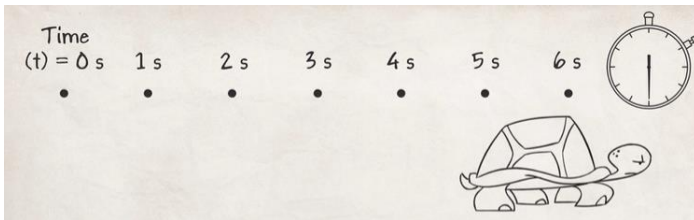PHY131 F   Fall 2020
Class 2

- 1.2 Modeling (we are **not** covering scaling in this course)
- 1.4 Making a rough estimate
- 1.3 Physical quantities, significant digits
- 2.1 What is motion?
- 2.2 Representing Motion with Diagrams

Hello and Welcome from PhySU!

https://www.facebook.com/groups/pasu.physics

- On behalf of the Physics Student Union (PhySU), welcome to the Physics Department!
- We invite you to join our official Discord server at http://tiny.cc/physu-discord . The Discord server contains group chats for all your physics, math, and astronomy classes. It is a great way to meet your peers (we have a channel specifically for first-years) and to get to know upper years who may be able to offer advice.
- If you are interested in getting involved with us as first-year representative, follow the instructions posted on our Facebook or Discord. Invite your friends to vote in the election on October 2, 2020.
- For private concerns, email us at physu@physics.utoronto.ca

Week 1 Pre-Practical Assignment

- You should see this on Quercus now
- The due-date depends on your Practical group (Sep.20-23
- There is no time limit – but we hope it won't take you more than around 30 minutes

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1.1 What Is Physics?

Here are some things physicists do:

- Collecting and analyzing experimental data.
- Making explanations and experimentally testing them.
- Creating different representations (pictures, graphs, bar charts, etc.) of physical processes.
- Finding mathematical relations—mathematical models—between different variables.
- Testing those relations in new experiments.

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1.2 Modeling

A simplified object

- To simplify real objects, physicists often neglect both the dimensions of objects (their sizes) and their structures (the different parts) and instead regard them as single **point-like objects.**

Model!

race car

Real life photo

Poll Question: Please ESTIMATE (don't go look it up)

What is the approximate density of water?

A. $10^{-5}\,\text{kg/m}^3$

B. $0.01\,\text{kg/m}^3$

C. $0.1\,\text{kg/m}^3$

D. $1\,\text{kg/m}^3$

E. $1000\,\text{kg/m}^3$

Poll Question: Please ESTIMATE (don't go look it up)

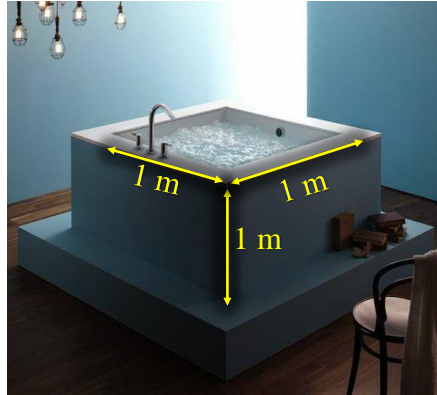## What is the approximate density of water?

A. $10^{-5}\,\text{kg/m}^3$

B. $0.01\,\text{kg/m}^3$

C. $0.1\,\text{kg/m}^3$

D. $1\,\text{kg/m}^3$

E. 1000 kg/m³

Think about a 1 m³ bath tub:

1 m 1 m

1 m

Density

"rho"

as
in
rho
rho
rho

- Amount of mass per unit volume of a material.

$$\rho = \text{Density} = \frac{\text{mass}}{\text{volume}}$$

- Unit of density is kg/m³ or g/cm³.
- Example:
    Density of water is 1000 kg/m³, or 1 g/cm³.

