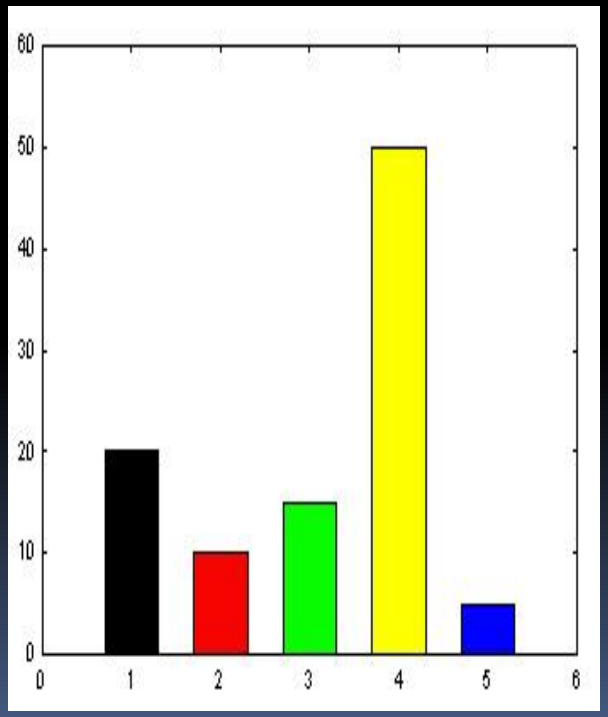
One bag of 100 M&M's has 70 reds

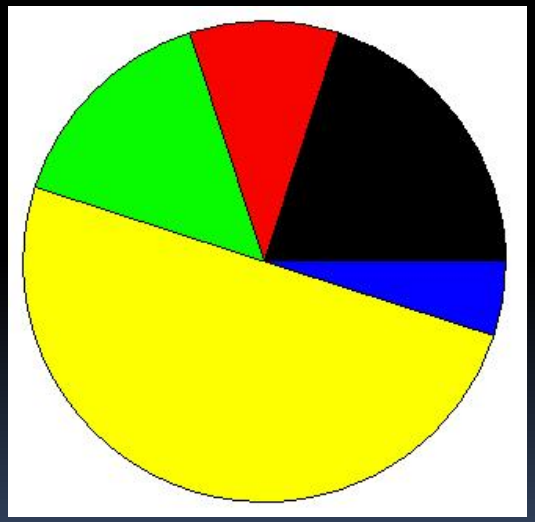
➔ The average # of red M&M's per bag is 70

