Course Announcement

- The total number of enrolled people in this course reached 190 people. This is the maximum capacity of classroom. No more extra enrollment will be approved.

Week	Date	Content
1	9/13(Tue.)	**Course Information** **Fundamental Tools**: measurement & unit
1	9/16(Fri.)	**Fundamental Tool:** vector & basic calculus
2	9/20(Tue.)	**Kinetics:** motion in 1D
2	9/23(Fri.)	**Kinetics:** motion in 2D and 3D
3	9/27(Tue.)	**Newton's law:** Newton's first and second law I
3	9/30(Fri.)	**Newton's law:** Newton's first and second law II (Homework 1)

GENERAL PHYSICS B1
KINETICS

Dynamics
Motion in one dimension
2022/09/20

Today’s topic

- What is dynamics and why do we study about it.
- Motion in 1D
- Definitions and relationship between position, velocity and acceleration.

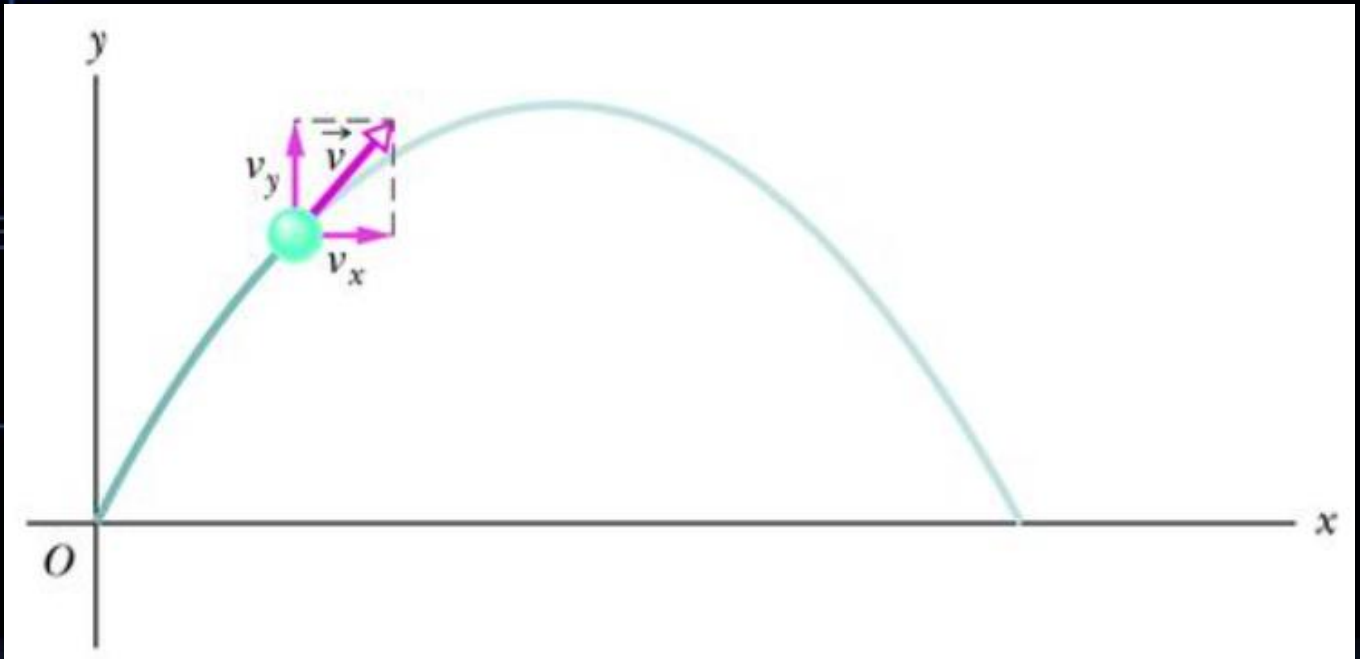
Dynamics: physical quantities evolving with time

- Physics is based on measurement and comparison of physical quantities. The main goal of physicists is finding out the relationships between physical quantities.
- If the physical quantities that we are interested in are a function of time. The study of how these physical quantities change with time is called dynamics.

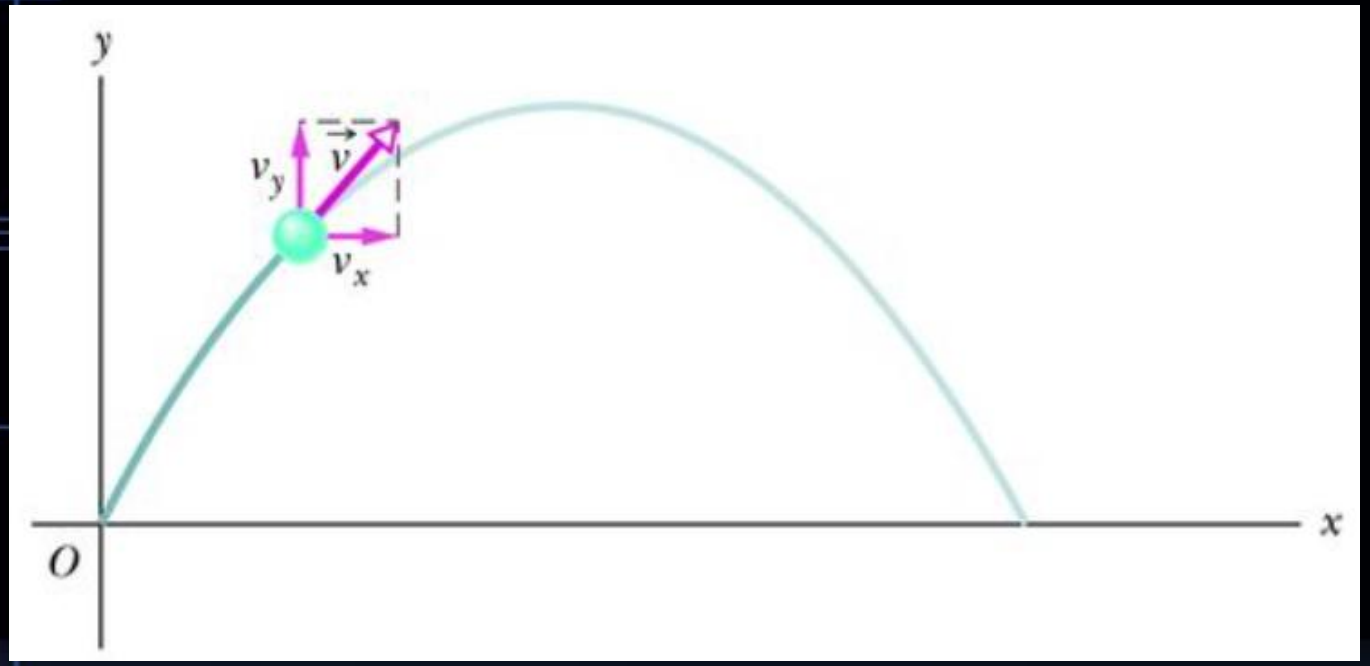
Why do we study dynamical systems?