[Image retrieved Jan. 11, 2013 from http://www.amazon.com/Evian-Water-Liter-Pack/dp/B0041HVMU0]

The SI Unit System

Quantity	Unit	Standard
Length	Meter	Length of the path traveled by light in 1/299,792,458 second
Time	Second	Time required for 9,192,631,770 periods of radiation emitted by cesium atoms
Mass	Kilogram	The kg is defined by taking the fixed numerical value of the Planck constant h to be $6.62607015 \times 10^{-34}$ when expressed in the unit J·s where the metre and the second are defined in terms as above.

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tera	T	10^{12}
giga	G	10^{9}
mega	M	10^{6}
kilo	k	10^{3}

These are the only prefixes used in PHY131/132.

deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro[†]	μ	10^{-6}
nano	n	10^{-9}

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Significant Digits

The number of significant digits is the number of **reliably known** digits in a number.

It is usually possible to tell the number of significant digits by the way the number is written:

- 23.21 cm has four significant digits. $\quad 4$

- 0.062 cm has two significant digits (the initial zeroes don't count). $\quad 6.2 \times 10^{-2}$

- 80 km is ambiguous—it could have one or two significant digits. If it has three, it should be written 80.0 km. $\quad 3$

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Rules for Significant Digits

When multiplying or dividing numbers, the result has as many significant digits as the number used in the calculation with the fewest significant digits.

Example: 11.3 cm x 6.8 cm = 76.84 cm^2 ≈ 77 cm^2.

When adding or subtracting, the answer is no more accurate than the least accurate number used.

The number of significant digits may be off by one; use the percentage uncertainty as a check.

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Scientific Notation and Significant Digits

Scientific notation is commonly used in physics; it allows the number of significant digits to be clearly shown.

For example, we cannot tell how many significant digits the number 36,900 has.

However, if we write 3.69 x 10^4, we know it has three; if we write 3.690 x 10^4, it has four.

Poll Question:

Rank in order, from the most to the least, the number of significant digits in the following numbers.

a. 82   b. 0,0052   c. 0.430   d. 4.321 × 10^{-10}

2   2   3   4

    A. a = b = d > c
    B. b = d > c > a
    C. d > c > b = a
    D. d > c > a > b
    E. b > a = c = d

Unit Conversion: What's wrong with this picture?

I don't like the significant digits on that conversion, Daddy!

No smoking within 9 metres or 29.5 feet of playground

Zainab Harlow

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Here is the actual bylaw from
http://www.toronto.ca/legdocs/municode/1184_608.pdf :

§ 608-8.1. Smoking.

[Added 2009-01-28 by By-law No. 87-2009[17]; amended 2013-12-17 by By-law No. 1643-2013]

A.   While in a park no person shall smoke within the boundaries of and a nine-metre radius surrounding the following amenities or areas in a park:

    (1)   A sports field;

    (2)   A playground safety surface or playground equipment;

Clearly Toronto City Council intended only **one** significant digit in this rule.

No smoking within 9 metres or 29.5 feet of playground

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Convert 9 m to feet

Facts you are given:

$$1 = \left(\frac{1 \text{ in}}{2.54 \text{ cm}}\right) = \left(\frac{2.54 \text{ cm}}{1 \text{ in}}\right)$$

$$1 = \left(\frac{100 \text{ cm}}{1 \text{ m}}\right) = \left(\frac{1 \text{ m}}{100 \text{ cm}}\right) \qquad 1 = \left(\frac{12 \text{ in}}{1 \text{ foot}}\right) = \left(\frac{1 \text{ foot}}{12 \text{ in}}\right)$$

No smoking within 9 metres or 29.5 feet of playground

TORONTO   Municipal Code: 608

$$d = 9 \text{ m} \left(\frac{100 \text{ cm}}{1 \text{ m}}\right)\left(\frac{1 \text{ in}}{2.54 \text{ cm}}\right)\left(\frac{1 \text{ foot}}{12 \text{ in}}\right)$$

$$= 9 \times 100 \div (2.54 \times 12)$$

$$= 29.523 \text{ foot}$$

$$d = 30 \text{ foot}$$
$$d = 3 \times 10^1 \text{ ft}$$

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Etkina's Suggested Problem Solving Strategy

- **SKETCH AND TRANSLATE** — Draw a sketch of the situation. Write down knowns and unknowns

- **SIMPLIFY AND DIAGRAM** — Neglect some of the irrelevant details, choose a "representation".

