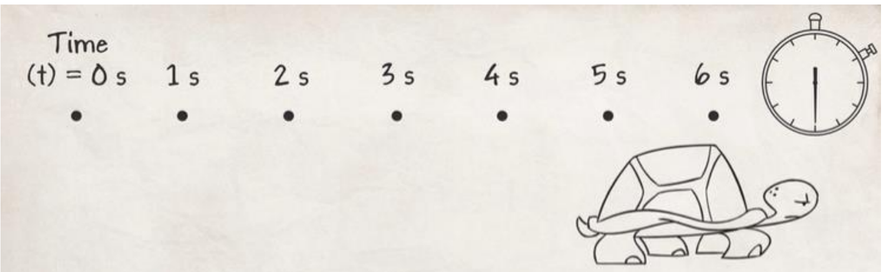
PHY131 F Fall 2020
Class 2

- Chapter 1
- 2.1 What is motion?
- 2.2 Representing Motion with Diagrams



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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.**

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

What is the approximate density of water?

A. 10^{-5} kg/m^3

B. 0.01 kg/m^3

C. 0.1 kg/m^3

D. 1 kg/m^3

E. 1000 kg/m^3

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Density

- Amount of mass per unit volume of a material.

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

- Unit of density is kg/m^3 or g/cm^3.
- Example:

  Density of water is 1000 kg/m^3, or 1 g/cm^3.

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

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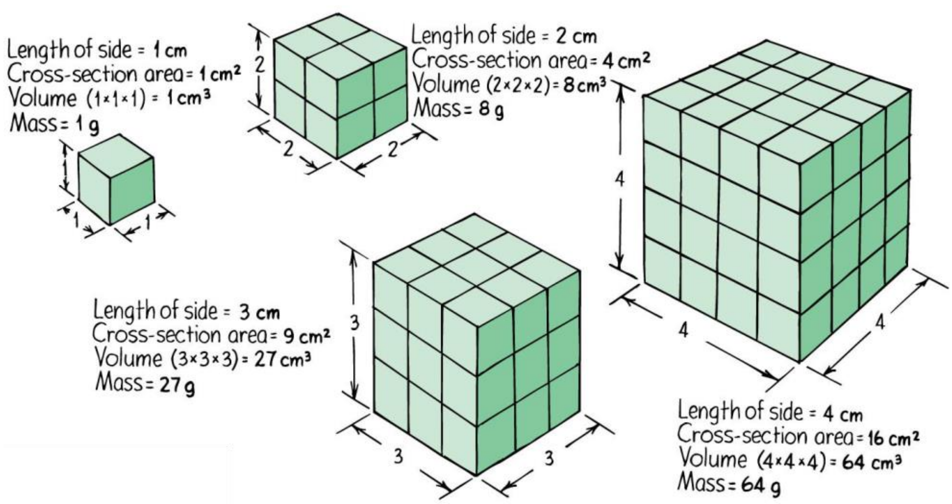
Scaling



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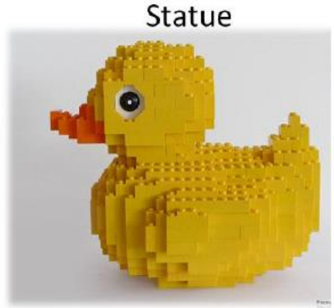
Scaling Example

- A sculptor is making a statue of a duck.
- She first creates a model.
- To make the model requires exactly 2 kg of bronze.
- The final statue will be 5 times the size of the model in all three dimensions.
- How much bronze will she require to cast the final statue?
- (You may find it helpful to think about the model being constructed of Lego blocks, with the final statue made of Lego blocks that are 5 times the size in each dimension as the ones used to make the model.)

Statue



Model

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Image of bronze duck from http://ancientpoint.com/category/220-antiques_decorative_arts_metalware_/page_34.html]

Scaling Example

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Poll Question:

When you “scale up” an object to 3 times its linear size, the surface area increases by

A. 3 and the volume by 3.
B. 3 and the volume by 9.
C. 3 and the volume by 27.
D. 9 and the volume by 27.
E. 4 and the volume by 8.