By observing **how** the dynamical systems we are interested in **change with time**, we can **deduce the law** of the nature of the subject and use the law to **describe or even predict the evolution of the systems** for better human life.

Examples of dynamical systems



Examples of dynamical systems

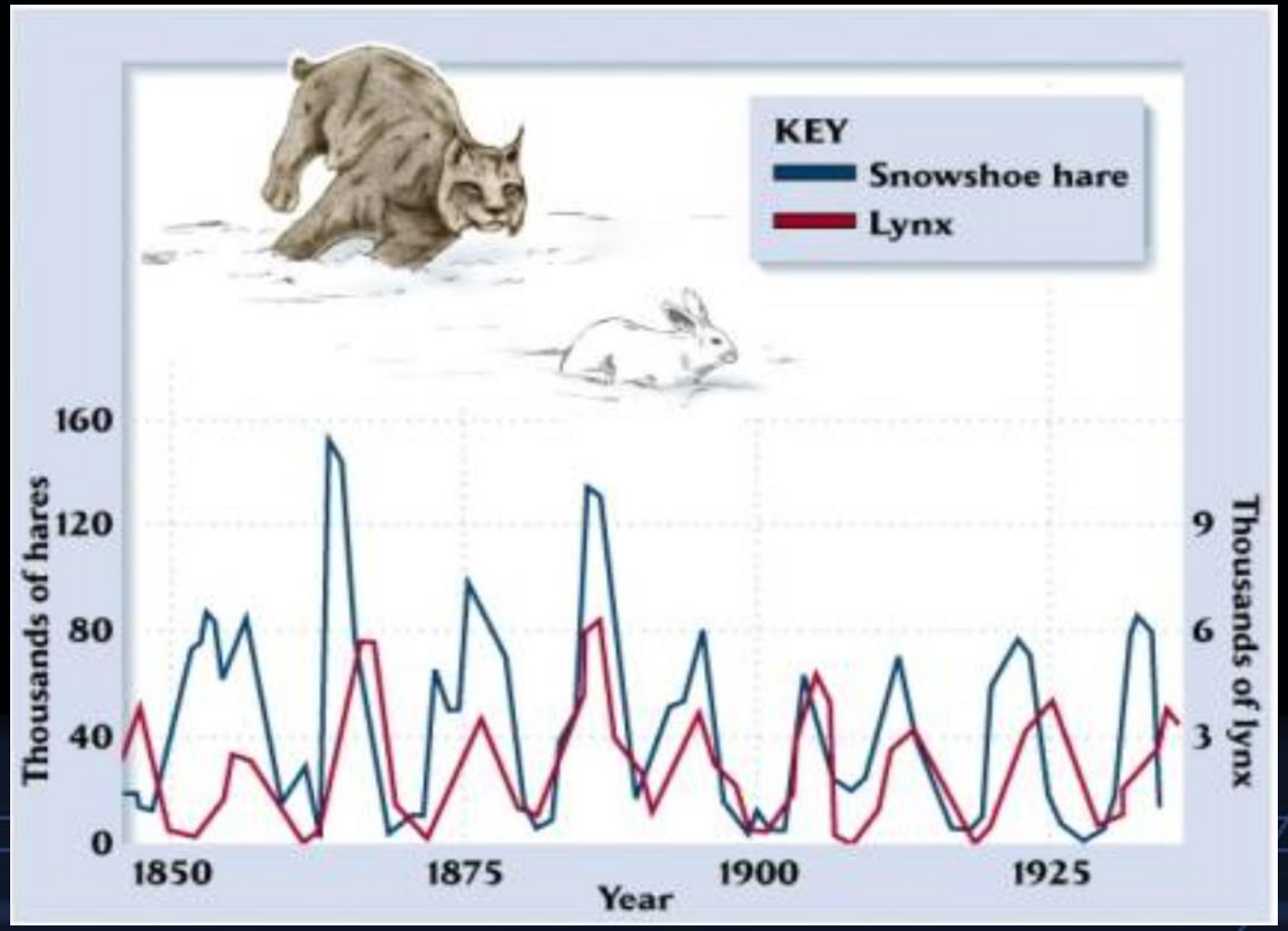


https://www.statspros.com/aaron-judge-vs-shohei-ohtani-stats/

Examples of dynamical systems

https://gifer.com/en/FOhe

Examples of dynamical systems



https://theglyptodon.wordpress.com/2011/05/02/the-fur-trades-records/

Examples of dynamical systems

https://www.nasdaq.com/

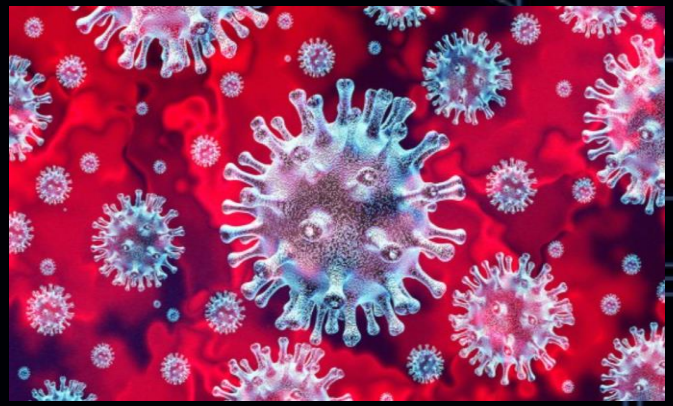
For understanding a dynamical system …

To study a dynamical system, we need to know

- Which quantity we're interested in
- Concepts of units
- Relation between different quantities
- Mathematical descriptions
- Solutions/Predictions

Think About It…

Without any controlling, the spreading rate of a disease is proportional to the population got infected. Which plot can represent the trend of population got infected? Why?