- **REPRESENT MATHEMATICALLY** — Write down the relevant equations, and solve them symbolically for what you want.

- **SOLVE AND EVALUATE** — Plug in the numbers, and then look at it to see if it makes sense (sanity check!)
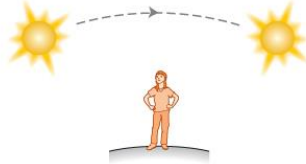
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2.1 What Is Motion?

Motion is

(a) An observer on Earth sees the Sun move in an arc across the sky.

(b) An observer in a spaceship sees the person on Earth as rotating under a stationary Sun.

- An observer in a spaceship describes the motion of the Sun differently than an observer standing on Earth.
- An "object of interest" and the "observer" must be specified when describing motion.

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2.1 What Is Motion?

Describing motion

- Motion is a change in an object's position relative to a given observer during a certain change in time.
- Without identifying the observer, it is impossible to say whether the object of interest moved.
- Physicists say motion is relative, meaning that the motion of any object of interest depends on the point of view of the observer. (This was brought up in Einstein's theory of relativity 1905).

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2.1 What Is Motion?

Reference frames

- Specifying the observer is important before describing the motion of an object of interest.

- A reference frame includes an object of reference, a coordinate system with a scale for measuring distances, and a clock to measure time.

2.1 What Is Motion?

Modeling motion

- Simplified assumptions are made in order to analyze complicated situations.

- Simplest type of motion is **linear motion**.

Linear motion is a model of motion that assumes that an object, considered as a point-like object, moves along a straight line.

Making a Motion Diagram

- An easy way to study motion is to make a video of a moving object.
- When making a video, a camera takes photos at a fixed rate, typically 30 photos every second.
- Each separate photo is called a frame.
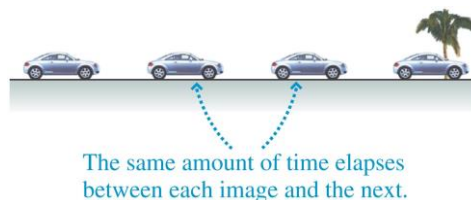- The car is in a somewhat different position in each frame.
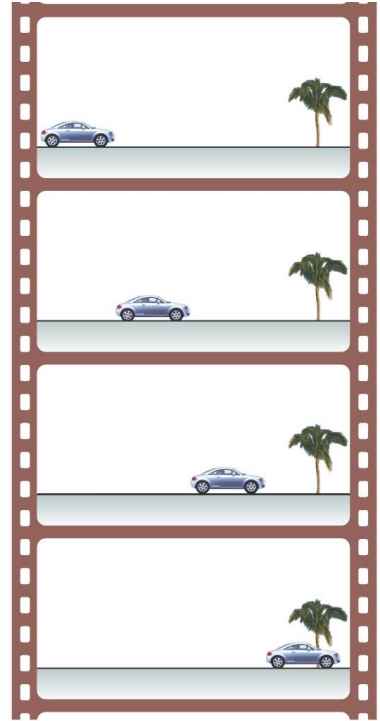
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Making a Motion Diagram

Suppose we stack the individual frames of the video on top of each other.

The composite photo shows the moving object at several equally spaced instants of time:

The same amount of time elapses between each image and the next.

By replacing the moving object with central dots, we get a "Motion Diagram":

•   •   •   •
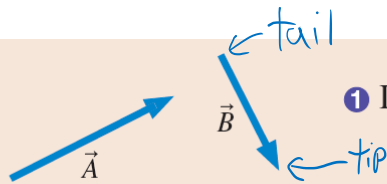
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Poll

Which object is going faster, A or B?
(Assume these are both motion diagrams.)
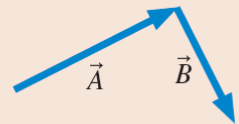
A

B

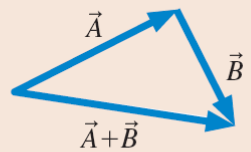25

Vector Addition

To add $\vec{B}$ to $\vec{A}$:

tail

$\vec{B}$

$\vec{A}$

tip

❶ Draw $\vec{A}$.