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So the **surface area to volume ratio** is

$$\frac{\text{Surface area}}{\text{Volume}} \sim \frac{\text{size}^2}{\text{size}^3} \sim \frac{1}{\text{size}}$$

[Image credit: http://eshgheman.livejournal.com/2025.html]

[Image credit http://bwog.com/2011/01/30/hidden-talents-the-skydiver/]

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Scaling

- Air resistance (drag) is proportional to **surface area**.
- Force of gravity is proportional to mass, which is proportional to **volume**.
- So the **ratio** of air resistance to weight *decreases* as size increases.

[Image credit: http://eshgheman.livejournal.com/2025.html]

[Image credit http://bwog.com/2011/01/30/hidden-talents-the-skydiver/]

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Poll Question:

If the volume of an object were to double, with no change in mass, what would happen to its density?

A. It would remain unchanged.
B. It would double.
C. It would decrease by a factor of two.
D. None of these.

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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	Platinum cylinder in International Bureau of Weights and Measures, Paris

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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 Figures

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

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

- 23.21 cm has four significant figures.
- 0.062 cm has two significant figures (the initial zeroes don't count).
- 80 km is ambiguous—it could have one or two significant figures. If it has three, it should be written 80.0 km.

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Rules for Significant Figures

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

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

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

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

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Scientific Notation and Significant Figures

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

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

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

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Poll Question:

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

a. 82 b. 0.0052 c. 0.430 d. 4.321×10^{-10}

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

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Unit Conversion: What's wrong with this picture?

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

§ 608-8.1. Smoking.

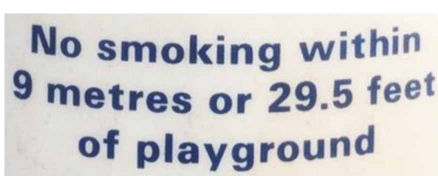
[Added 2009-01-28 by By-law No. 87-2009[17]; amended 2013-12-17 by By-law No. 1643-2013]

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 figure in this rule.



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Convert 9 m to feet

Facts you are given: $1 = \left(\frac{1\text{ in}}{2.54\text{ cm}}\right) = \left(\frac{2.54\text{ cm}}{1\text{ in}}\right)$

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

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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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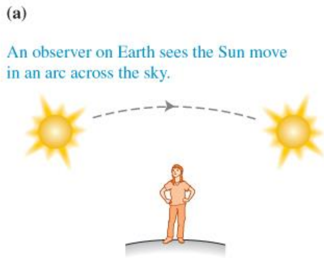
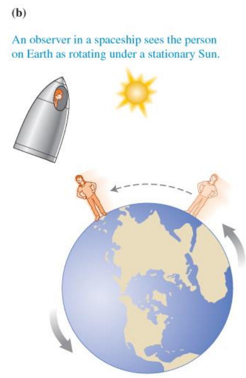
2.1 What Is Motion?

Motion is





- 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.

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).

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.

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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.

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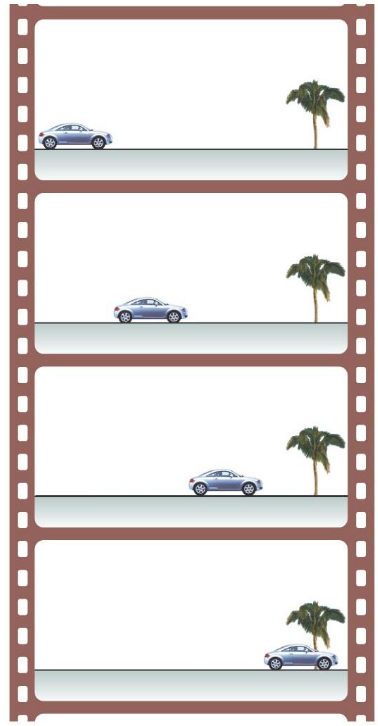
Making a Motion Diagram



- 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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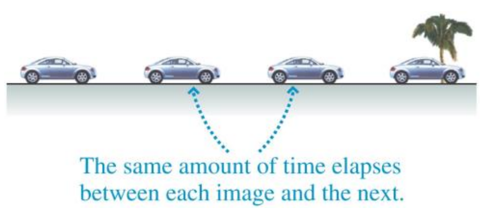
Making a Motion Diagram

- Suppose we stack the individual frames of the video on top of each other.
- The result is shown.
- This composite photo, showing an object's position at several equally spaced instants of time, is called a **motion diagram.**