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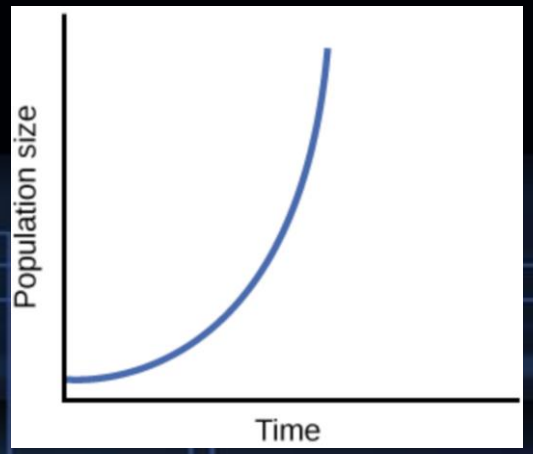
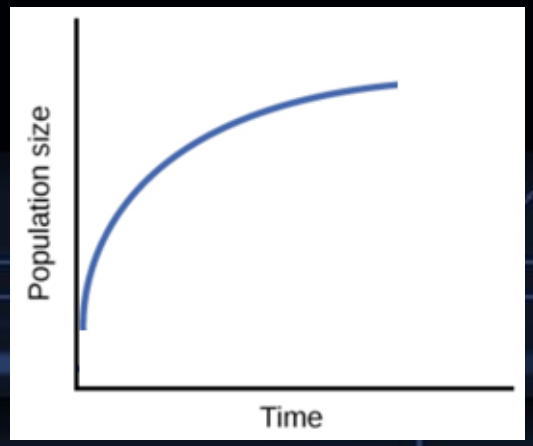


A

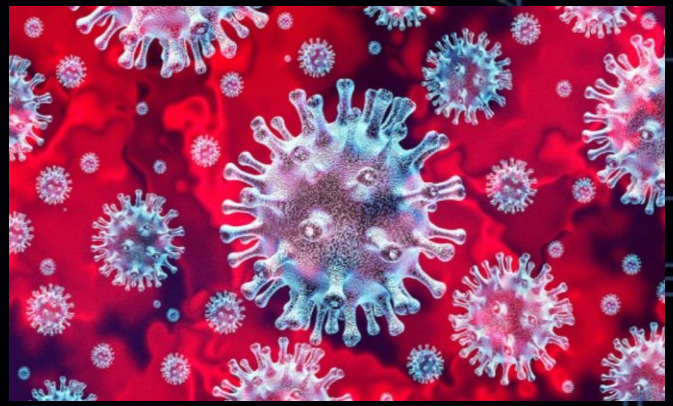
B



C

Think About It…

Without any controlling, the spreading rate of a disease is proportional to the population got infected. Which plot can represent the trend of population got infected? Why?



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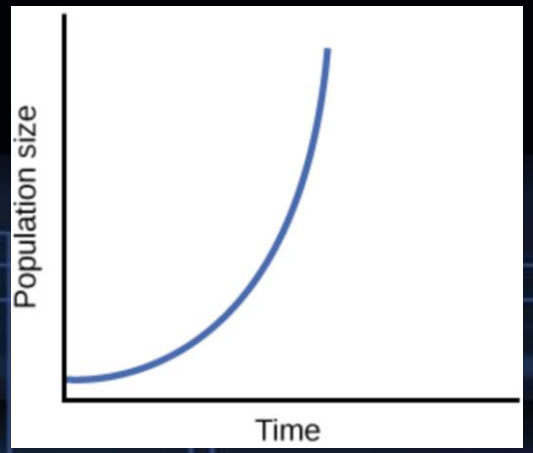


A

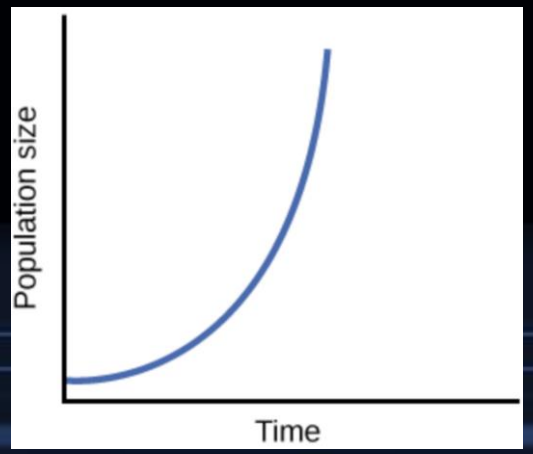
Think About It…

Without any controlling, the spreading rate of a disease is proportional to the population got infected.