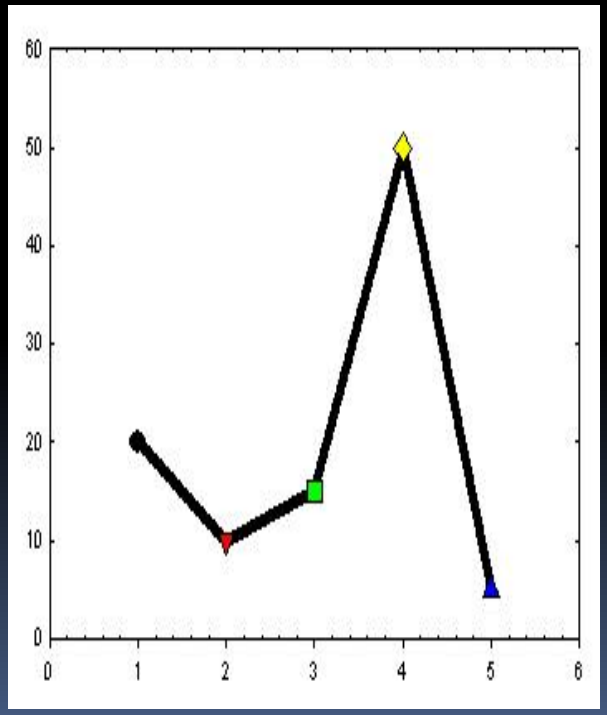
Graphing

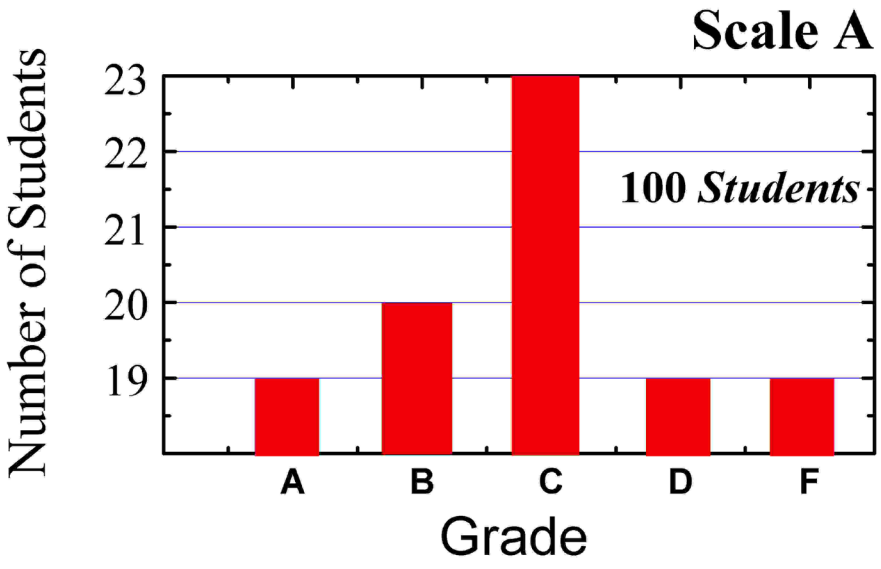
Graphs are a visual representation of the relationships between quantities

Graphs can come in many different forms:





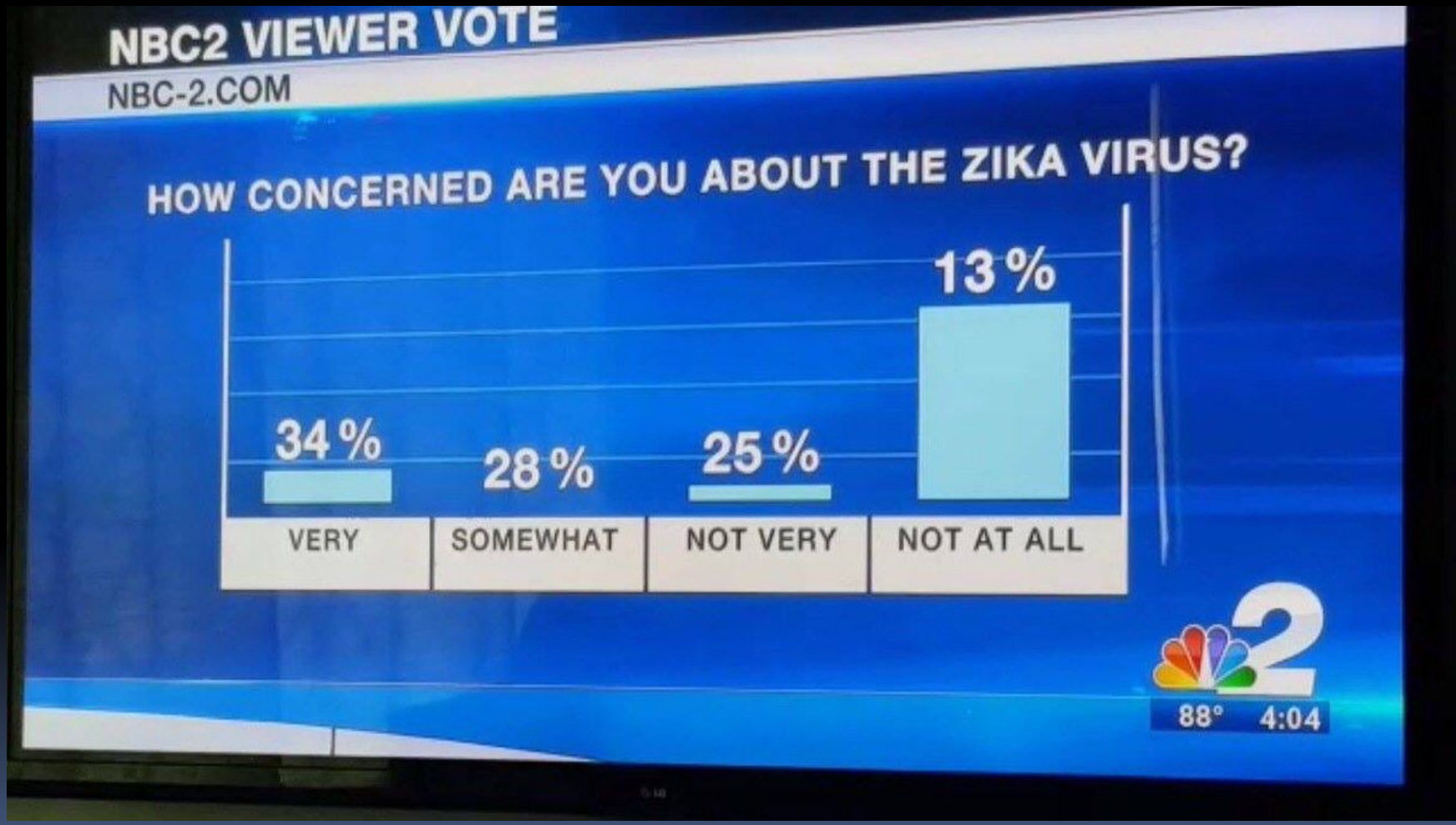




Graphs are one of the quickest and easiest methods to convey information, ***but*** they can also be one of the most deceptive!

How many students got A's using Scale A?
How many students got C's using Scale A?

What's Wrong with this Picture?



Scalars and Vectors

Scalar – a quantity with magnitude only

(*just a number with units*)

Vector – a quantity with magnitude and direction

What can we use to indicate direction?

NSEW, left/right/, up/down, +/- …

Ex.

We are driving at 55 mph.

We are driving at 55 mph west.

Vector Properties

- Represented by bold face letters or letters with arrows over them:

$$\mathbf{A},\ \vec{A},\ \vec{A} \qquad [\underline{A}:\ (old\ school)]$$

- Are additive (*many vectors can be combined into one*)

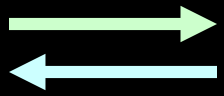
  Resultant Vector – sum of all the individual vector

- Can be represented graphically using arrows:
  - The arrow points in the direction of the vector

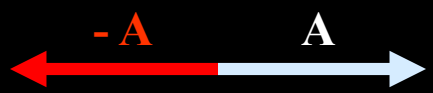
  - The length of the arrow indicates the magnitude of a vector

- Vectors are only equal if their magnitudes and directions are the same
  - If 2 vectors are equal, they are **parallel** to each other

  - If 2 vectors are have the same magnitude, but are in opposite directions, they are **anti-parallel** to each other



- The negative of a vector **only** changes its direction, not its magnitude



- When multiplying a vector by a positive scalar, **only** the magnitude changes

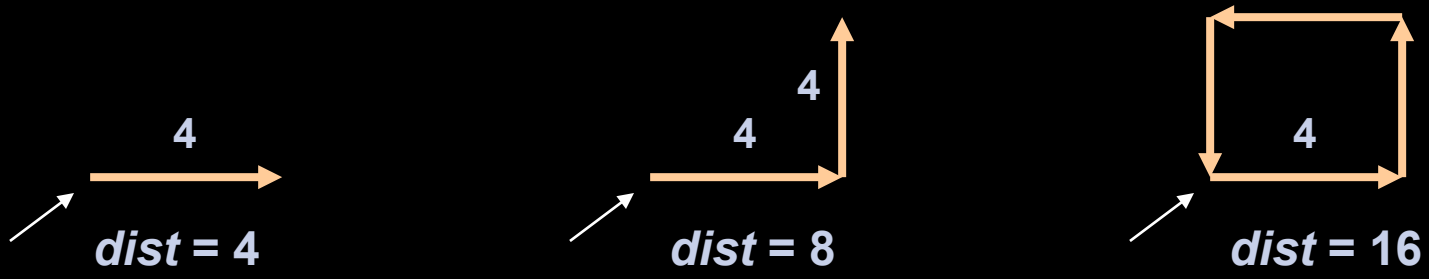
- Can only add vectors (*or vector components*) that are in the same or opposite direction!

