hi

Lecture 2

accelerated motion, momentum, and force

housekeeping

Remember:

MasteringPhysics! Facebook Group!

Homework posted Saturday!

Manuscript:

chapters 2, *Tools*, and *Motion* are up at

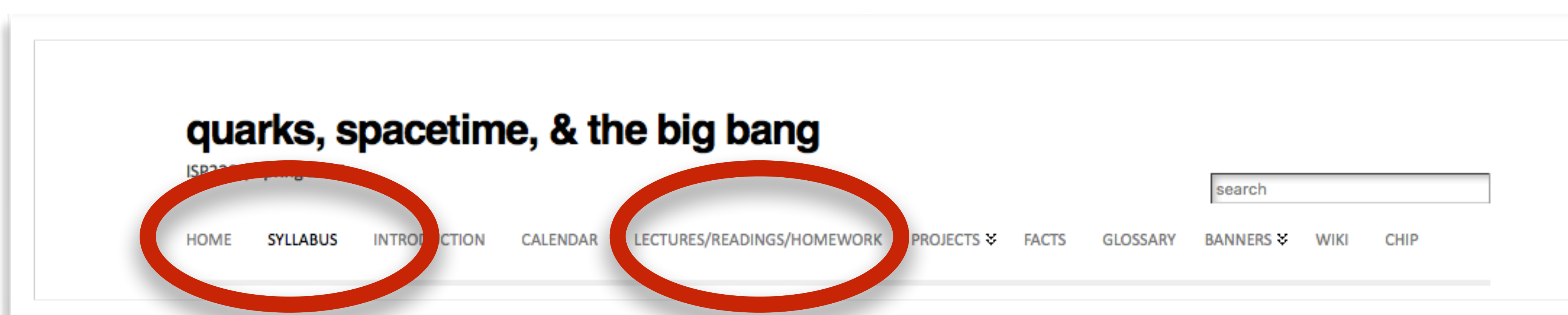
`http://www.chipbrock.org/details/#head1234`

Remember

Did I mention the syllabus and LECTURES/READINGS/HOMEWORK tabs?? http://www.chipbrock.org/

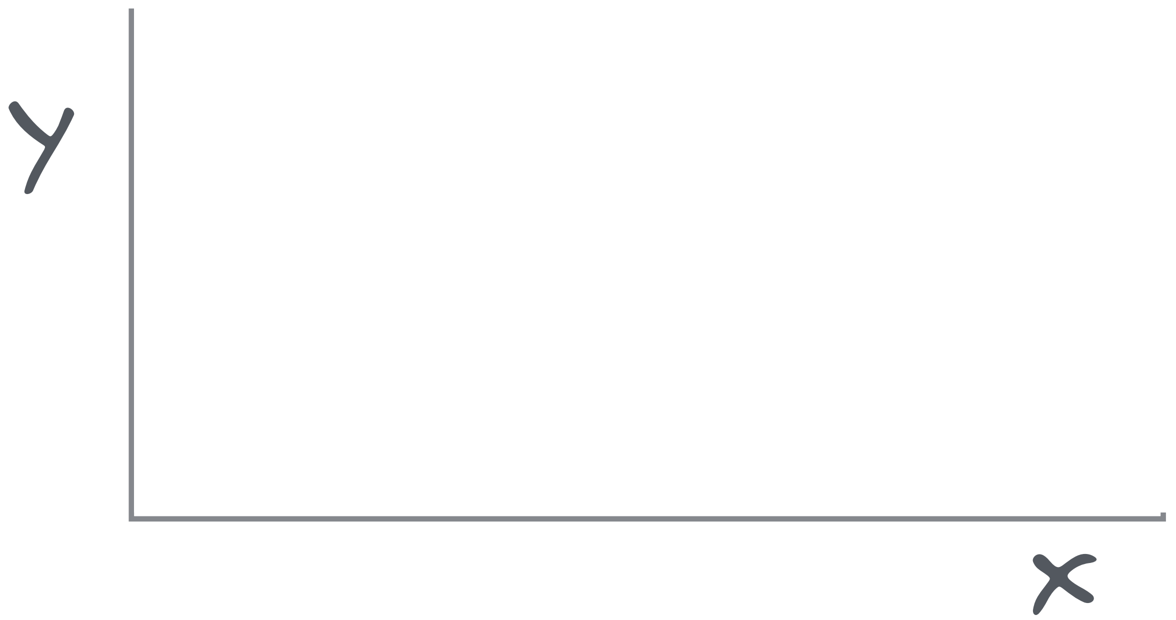
stats:

22 F, 37 S, 23 J, 14 S

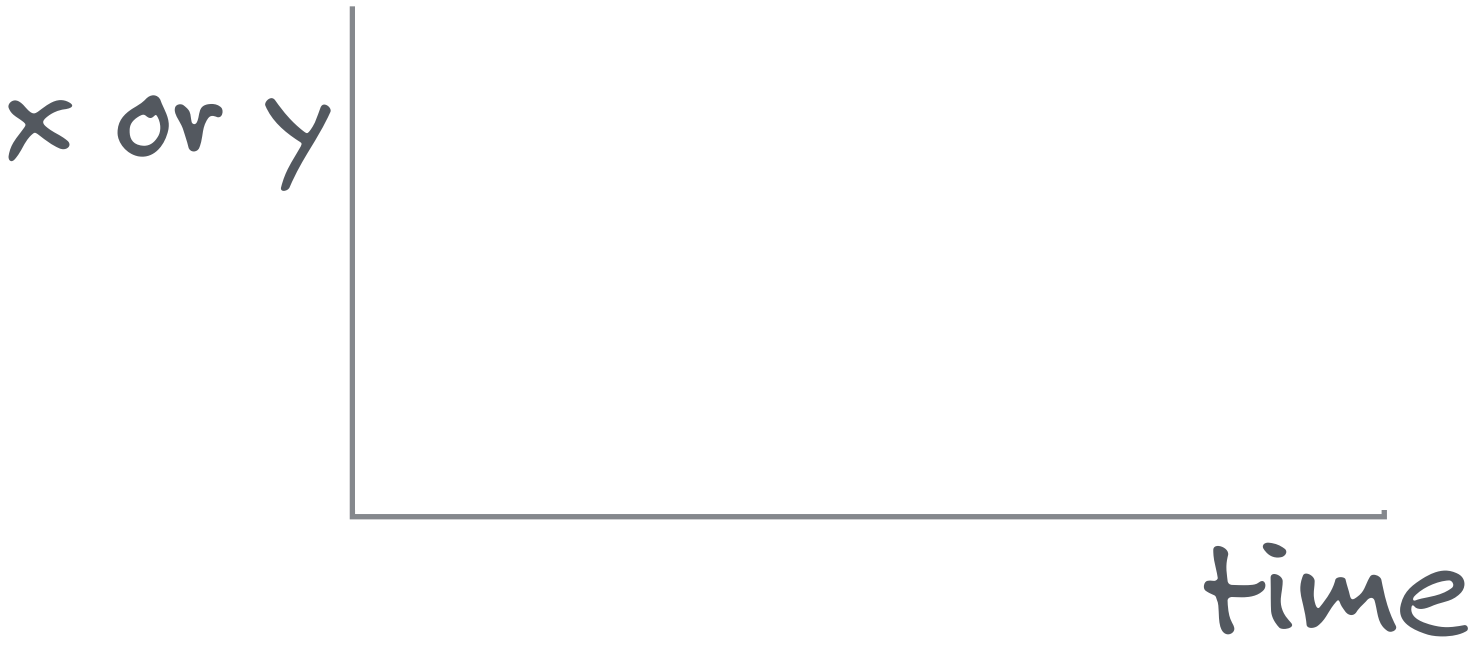


3 kinds of graphs

Space Diagrams



Spacetime Diagrams

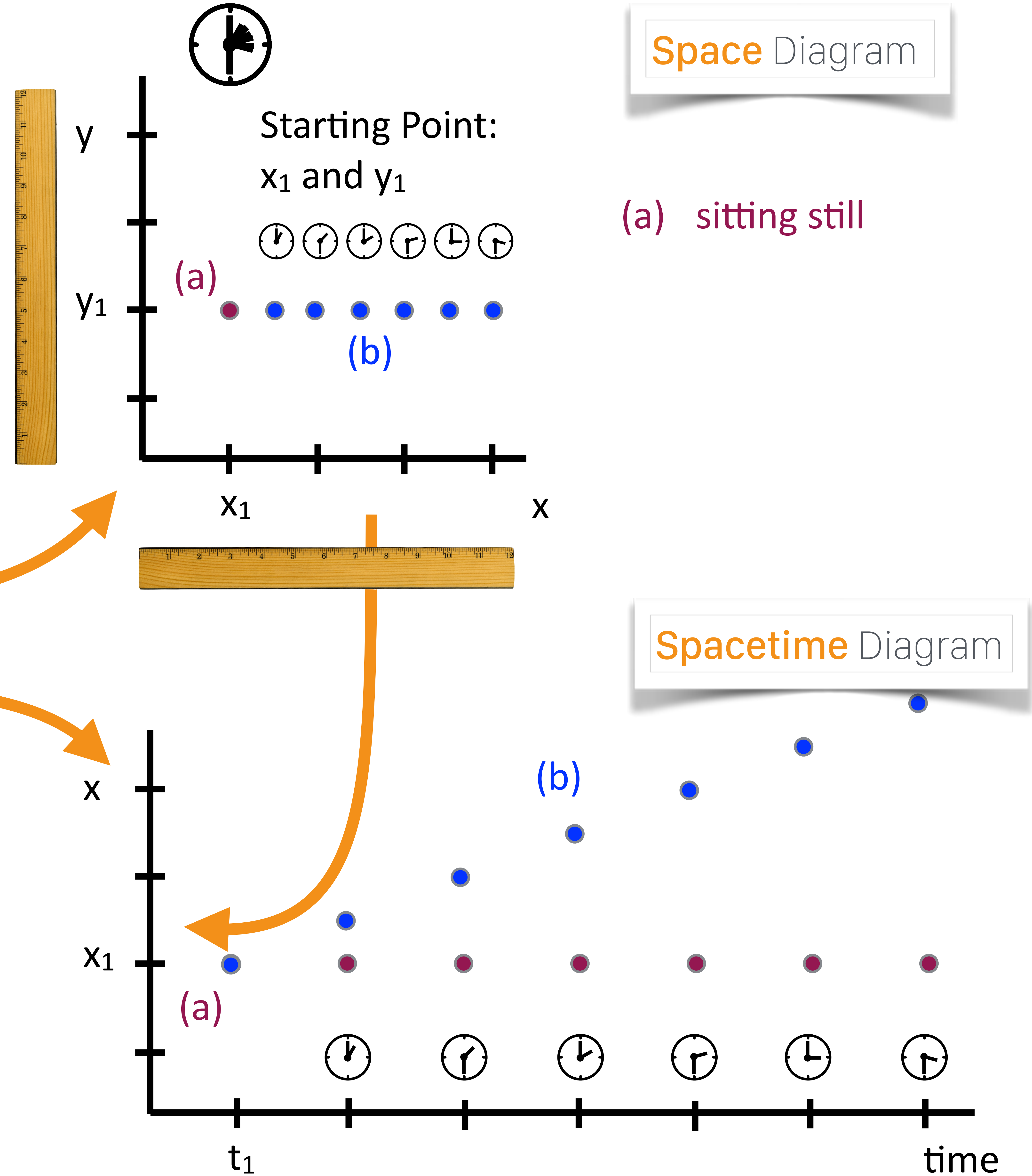


a third one…

take snapshots of something moving and report the results in 2 ways

space v space

space v time



we'll use functions...remember

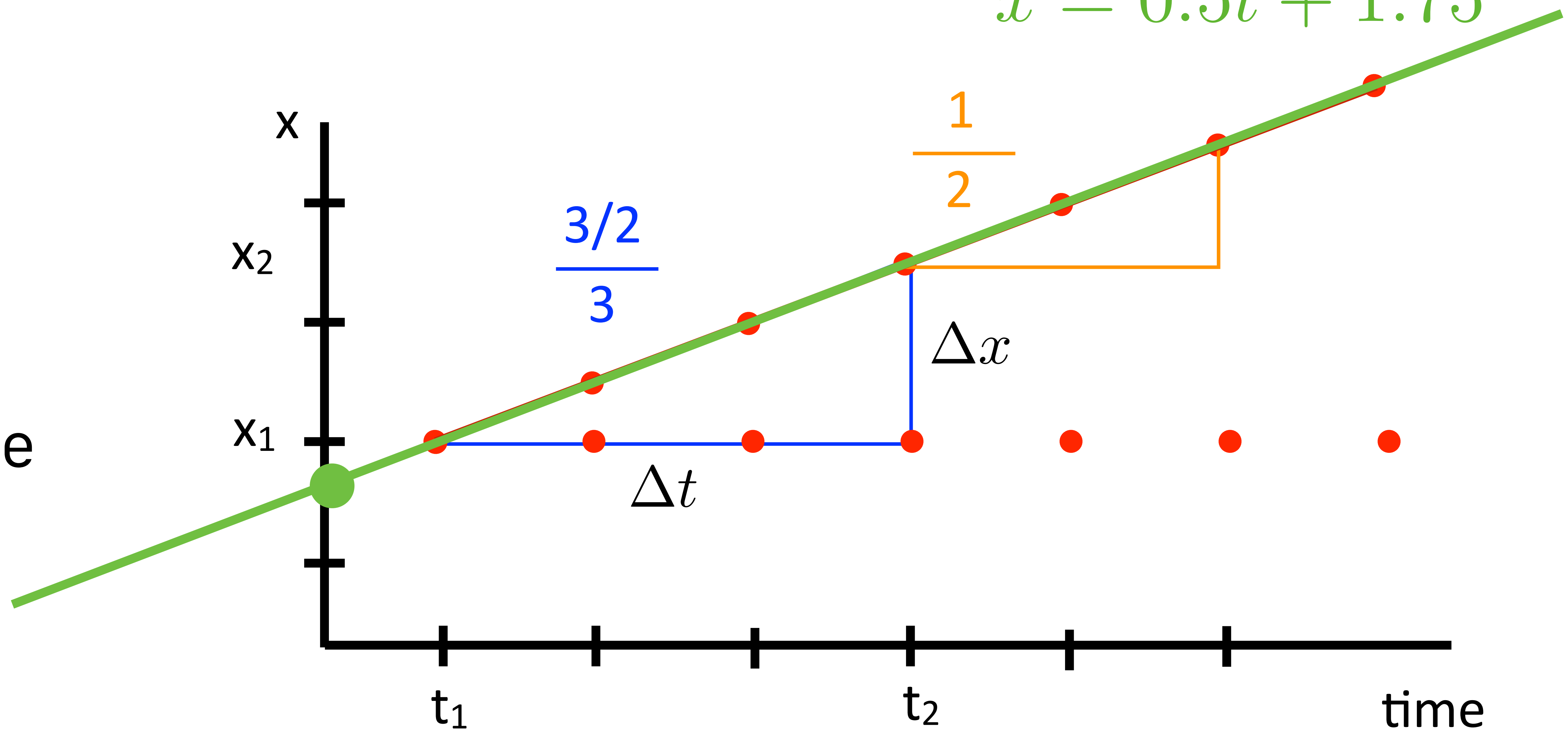
"$y = mx + b$" ?

$x = vt + b$

$x = 0.5t + 1.75$

Speed

Distance over time



$$v = \text{speed} = \frac{x_2 - x_1}{t_2 - t_1} = \frac{\Delta x}{\Delta t}$$

the slope of the x-t curve

"v" for "velocity"
(stay tuned)

Velocity is the change of distance in time:

$$v = \frac{\Delta x}{\Delta t}$$

kinds of motion

in time:

constant speed: "uniform motion"

changing speed: "accelerated motion"

changing speed at constant rate: "uniformly accelerated motion"