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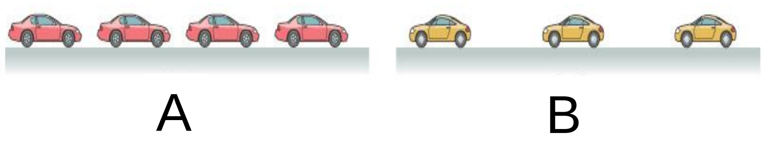
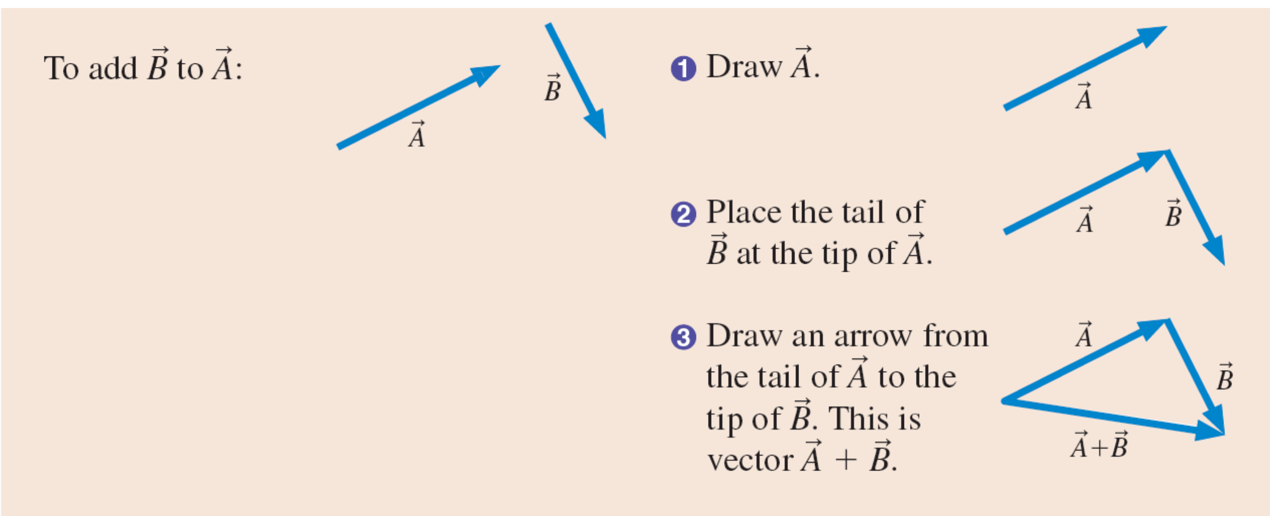
Poll

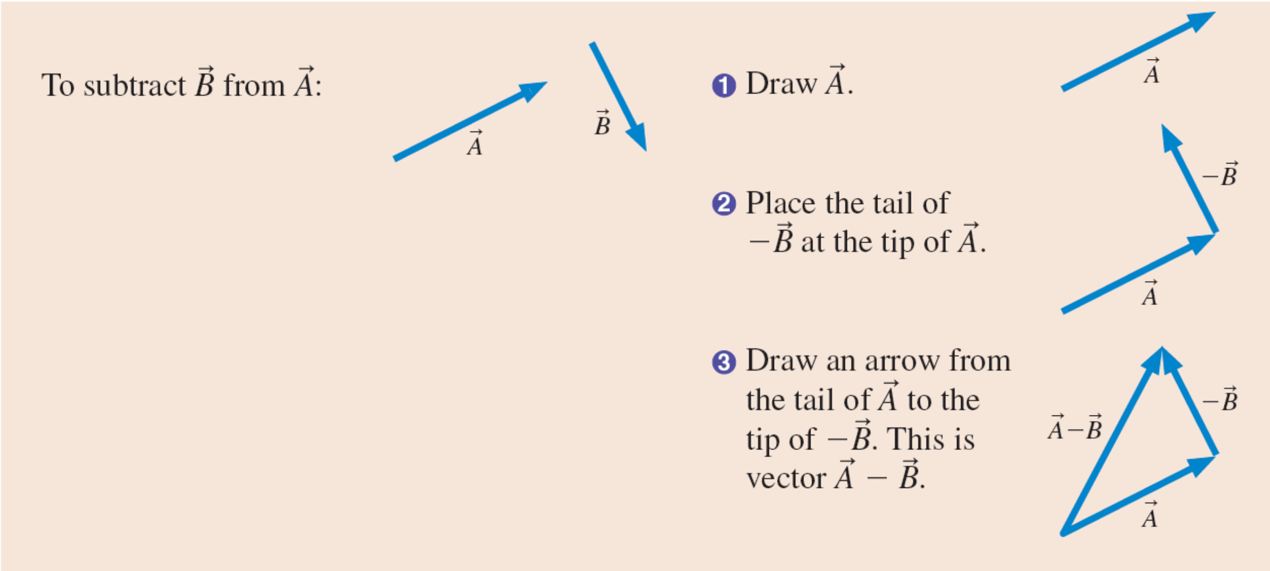
Which car is going faster, A or B?
(Assume these are both motion diagrams.)