Ways of Measuring Length

Distance vs. Displacement

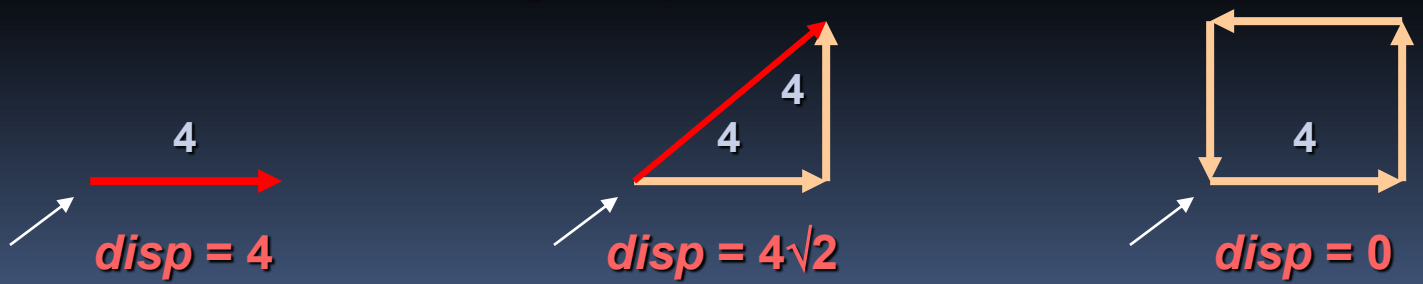
- **Distance** (scalar)

  the total path length traveled



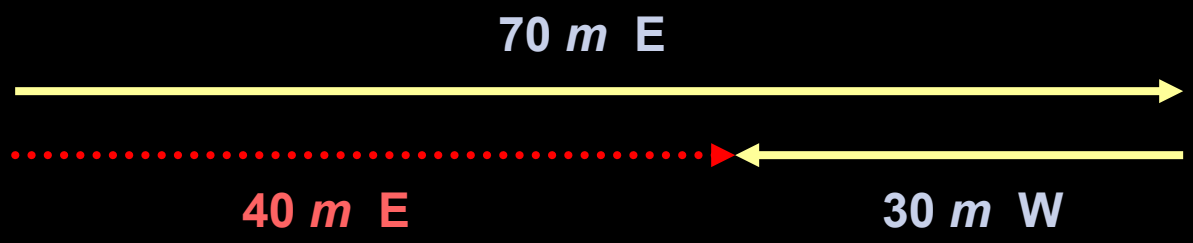
- **Displacement** (vector)

  the net change in position



Ex. *There and Back Again*

A person walks 70 m East and then walks back along the same path 30 m West. What is the total distance traveled and the net displacement relative to the starting point?



Distance = 100 m

Displacement = 40 m E

Ex. Road Trip (Part I)

A college students road trip through several states. What is the students total distance and displacement relative to OBU?

OBU – LR = 60 mi

LR – OKC = 350 mi

OKC – Big D = 200 mi

Big D – OBU = 240 mi

Distance = 850 mi

Displacement = 0 mi

Ex. Road Trip (Part II)

What is the students total distance and displacement relative to OBU if they stop in Dallas?

OBU – LR = 60 mi

LR – OKC = 350 mi

OKC – Big D = 200 mi

Big D – OBU = 240 mi

Distance = 610 mi

Displacement = 240 mi SW

Ex. *The Lake*

How many minimum distances are there around a lake between two points? **2**

How many displacements are there between two points? **1**

There are an infinite number of trajectories (distances) between two points, each with a potentially unique distance. But, there can only ever be ONE displacement!

- HWK #1