many times

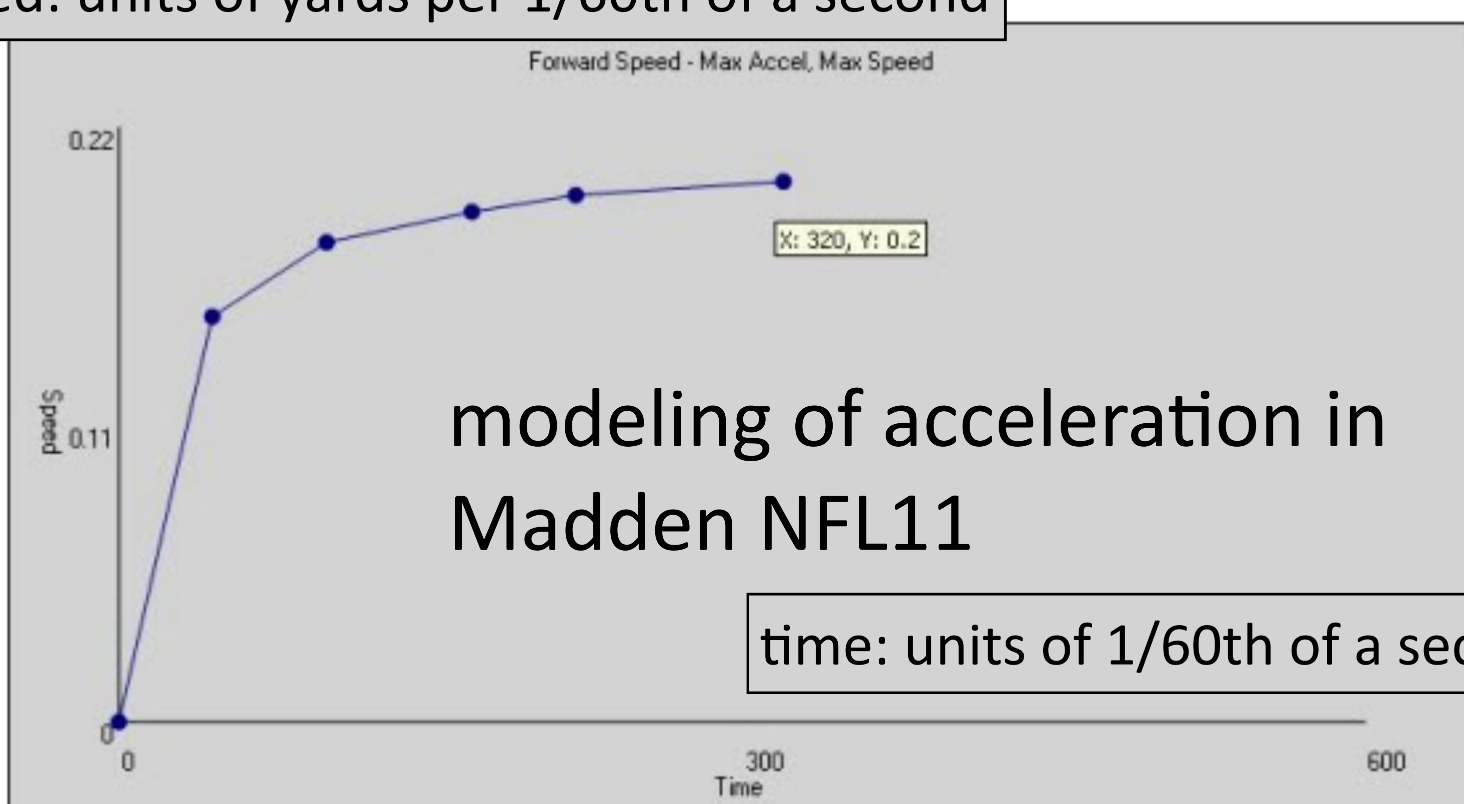
we deal with constant acceleration

the rate at which the velocity increases is constant

not all acceleration

is constant

speed: units of yards per 1/60th of a second

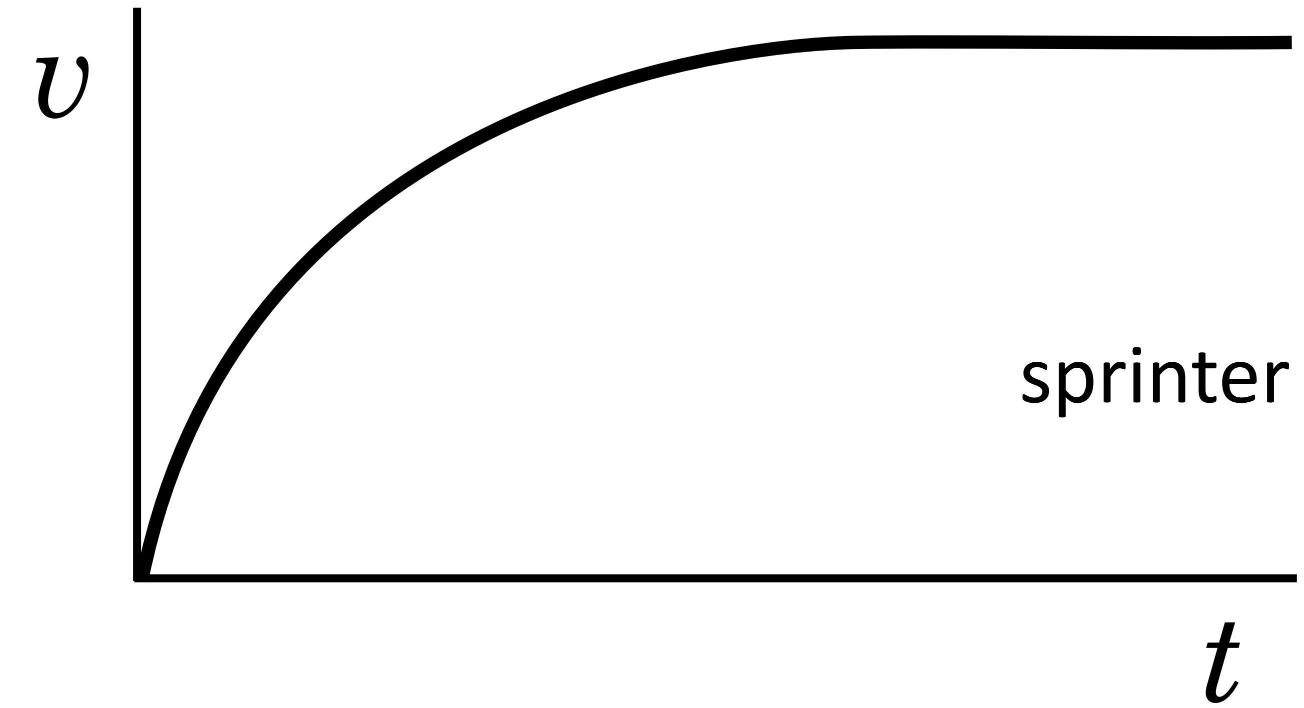


modeling of acceleration in Madden NFL11

time: units of 1/60th of a second

http://www.operationsports.com/ncaa/utopia/topic/69752-madden-nfl-11-locomotion/

It often varies in time.



Historically: constant acceleration was understood first.

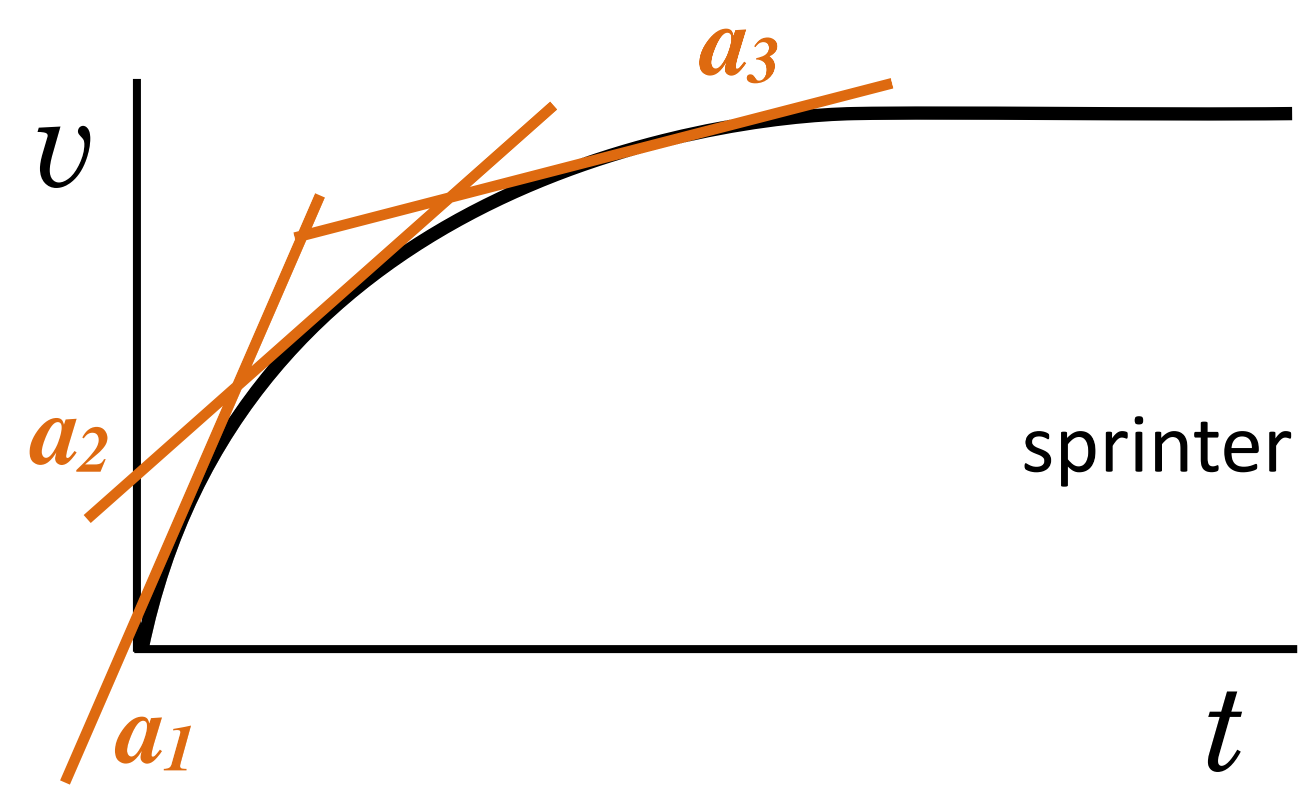
acceleration

In the same sense that $v = \dfrac{\Delta x}{\Delta t}$

Acceleration is the change of velocity in time:

$$a = \frac{\Delta v}{\Delta t}$$

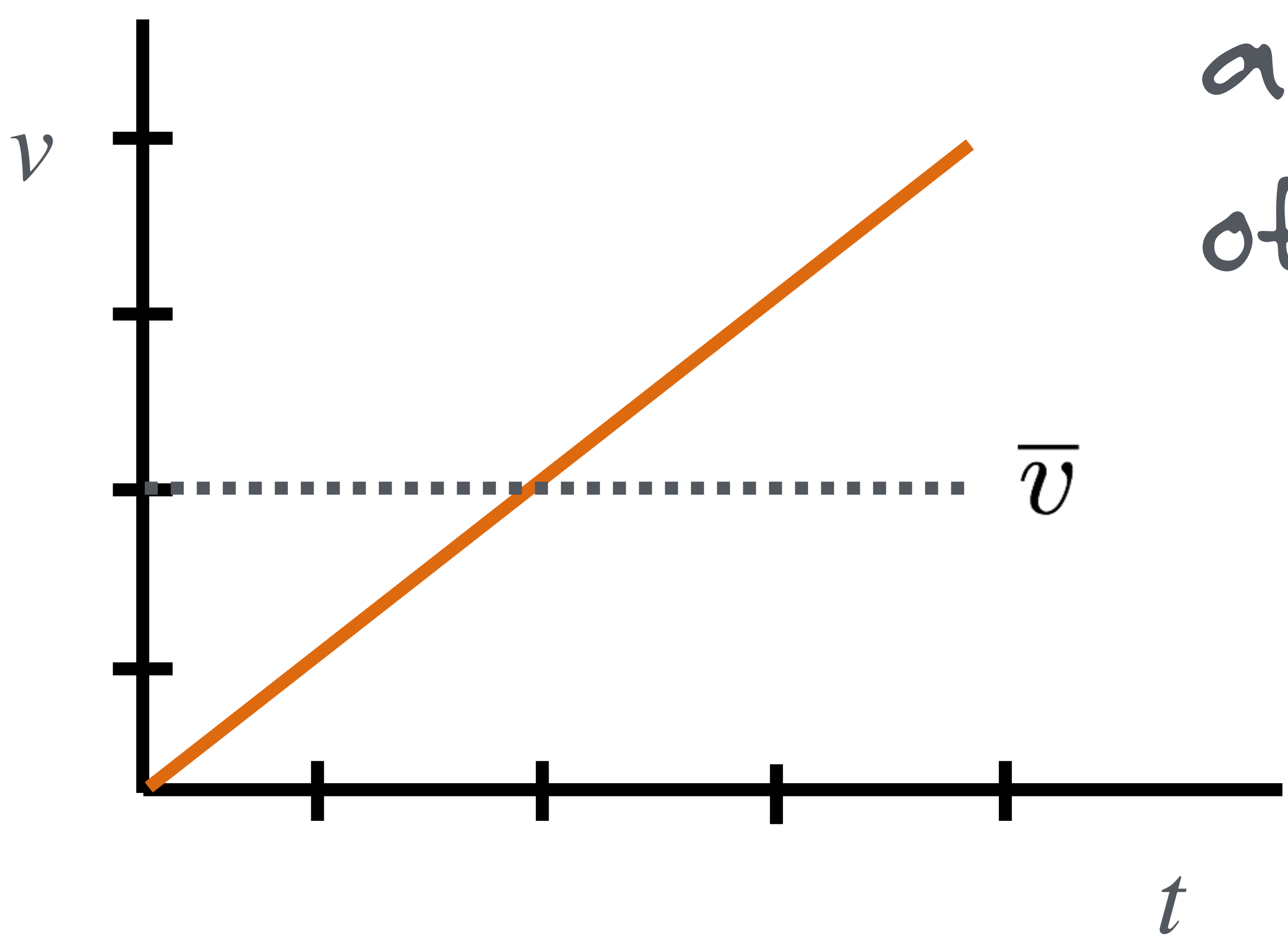
also a geometrical interpretation as a slope:



Velocity increases? **Acceleration...**Velocity decreases? **Deceleration**

constant acceleration

is special



acceleration is also the slope of this...it's constant

If. Acceleration is constant, then we deal in the average:

Then the average velocity = $\overline{v} = \dfrac{v_1 + v_2}{2}$

my favorite airplane

To get to speed, it needs to start from rest...and accelerate.

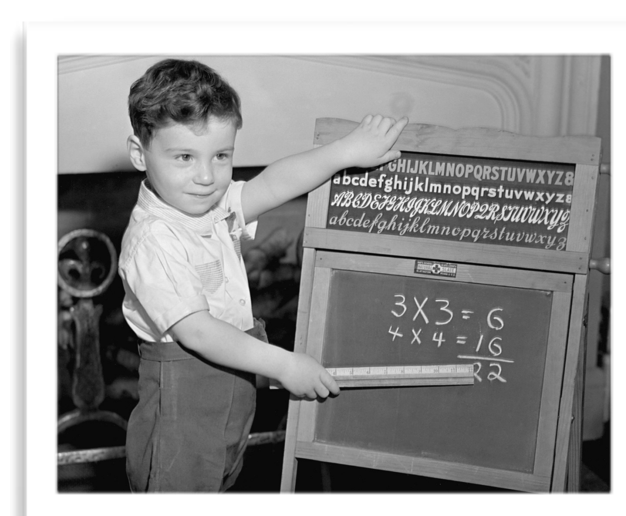
Need a force.

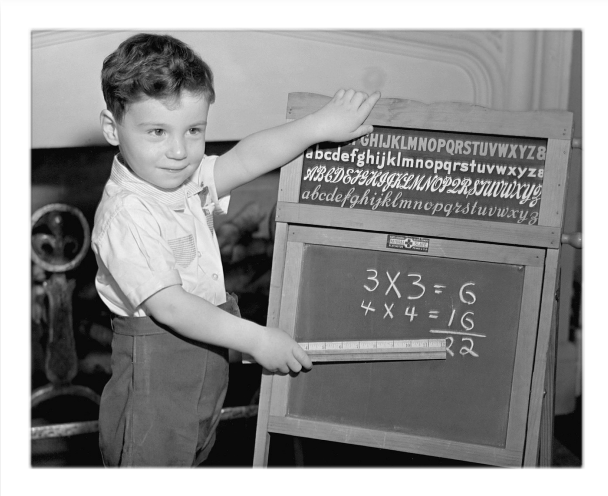
Airbus 330-300

After some time, it reaches "v1" and "vR"

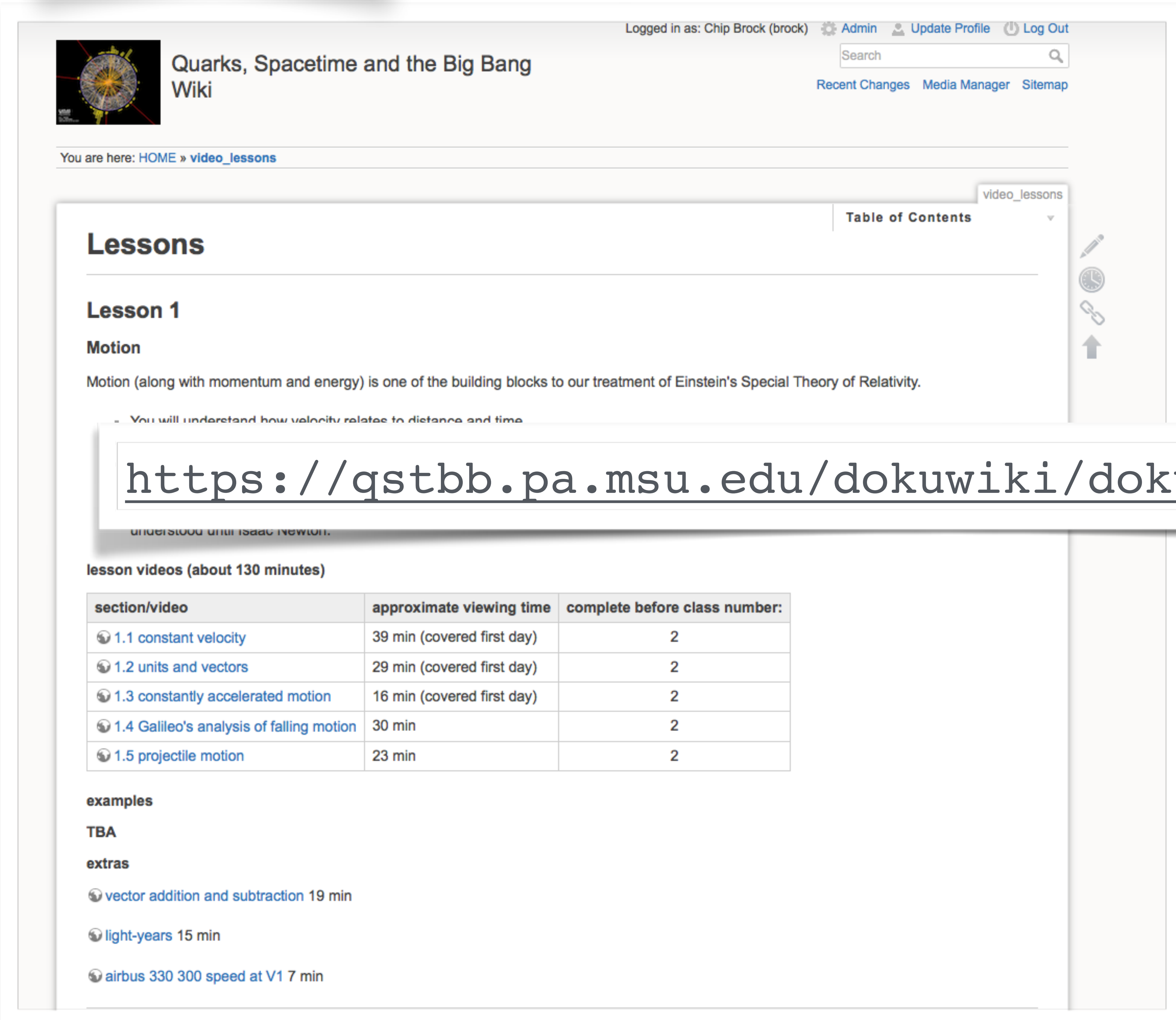
The runway is 6,000 feet.
Assume a constant acceleration.

What is the average speed to vR?
What is the actual speed at vR?





= in the video



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Lessons

Lesson 1

Motion

Motion (along with momentum and energy) is one of the building blocks to our treatment of Einstein's Special Theory of Relativity.