Vector Addition



Vector Subtraction



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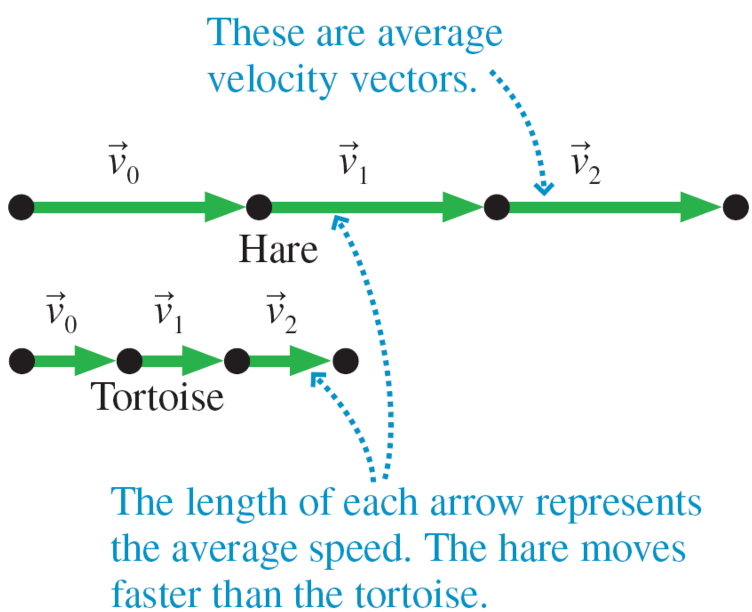
Motion Diagrams with Velocity Vectors



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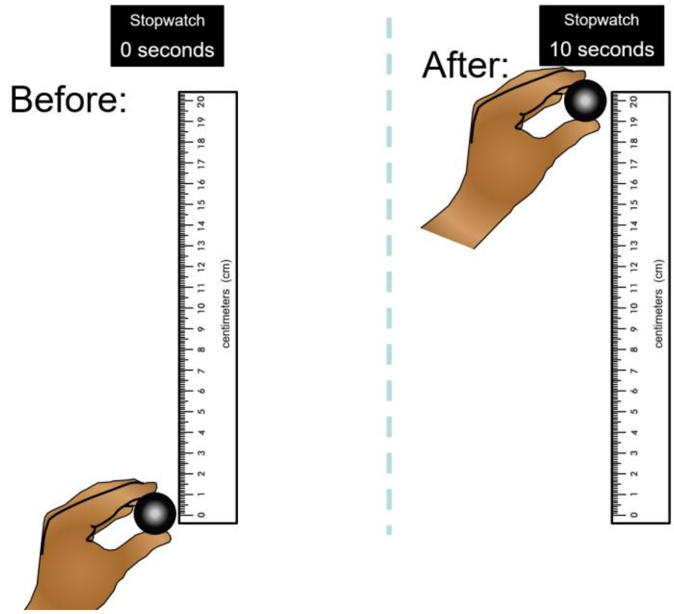
Position-Time Graphs

- 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?
- One easy way would be to take photos of the "before" and "after" situations
- These "before" and "after" photos let you know *that* the ball moved, and how much time it took.
- However, they don't tell you what happened in *between* 0 and 10 seconds.



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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.