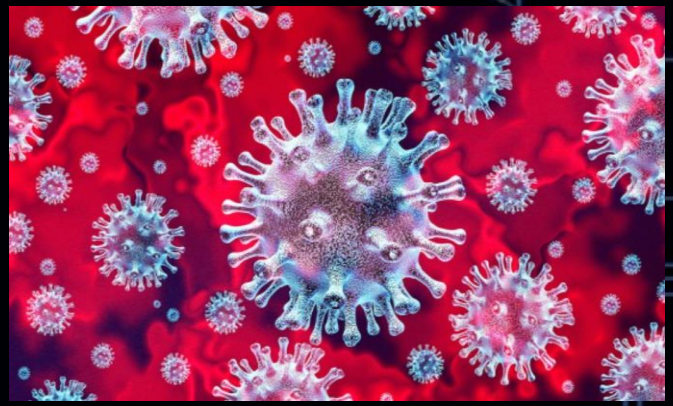
$$\frac{dN}{dt} = \alpha N$$

$$\int \frac{dN}{N} = \int \alpha dt$$

$$N(t) \sim e^{\alpha t}$$

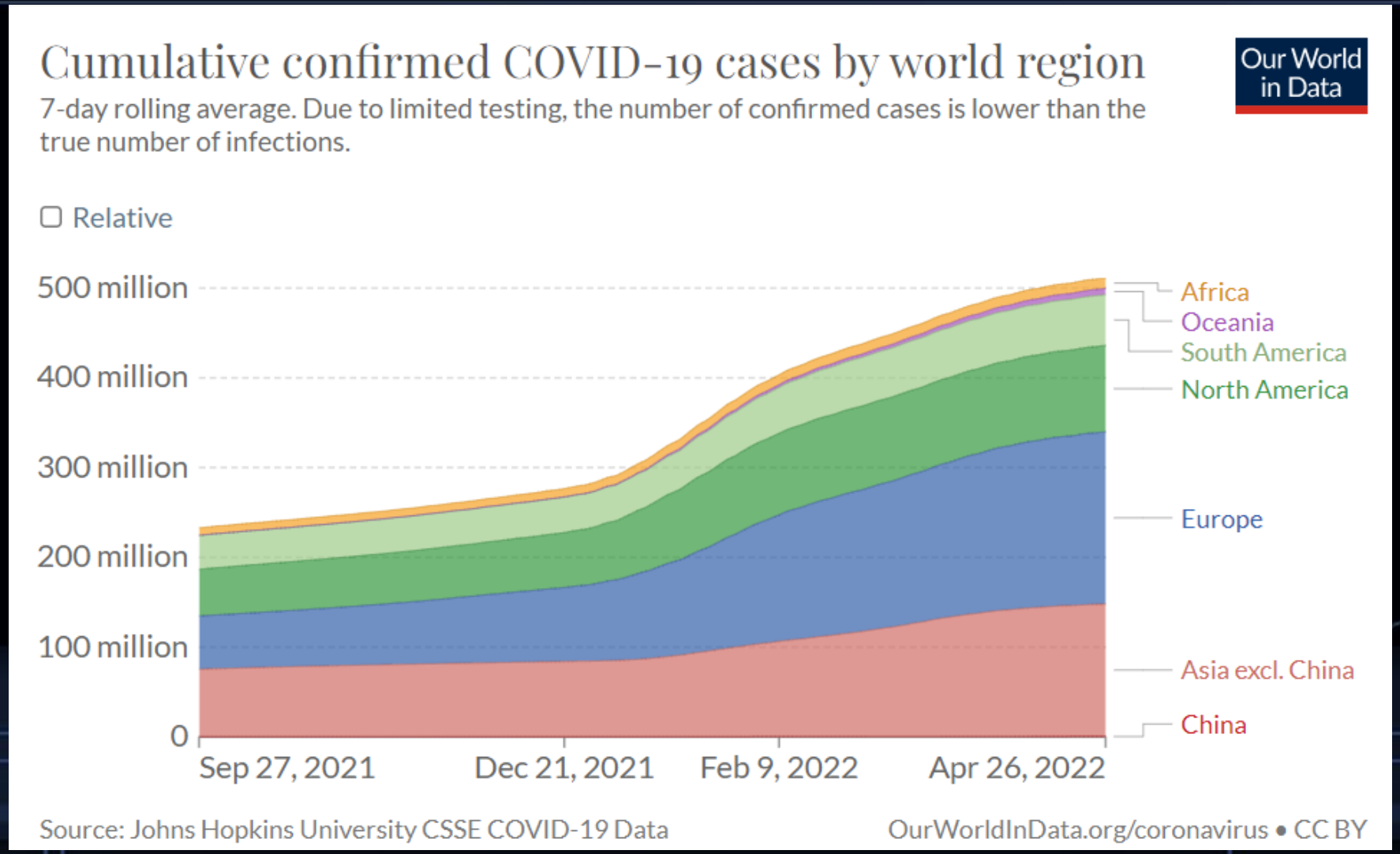


A



https://www.nature.com/collections/hajgidghjb/

Worldwide COVID-19 at the end of 2021



https://ourworldindata.org/grapher/cumulative-covid-cases-region?time=2021-09-27..2022-04-26

Questions?

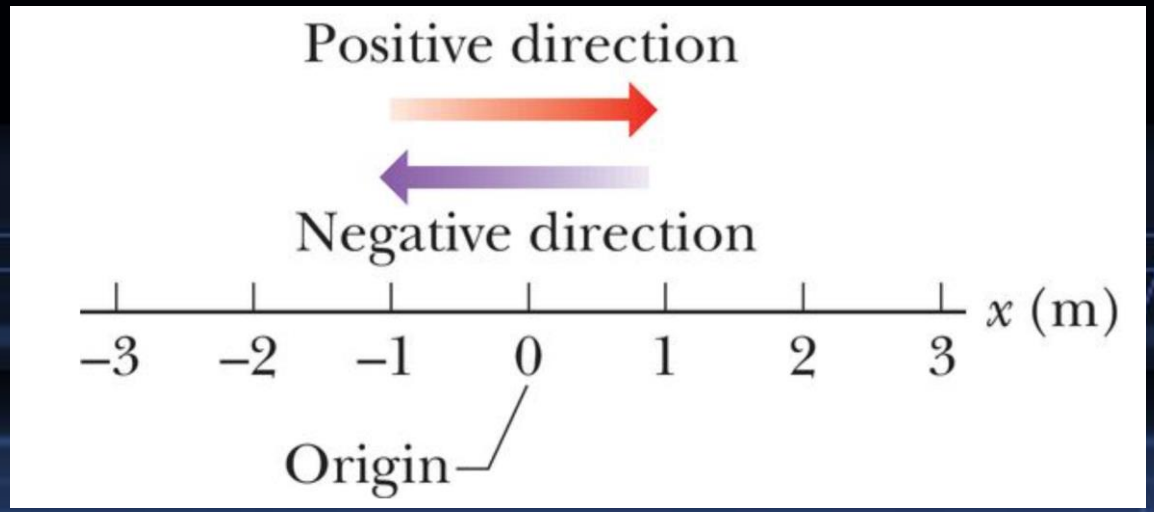
Motion in one dimension

- One of the simplest dynamical system: motion in 1D
- Physical quantities that we are interested in to describe the motion of an object along a straight line:

position, velocity, and acceleration.

Position and displacement

- Position: the location of the object relative to reference point, often the origin of an axis.
- Displacement: A change from position x_1 to position x_2 is called a displacement $\Delta x = x_2 - x_1$ (a vector, the sign is its direction)



Change of position as function of time

- We use position vs. time to represent the motion of an object.