- You will understand how velocity relates to distance and time

understood until Isaac Newton.

lesson videos (about 130 minutes)

section/video	approximate viewing time	complete before class number:
1.1 constant velocity	39 min (covered first day)	2
1.2 units and vectors	29 min (covered first day)	2
1.3 constantly accelerated motion	16 min (covered first day)	2
1.4 Galileo's analysis of falling motion	30 min	2
1.5 projectile motion	23 min	2

examples

TBA

extras

vector addition and subtraction 19 min

light-years 15 min

airbus 330 300 speed at V1 7 min

https://qstbb.pa.msu.edu/dokuwiki/doku.php?id=video_lessons

buzz words

In Physics

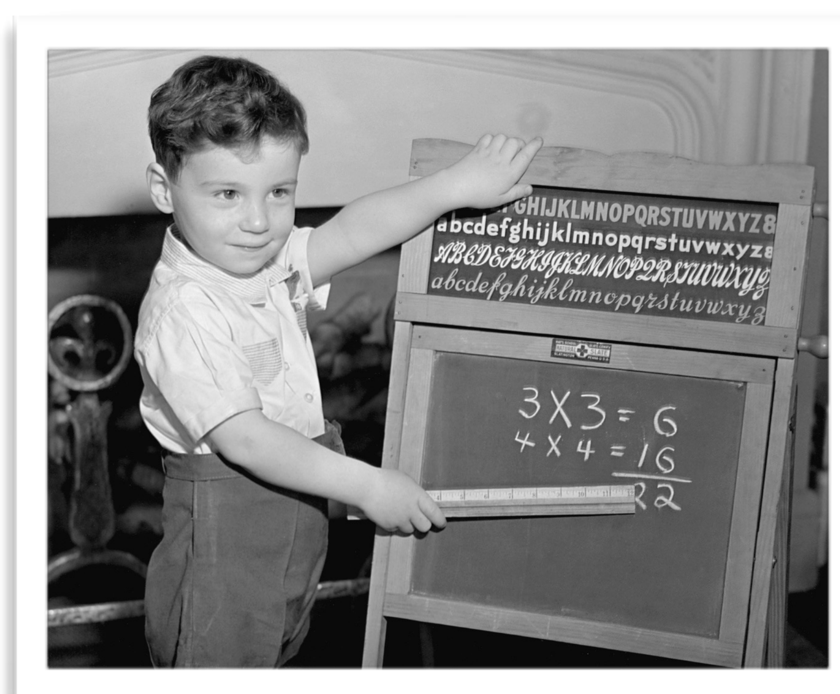
“kinematics” describes motion

“dynamics” describes the cause of motion (forces)

kinematics equations

for constant acceleration

$$v = \frac{\Delta x}{\Delta t} \qquad a = \frac{\Delta v}{\Delta t}$$



the equations of constant acceleration

$$a = \frac{v - v_0}{t - t_0}$$

t_0 typically set to 0

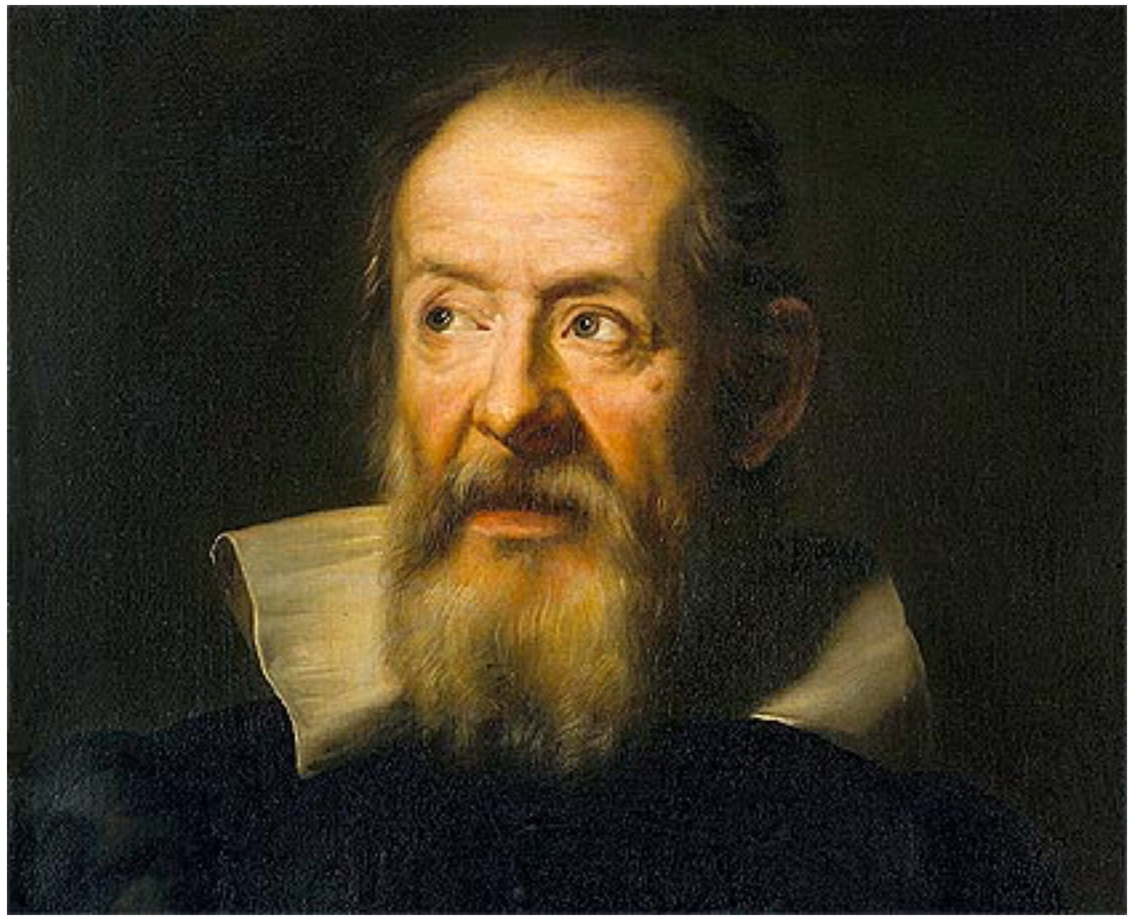
$$a = \frac{v - v_0}{t}$$

that's it

for any circumstance of constant acceleration

also historically important

Galileo Galilei



1564-1642

our first

Galileo Galilei

mathematician, natural scientist, astronomer

the first physicist

trouble-maker

how do things move?

Aristotle's insistence:

Always by direct contact with a pusher...unnatural motion

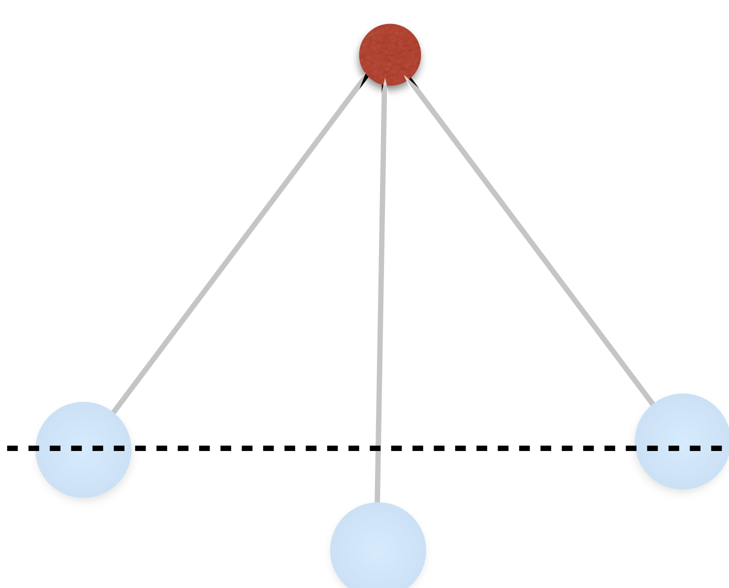
except for a planet, sun, or the moon...or by something falling: natural motion

Galileo's contention: moving objects have ax "quality"

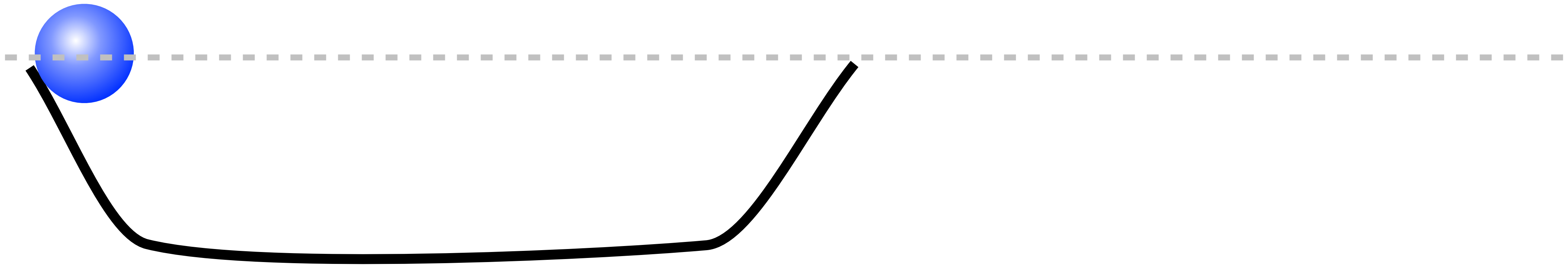
he couldn't be precise

`inspired by`

a simple pendulum



And:
period depends only
on length (and *g*)



Galileo asserted that if no force acts on something, it goes for ever….

So of course this is called "Newton's First Law."