$\vec{A}$

❷ Place the tail of $\vec{B}$ at the tip of $\vec{A}$.

$\vec{A}$ $\vec{B}$

❸ Draw an arrow from the tail of $\vec{A}$ to the tip of $\vec{B}$. This is vector $\vec{A} + \vec{B}$.
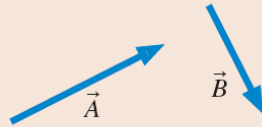
$\vec{A}$

$\vec{B}$

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

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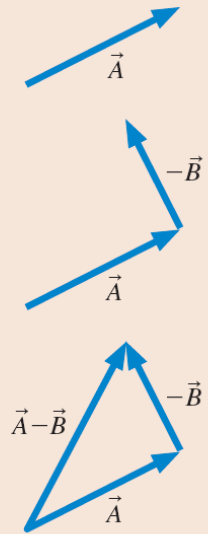# Vector Subtraction

To subtract $\vec{B}$ from $\vec{A}$:

$$\vec{A} - \vec{B} = \vec{A} + (-\vec{B})$$

❶ Draw $\vec{A}$.
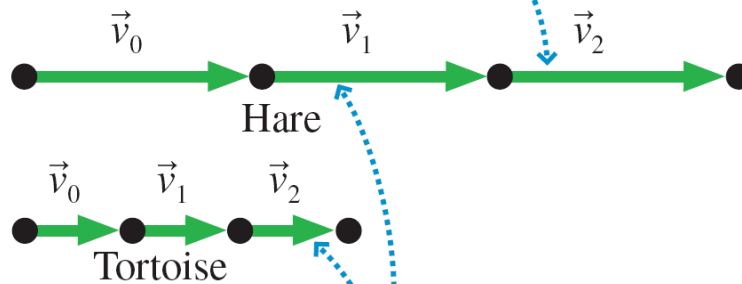
❷ Place the tail of $-\vec{B}$ at the tip of $\vec{A}$.

❸ Draw an arrow from the tail of $\vec{A}$ to the tip of $-\vec{B}$. This is vector $\vec{A} - \vec{B}$.

# Motion Diagrams with Velocity Vectors

These are average velocity vectors.

$\vec{v}_0$ $\vec{v}_1$ $\vec{v}_2$

Hare

$\vec{v}_0$ $\vec{v}_1$ $\vec{v}_2$

Tortoise

The length of each arrow represents the average speed. The hare moves faster than the tortoise.