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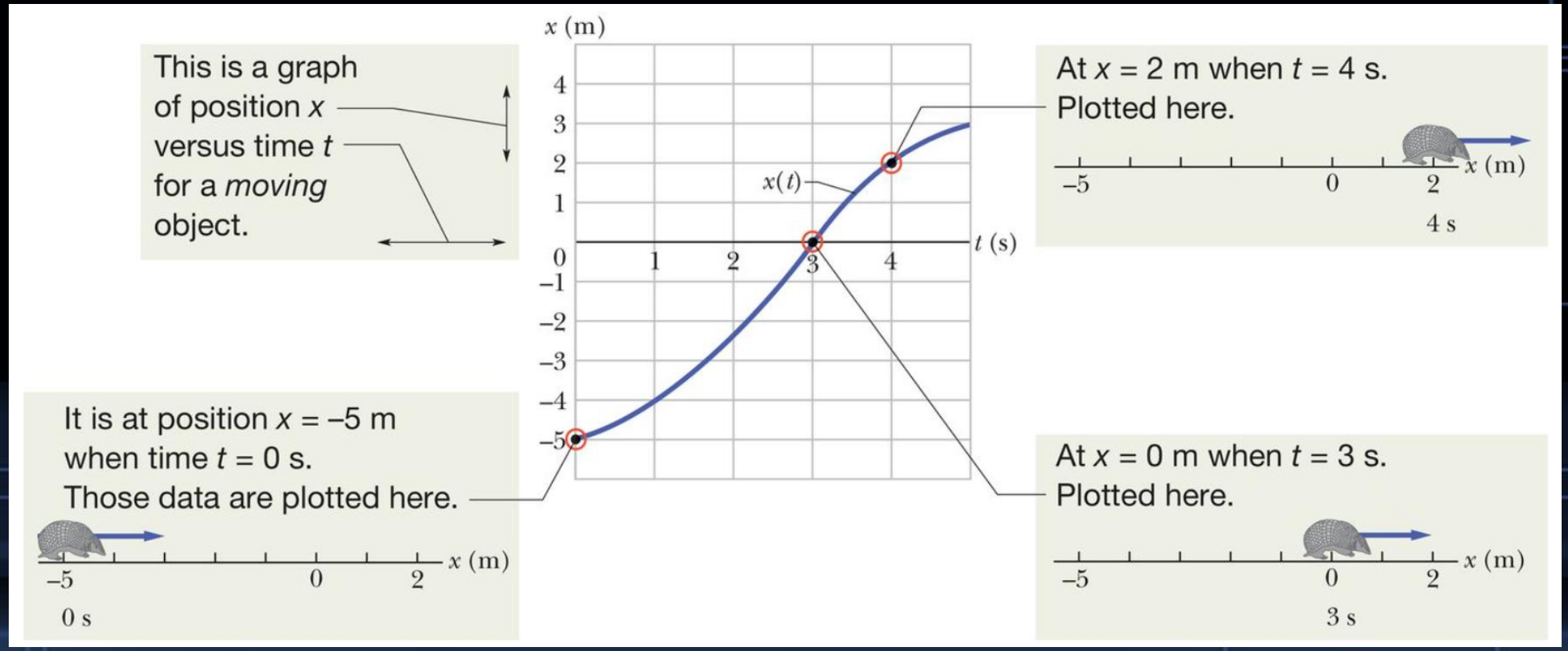


Average velocity and average speed

- Average velocity: ratio of displacement Δx that occurs during a period time to the interval of time Δt: (a vector)

$$v_{\text{avg}} = \frac{\Delta x}{\Delta t} = \frac{x_2 - x_1}{t_2 - t_1}$$

- Average speed: ratio of total distance of the object travels, independent of direction, that occurs during a period time to the interval of time Δt: (a scalar)

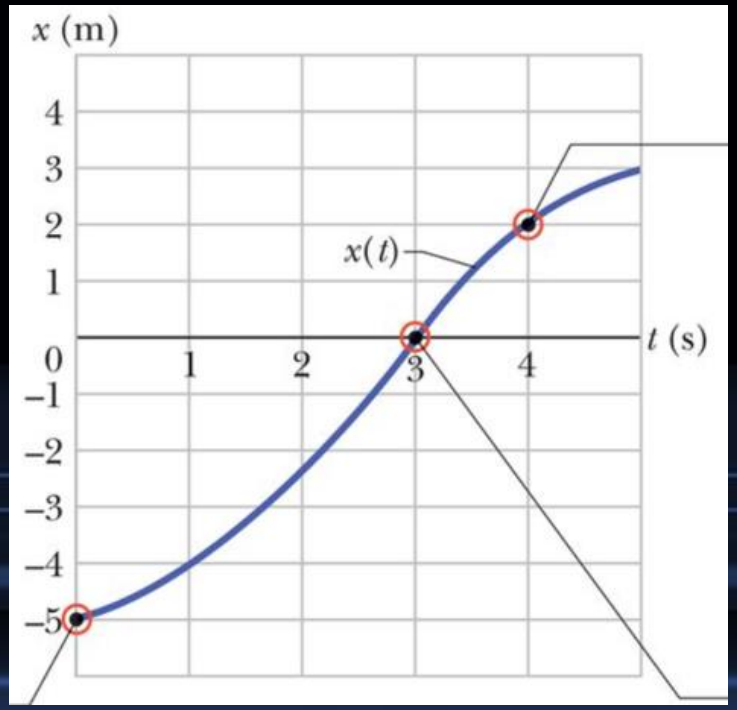
$$S_{\text{avg}} = \frac{\text{total distance}}{\Delta t}$$

Think about it

- In the case of the armadillo moving along x-axis.

What is average velocity from 1st second to 4th second?

What is average speed from 1st second to 4th second?