Galileo's Big Scores

gravity

- objects fall at a constant acceleration
- **all** objects

distance: $$d = \frac{1}{2}at^2$$

speed: $$v = at$$

projectiles

- 2 motions

astronomy

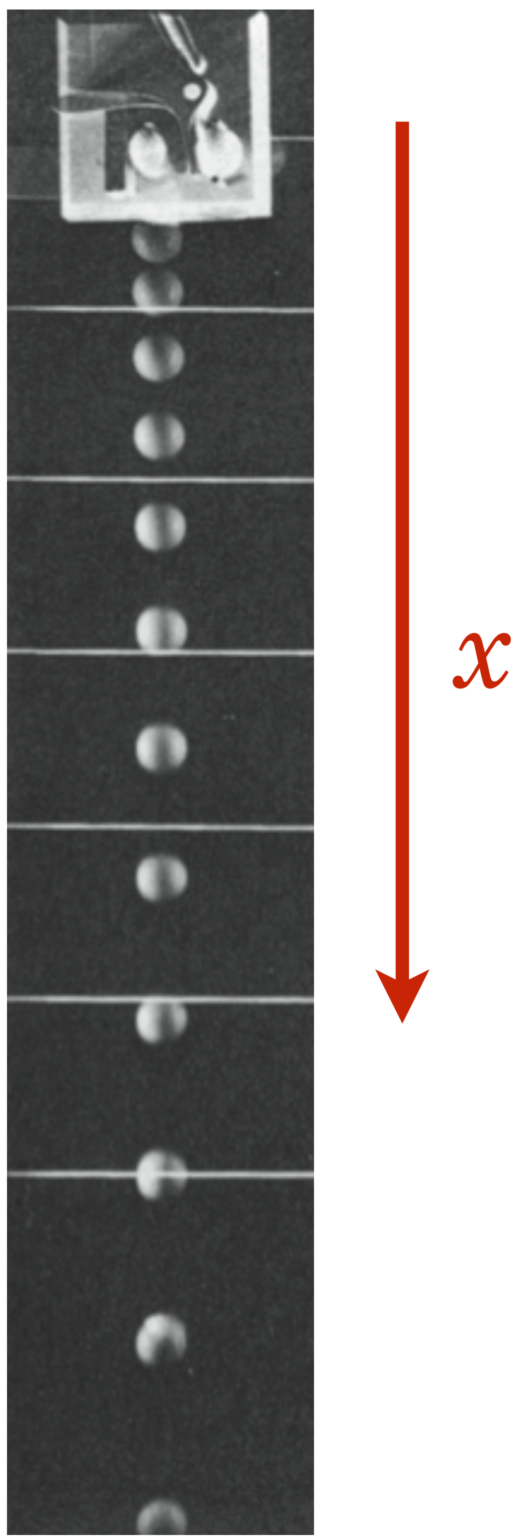
- lots…which we'll cover later

his ah-ha moment

measuring time was hard

near the Earth

strobe shows increasing distance with time



extrapolating to vertical fall...

From his ramp, Galileo's finding says, the distance traveled is:

$$x = \frac{1}{2}at^2$$

An old argument that then...gravity induces a constant acceleration,

Gravity near the Earth is a special acceleration!

little "*g*" is the symbol used for the gravitational acceleration near the surface of the Earth.

$$x = \frac{1}{2}gt^2$$

$g = 9.8 \text{ m/s}^2 = 32 \text{ ft/s}^2$

Aristotle has left the building

Galileo concluded that gravitation is

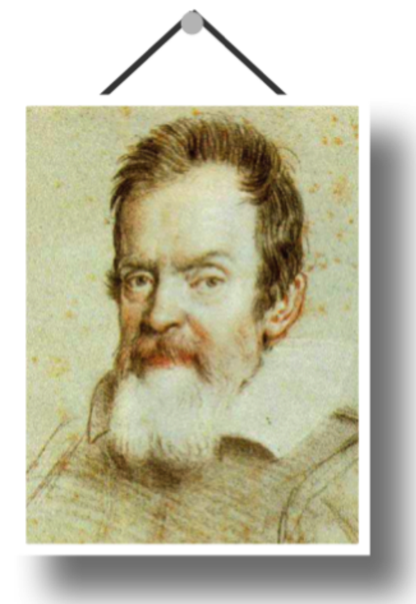
independent of the material object

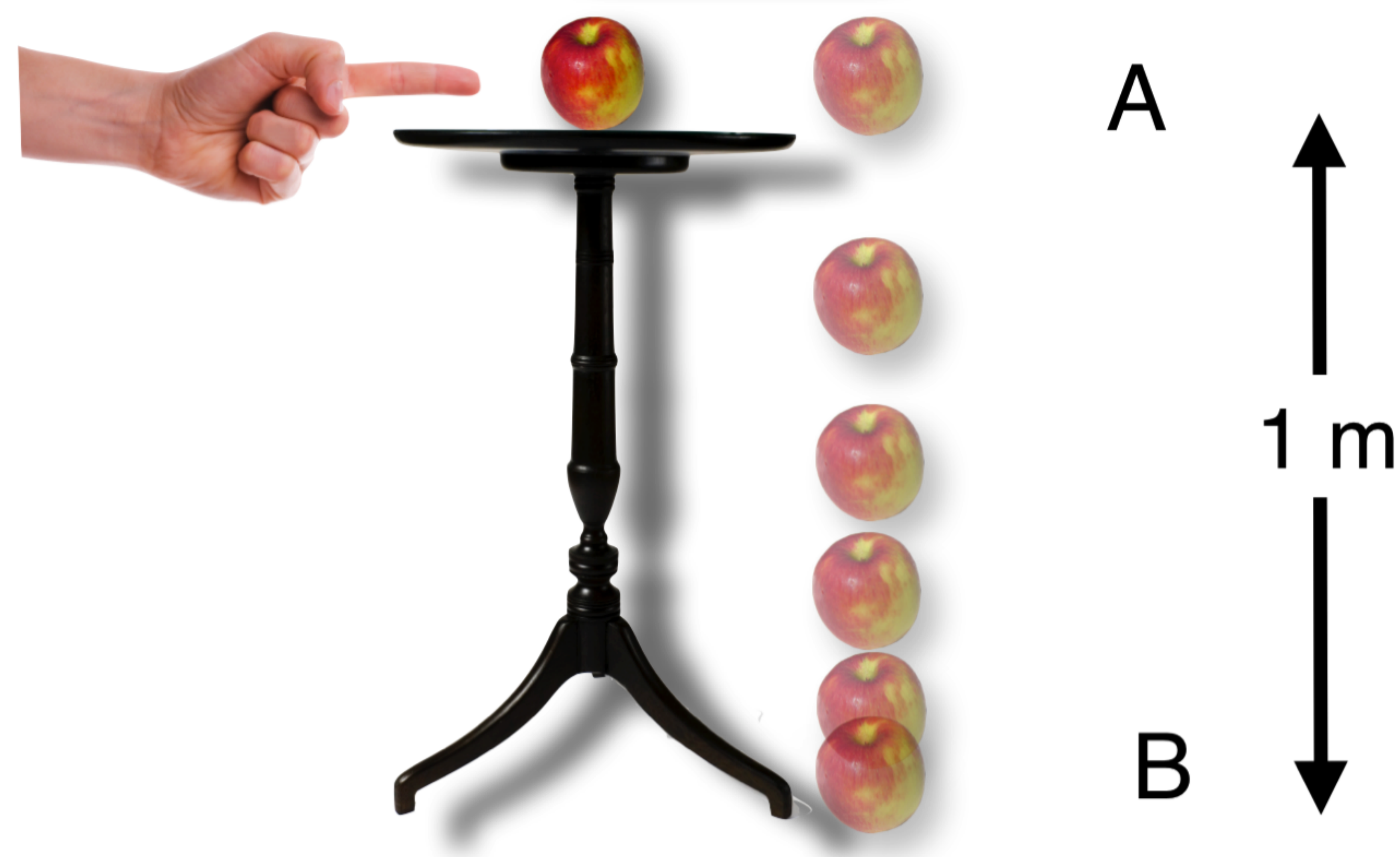
https://www.youtube.com/watch?v=E43-CfukEgs

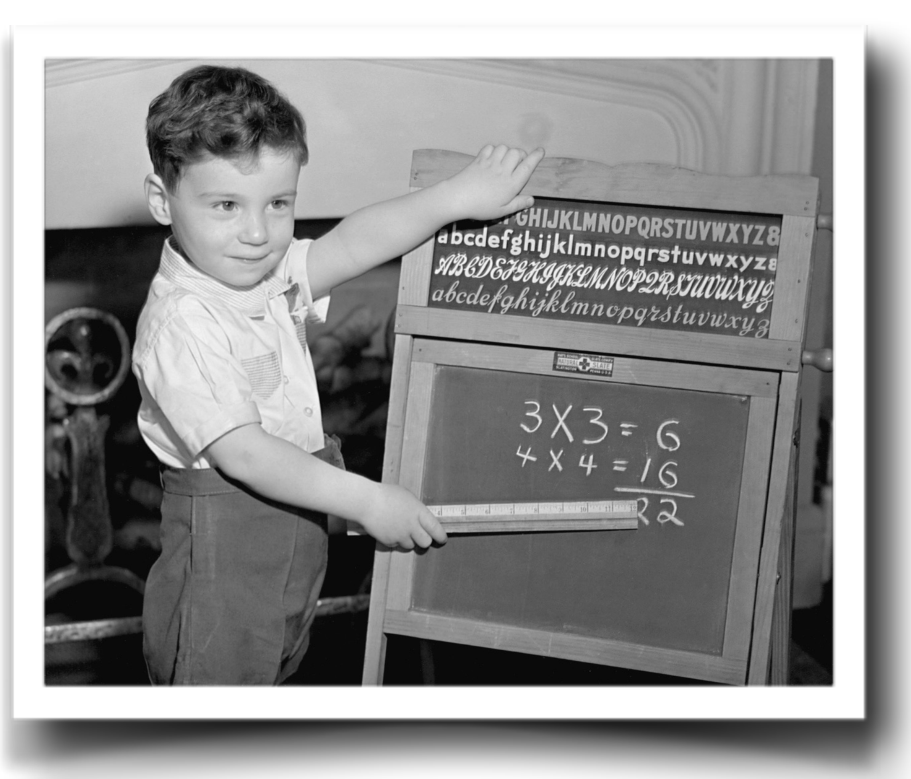
fruit

how fast just before the apple hits the ground?