Position-Time Graphs

Before:
Stopwatch
0 seconds

After:
Stopwatch
10 seconds

- Suppose I take a ball and move it from 0cm on a ruler to 20cm, and I do that in 10 seconds.
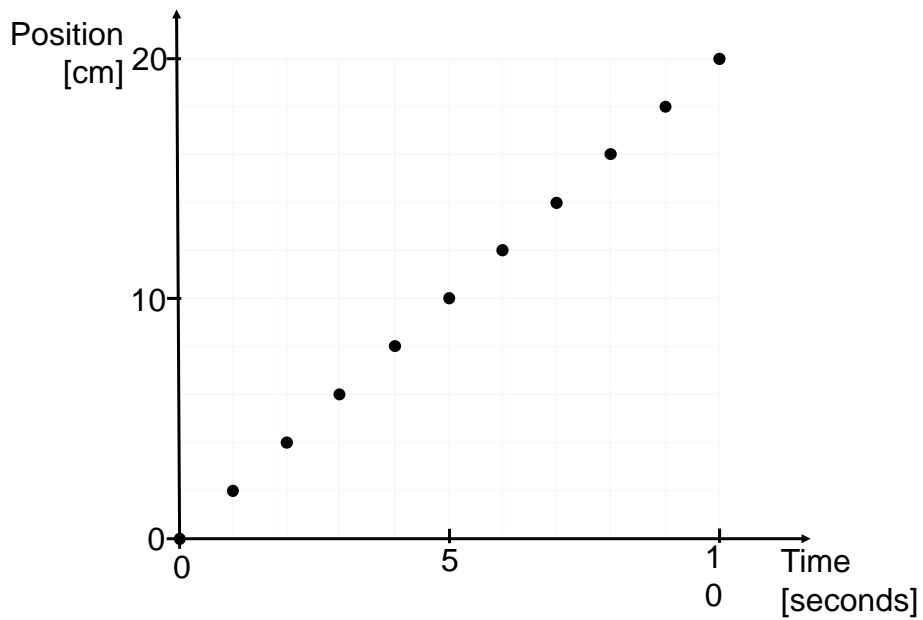- How can you describe this motion in a simple way?
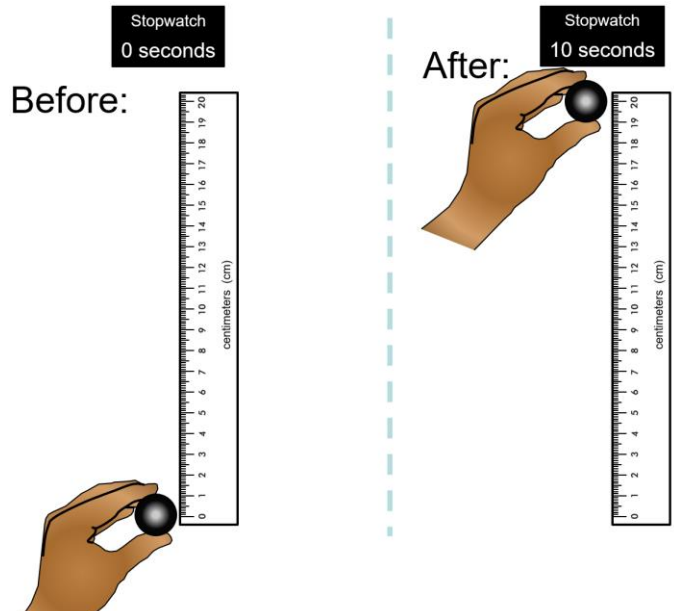
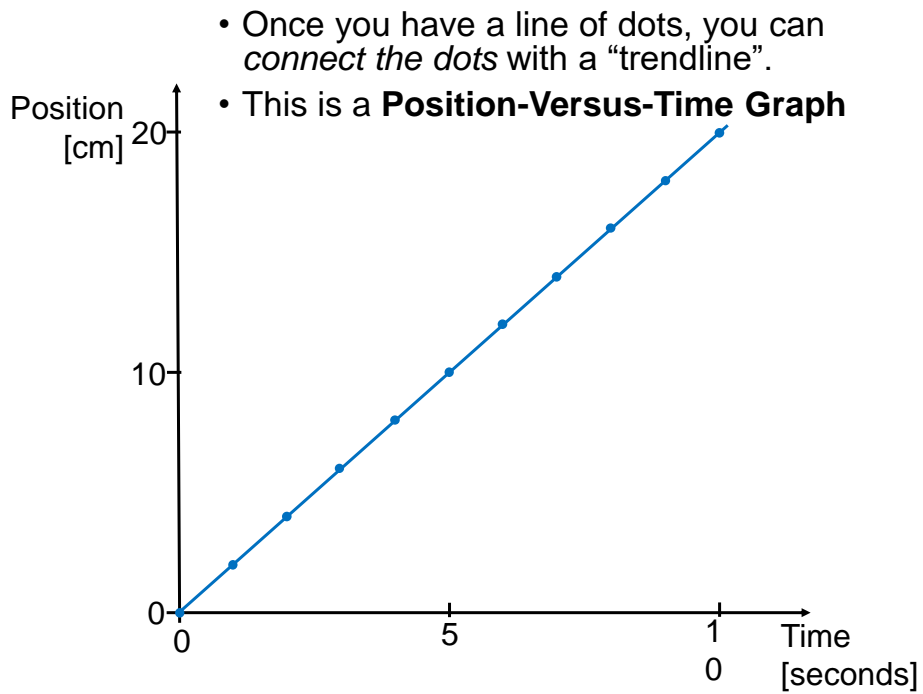| Time [seconds]	Position [cm]
0	0
1	2
2	4
3	6
4	8
5	10
6	12
7	14
8	16
9	18
10	20