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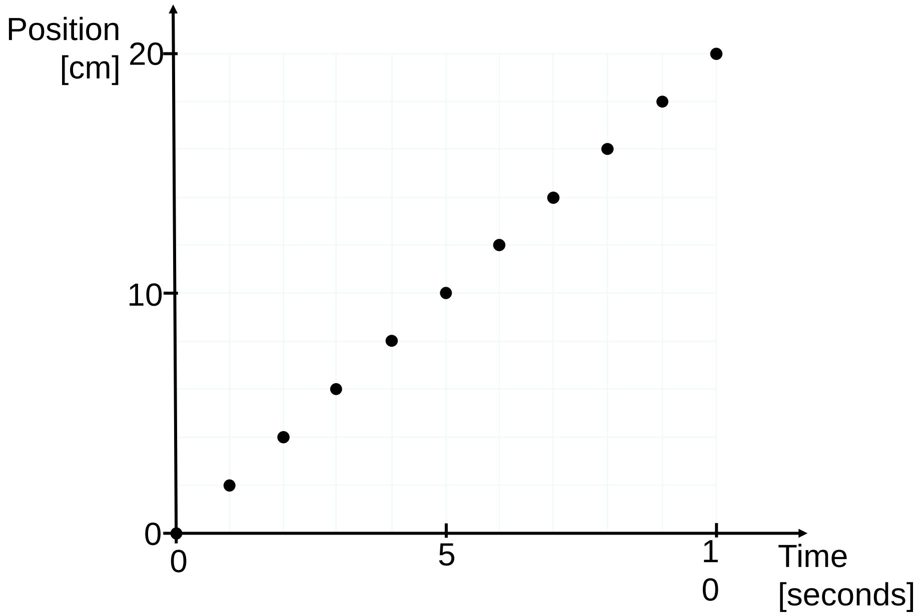

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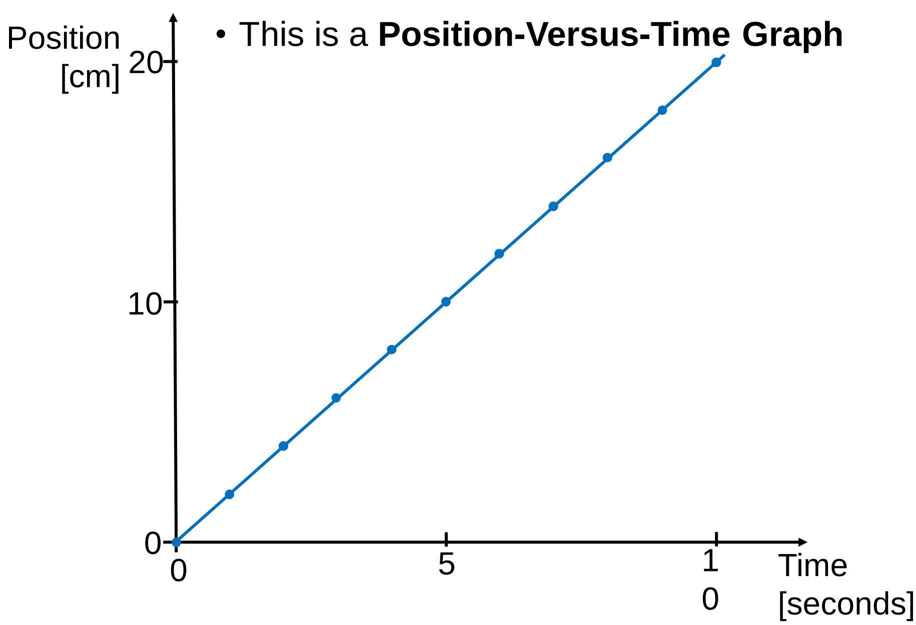
- Once you have a line of dots, you can *connect the dots* with a “trendline”.
- This is a **Position-Versus-Time Graph**



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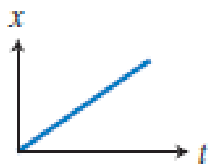
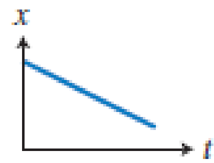
Poll

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?