m/s







vectors

reviewed in manuscript chapter 2

and in the video corresponding to lesson 1

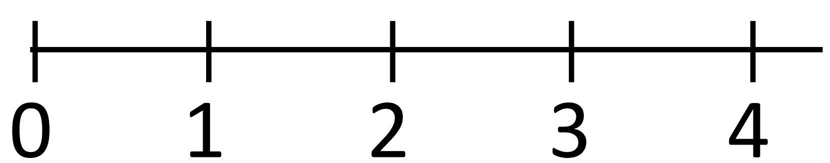
vectors

encode both magnitude and direction

in a single notation

words...unit vectors...drawn arrows ✓

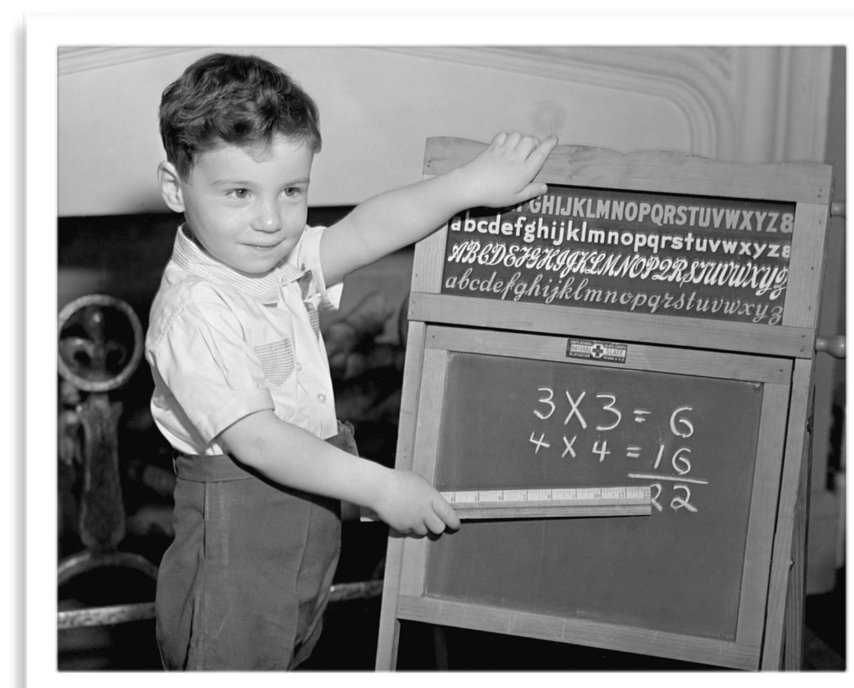
scale



ft, mi, m, km, furlongs, light years, ...

x or $\vec{x}$

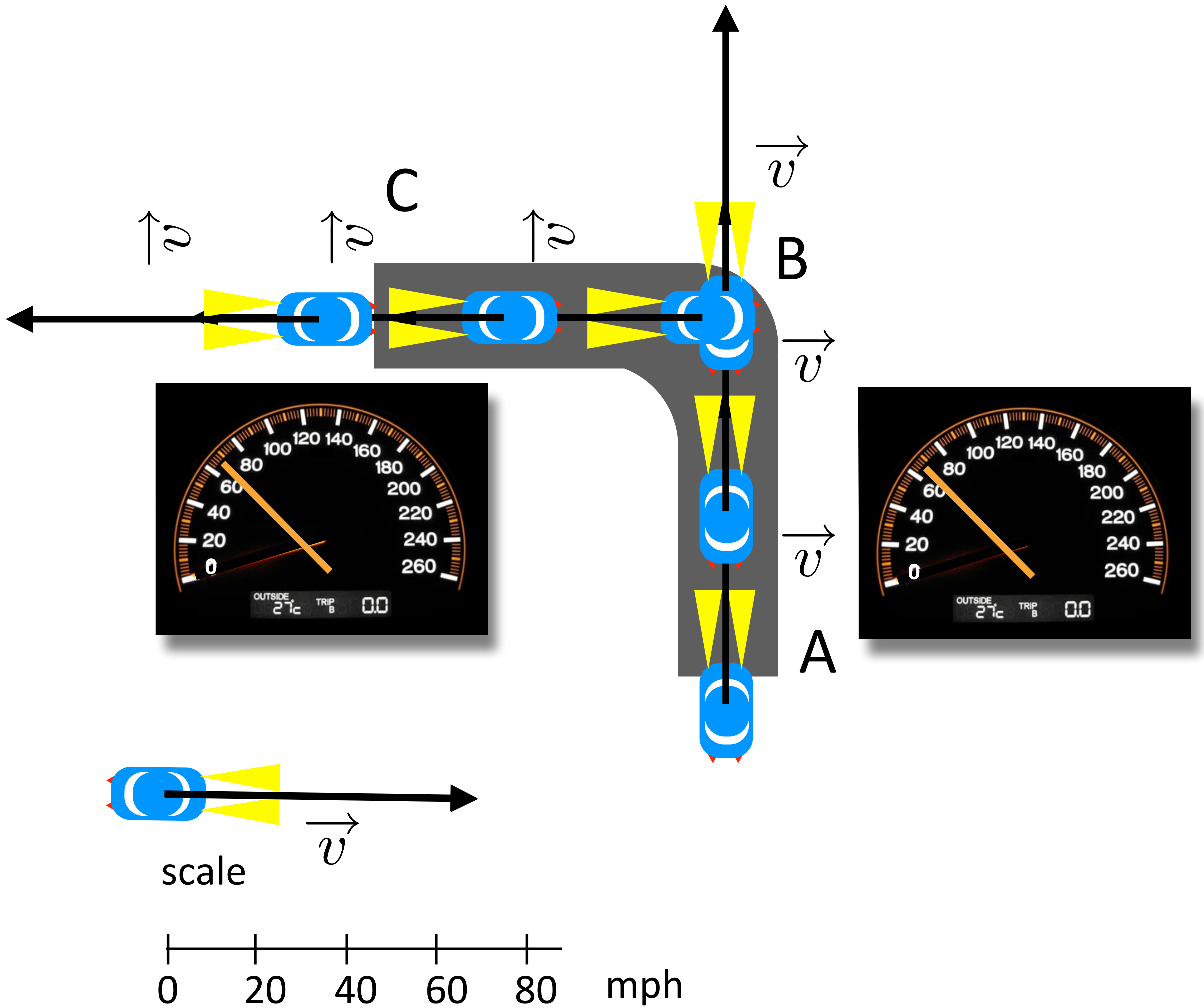
{ magnitude
direction



For distances: magnitude = distance
For velocities: magnitude = speed

see the arrows.