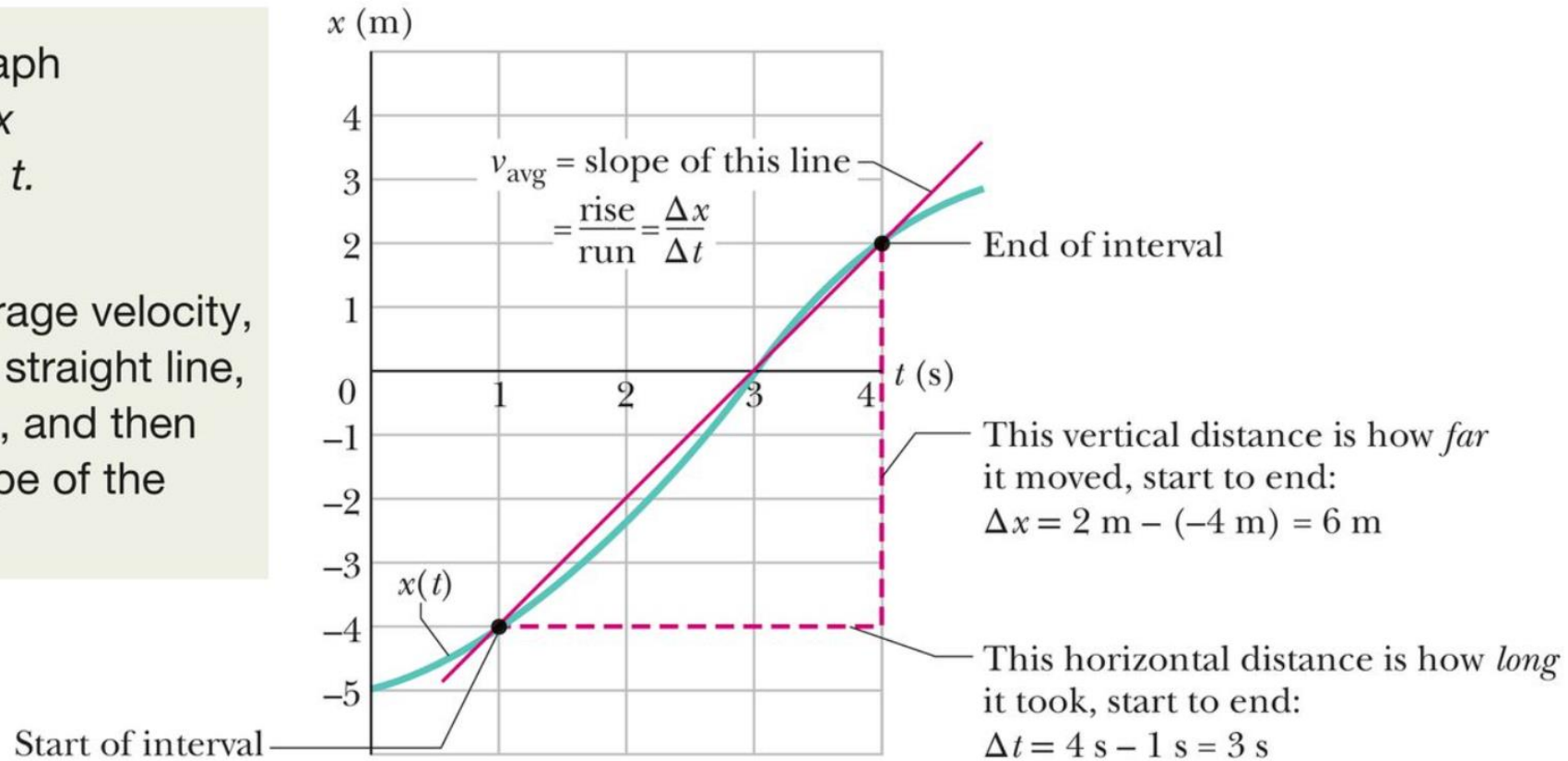
Average velocity and average speed

$$v_{\text{avg}} = \frac{\Delta x}{\Delta t} = \frac{x_2 - x_1}{t_2 - t_1}$$

$$S_{\text{avg}} = \frac{\text{total distance}}{\Delta t}$$

This is a graph of position *x* versus time *t*.

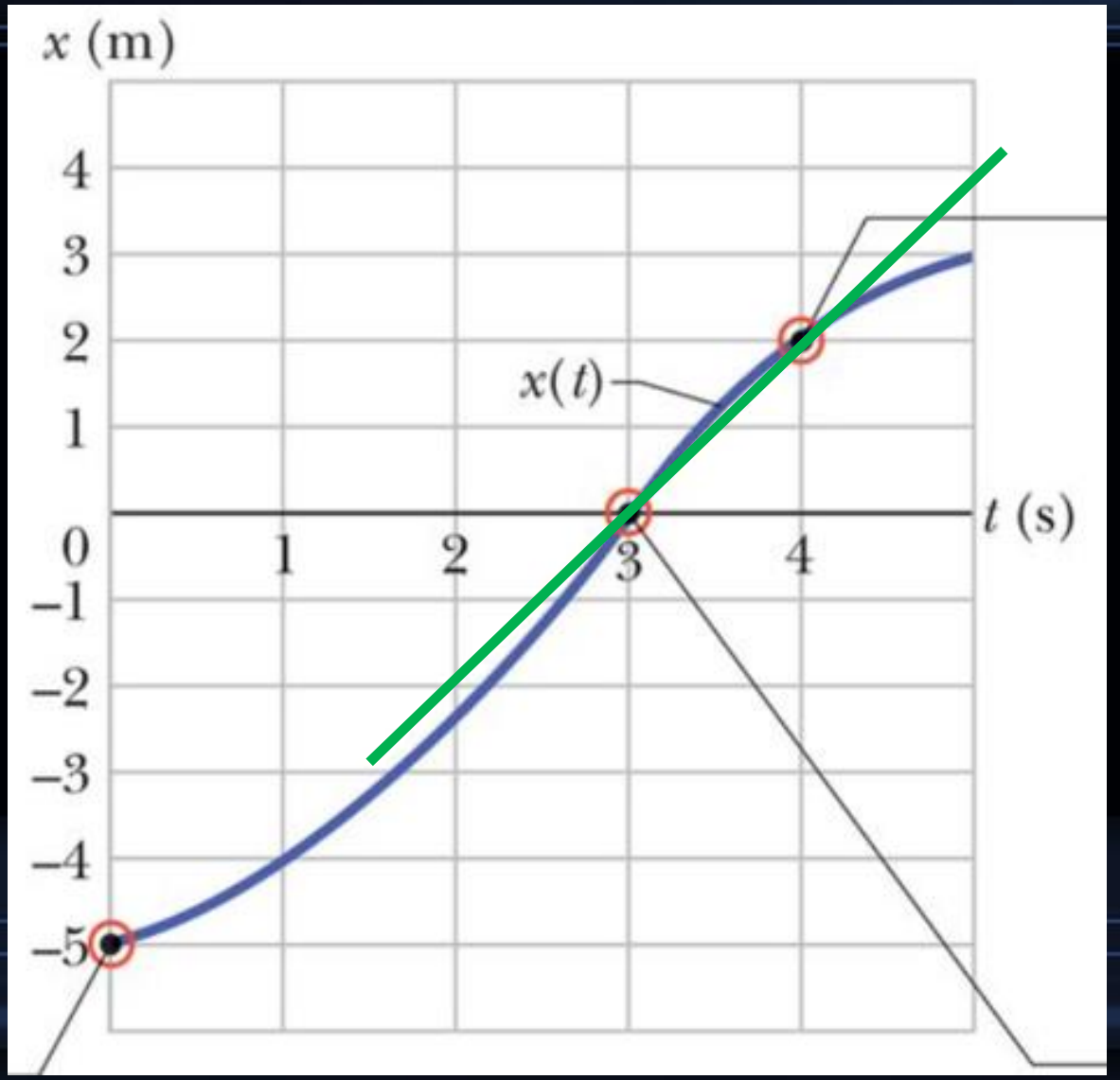
To find average velocity, first draw a straight line, start to end, and then find the slope of the line.