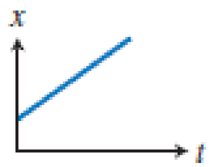
A



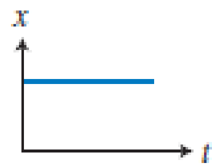
C



B



D



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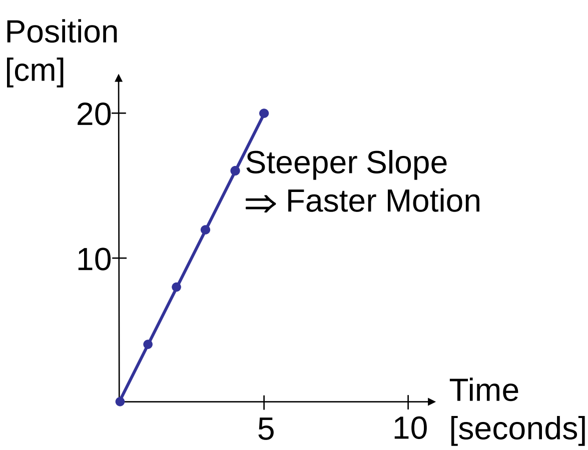

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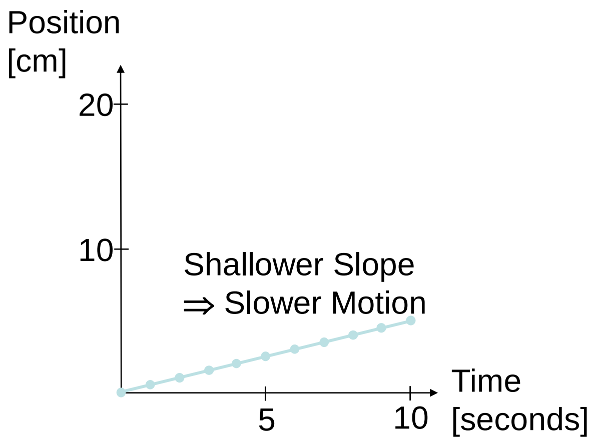
Position
[cm]
20
10
Shallower Slope
⇒ Slower Motion
Time
[seconds]
5
10

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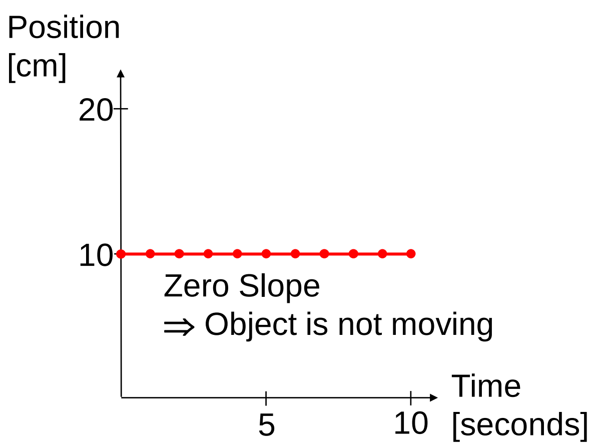
Position
[cm]
20
10
Zero Slope
⇒ Object is not moving
Time
[seconds]
5
10

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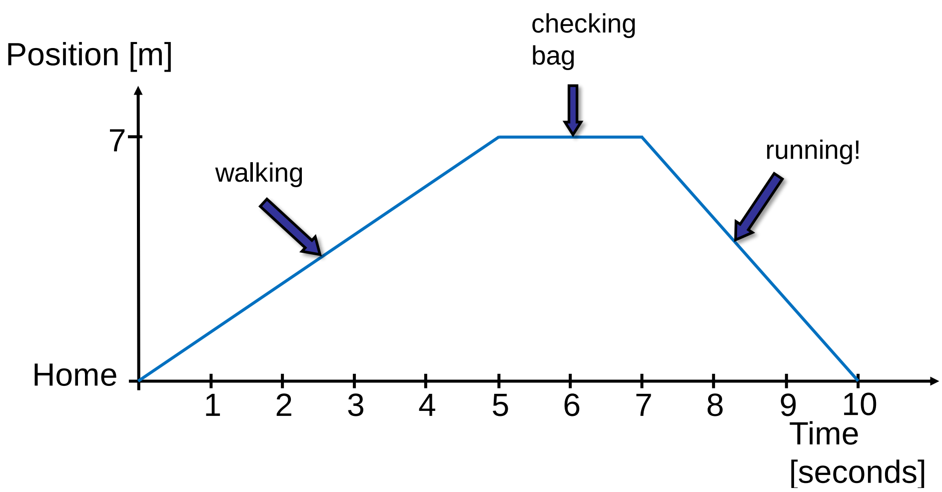
- Imagine you steadily walked 7 m away from your house in 5 seconds, then you stopped for 2 seconds to check your bag, then you ran back to your house in 3 seconds.



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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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