- One way of keeping track of the position of the ball in between 0 and 10 seconds would be to make a **table**.
- For each second of **time** on the stopwatch, you list the **position** of the ball.
- Once you have any table like this of pairs of numbers, it is possible to make a **graph** (next slide).
- The left-right location on the grid is determined by the **time** in seconds, and the up-down location on the grid is determined by the **position** in cm.

Position
[cm]

20

10

0

0   5   1
                                         0

Time
[seconds]

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• Once you have a line of dots, you can *connect the dots* with a "trendline".

• This is a **Position-Versus-Time Graph**

Position
[cm]

20

10

0

0   5   1
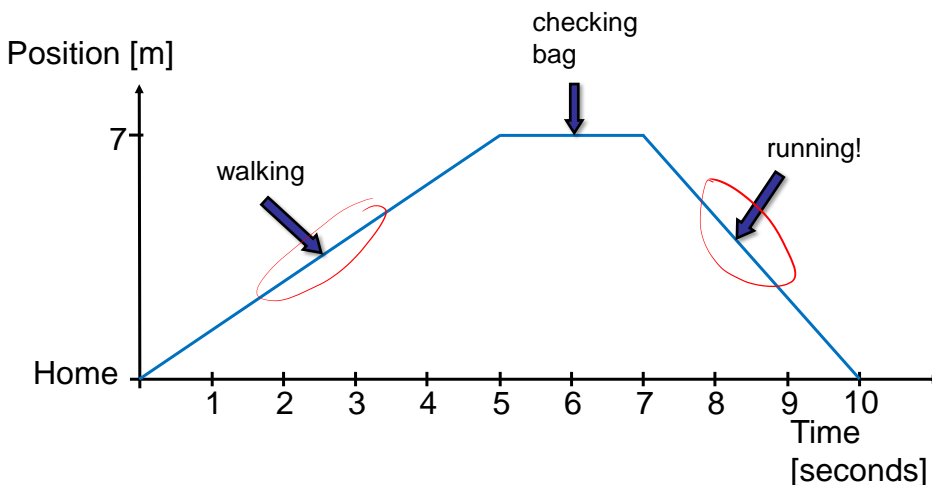   0

Time
[seconds]

32

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Poll   Mia knows how to ride a bike. She is cycling along a
       straight stretch of track. Her speed is 12 m/s. Which
       position-versus-time graph is *not* possible for the
       description of Mia's motion?

A

C

B

D
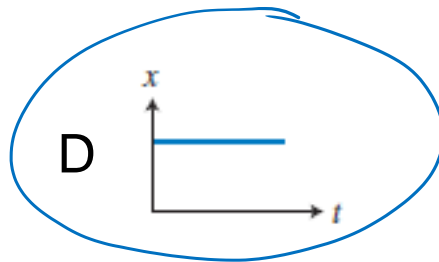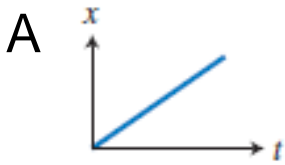
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- Imagine you steadily walked 7 m away from your house in 5 seconds, then
  you stopped for 2 seconds to check your bag, then you ran back to your
  house in 3 seconds.

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Before Class 3 on Wednesday

- Read the following from Etkina:
- 2.3 Vector Math (not the same as regular math!)
- 2.4 Position, Displacement, Distance and Path Length.
- Something to think about: Does constant velocity imply constant acceleration? Does constant acceleration imply constant velocity?

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