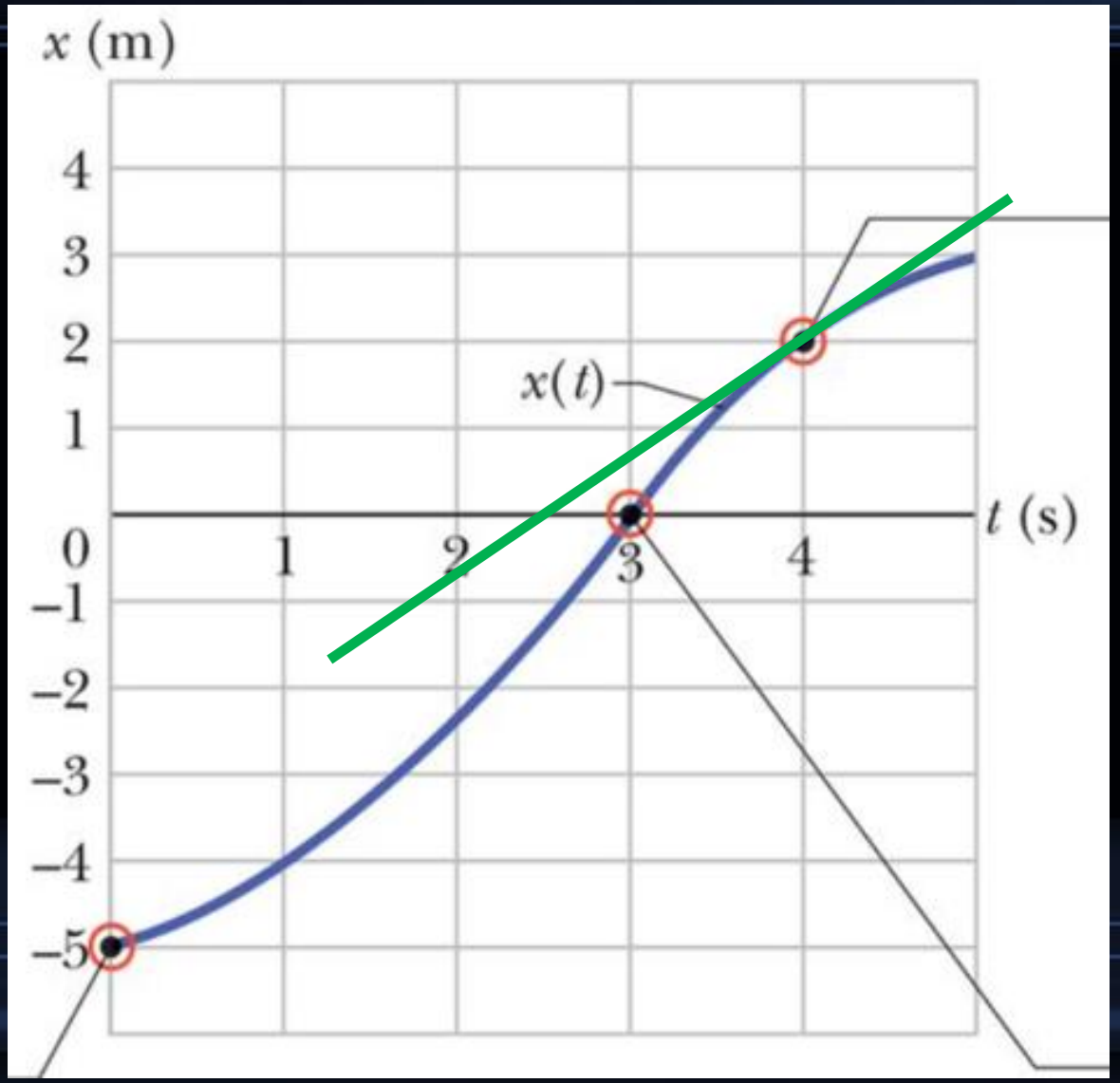


Instantaneous velocity and speed

- Instantaneous velocity: the average velocity by shrinking the time interval Δt closer and closer to 0.

$$v = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t} = \frac{dx}{dt}$$


x (m)
4
3
2
1
0
−1
−2
−3
−4
−5
x(t)
1
2
3
4
t (s)


x (m)
4
3
2
1
0
−1
−2
−3
−4
−5
x(t)
t (s)
1
2
3
4

Acceleration

- Average acceleration: change of velocity Δv over a time interval Δt.

$$a_{\text{avg}} = \frac{v_2 - v_1}{t_2 - t_1} = \frac{\Delta v}{\Delta t};$$

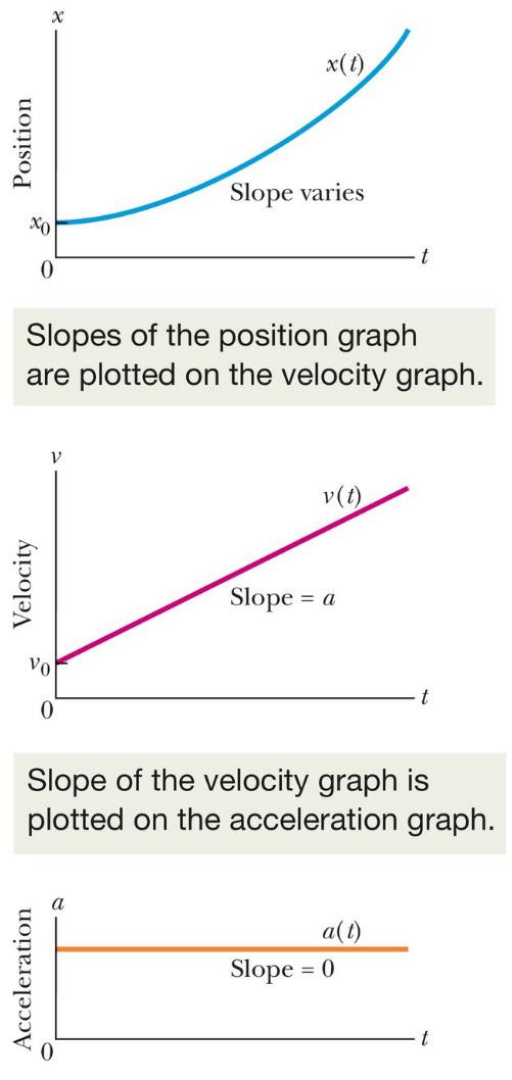
- Instantaneous acceleration(or simply acceleration) : change of velocity Δv over a time interval Δt nearly 0

$$a = \frac{dv}{dt} = \frac{d}{dt}\left(\frac{dx}{dt}\right) = \frac{d^2x}{dt^2}$$

Constant acceleration motion

- When acceleration is constant, we have:

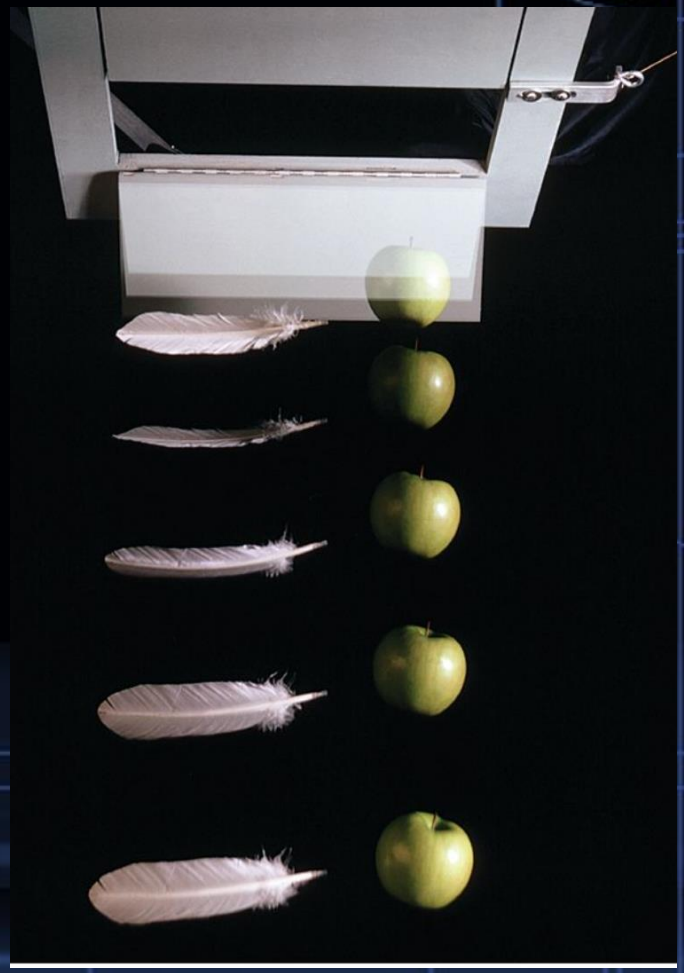
Equation	Missing Quantity
$v = v_0 + at$	$x - x_0$
$x - x_0 = v_0 t + \frac{1}{2}at^2$	v
$v^2 = v_0^2 + 2a(x - x_0)$	t
$x - x_0 = \frac{1}{2}(v_0 + v)t$	a
$x - x_0 = vt - \frac{1}{2}at^2$	v_0



Free fall acceleration

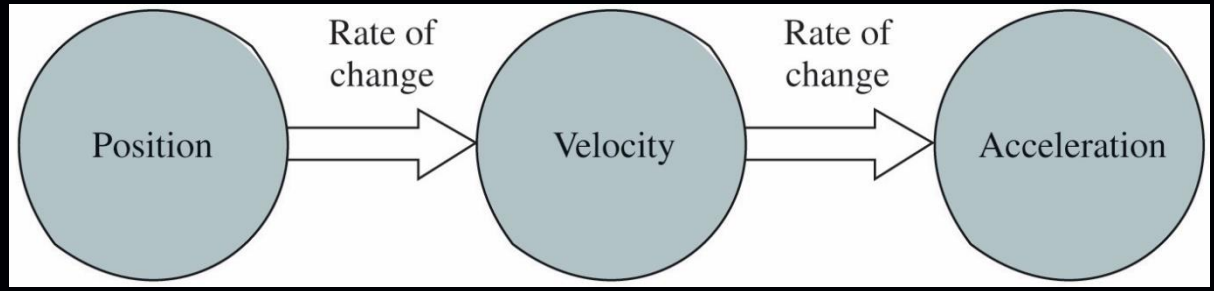
- If you tossed an object either up or down and could somehow eliminate the effects of air on its flight, you would find that the object accelerates downward at a certain constant rate. That rate is called the free-fall acceleration, and its magnitude is represented by g.

$$g = 9.8\ \mathrm{m/s^2}$$



Summary

- Position, velocity, and acceleration are the quantities that characterize motion:
  - Velocity is the rate of change of position.
  - Acceleration is the rate of change of velocity.



- When acceleration is constant, simple equations relate position, velocity, acceleration, and time.
  - An important case is the acceleration due to gravity near Earth's surface, where we set

$$g = 9.8\ \mathrm{m/s^2}$$

Equation	Missing Quantity
$v = v_0 + at$	$x - x_0$
$x - x_0 = v_0 t + \frac{1}{2}at^2$	v
$v^2 = v_0^2 + 2a\,(x - x_0)$	t
$x - x_0 = \frac{1}{2}(v_0 + v)\,t$	a
$x - x_0 = vt - \frac{1}{2}at^2$	v_0