everywhere
you go



our vectors

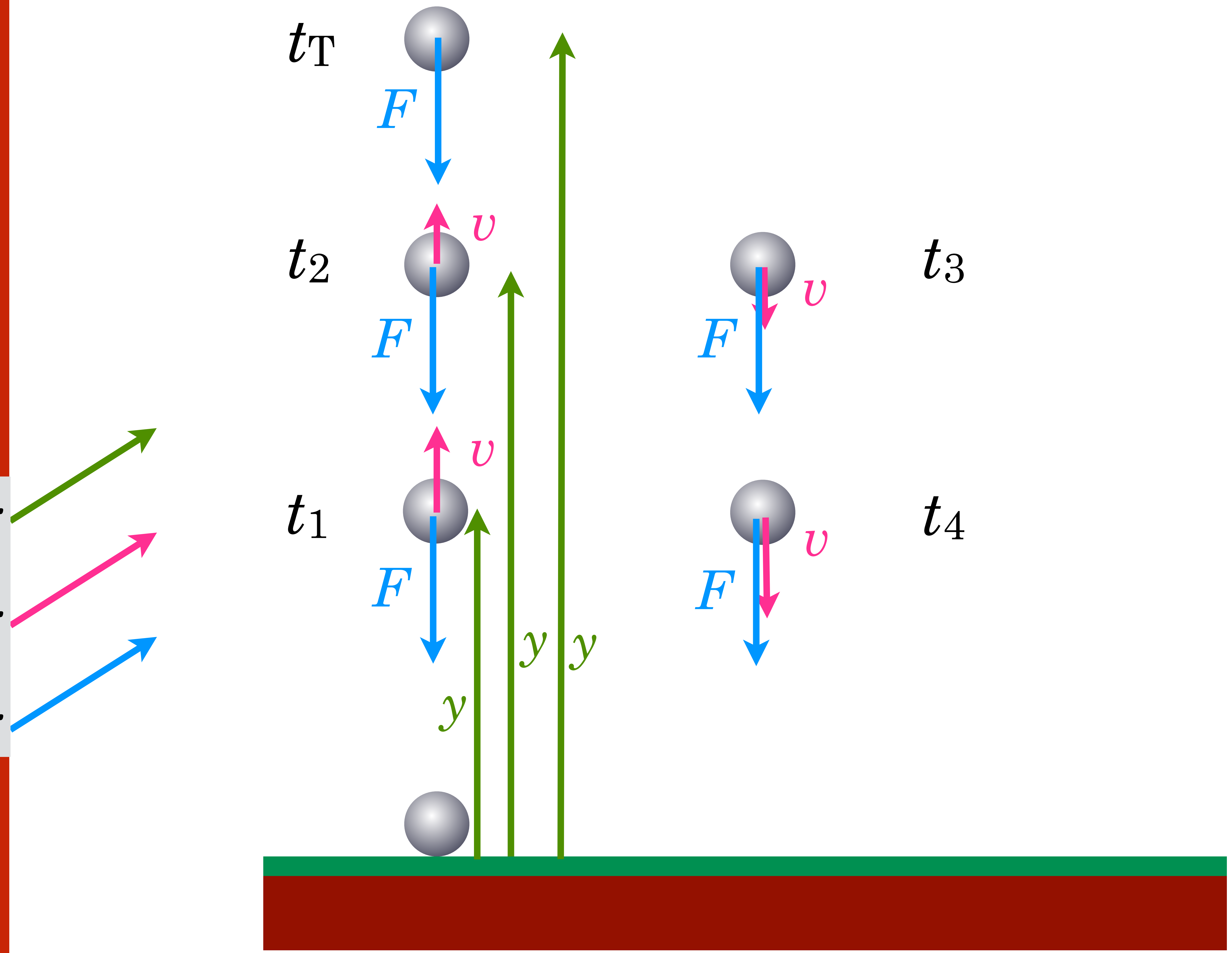
so far:

Displacement, Velocity, Acceleration

deceleration is a vector that points the opposite of the velocity

what goes up…

position:
velocity:
force:

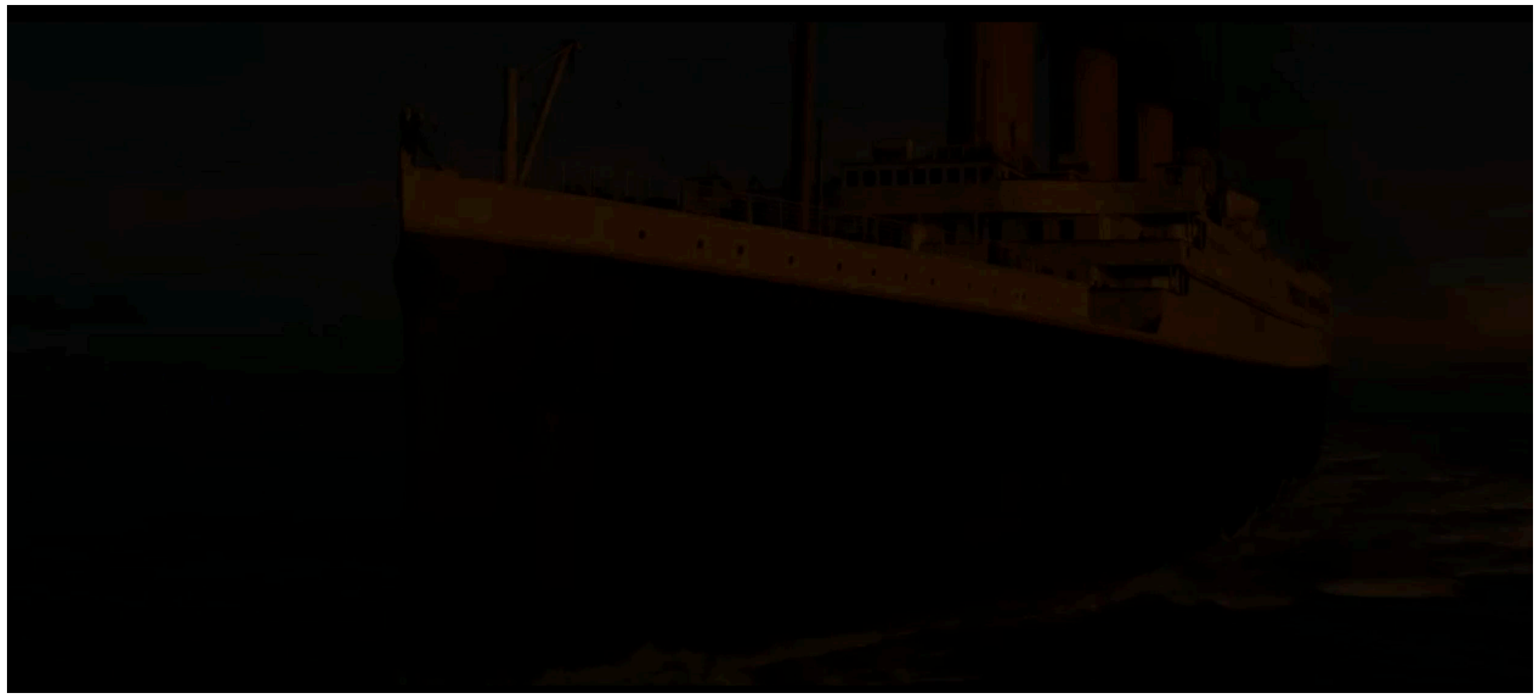


latest $t_4 > t_3 > t_T > t_2 > t_1$ earliest

projectiles

Galileo was really smart about this.

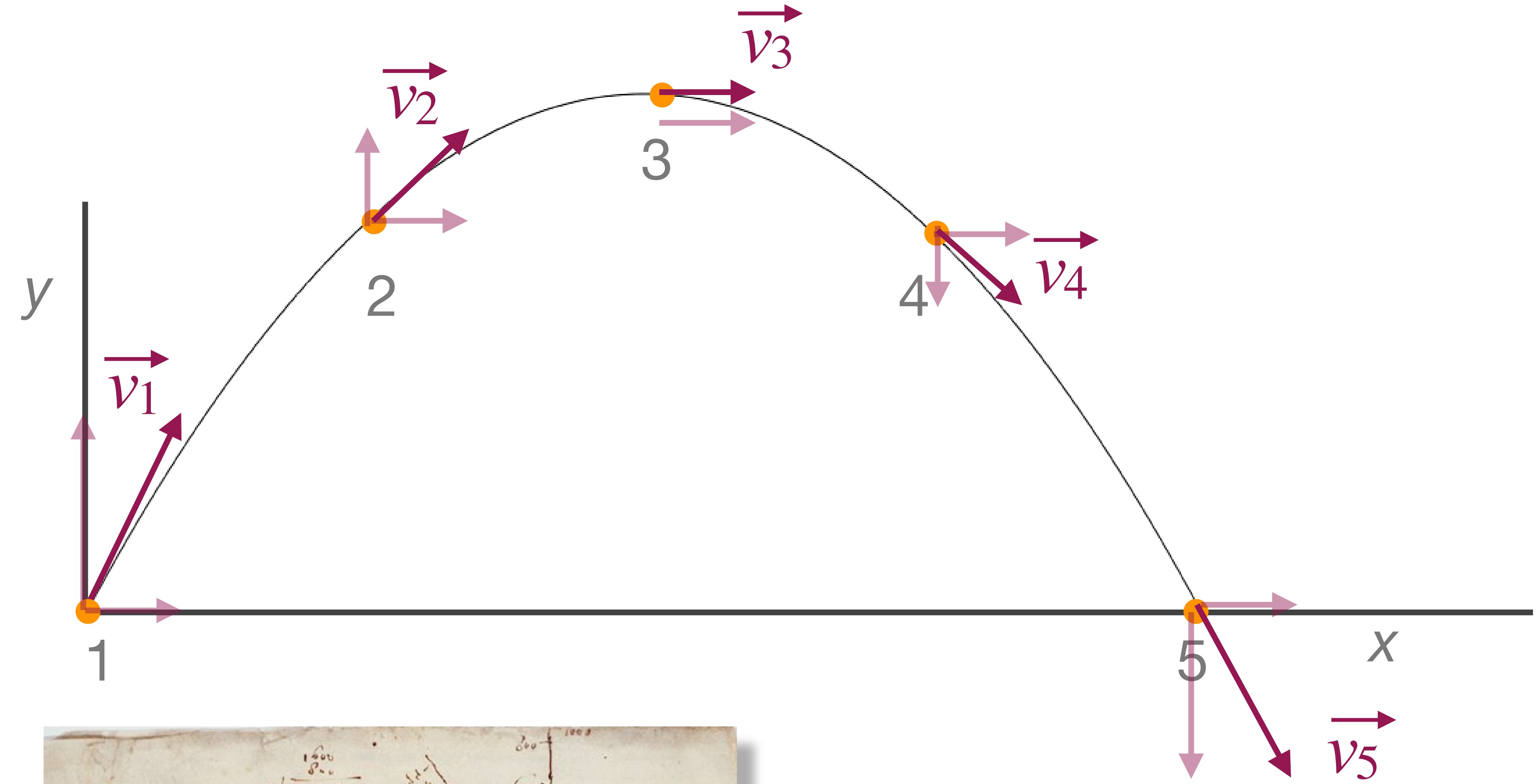
solved the centuries-old Aristotelian nonsense

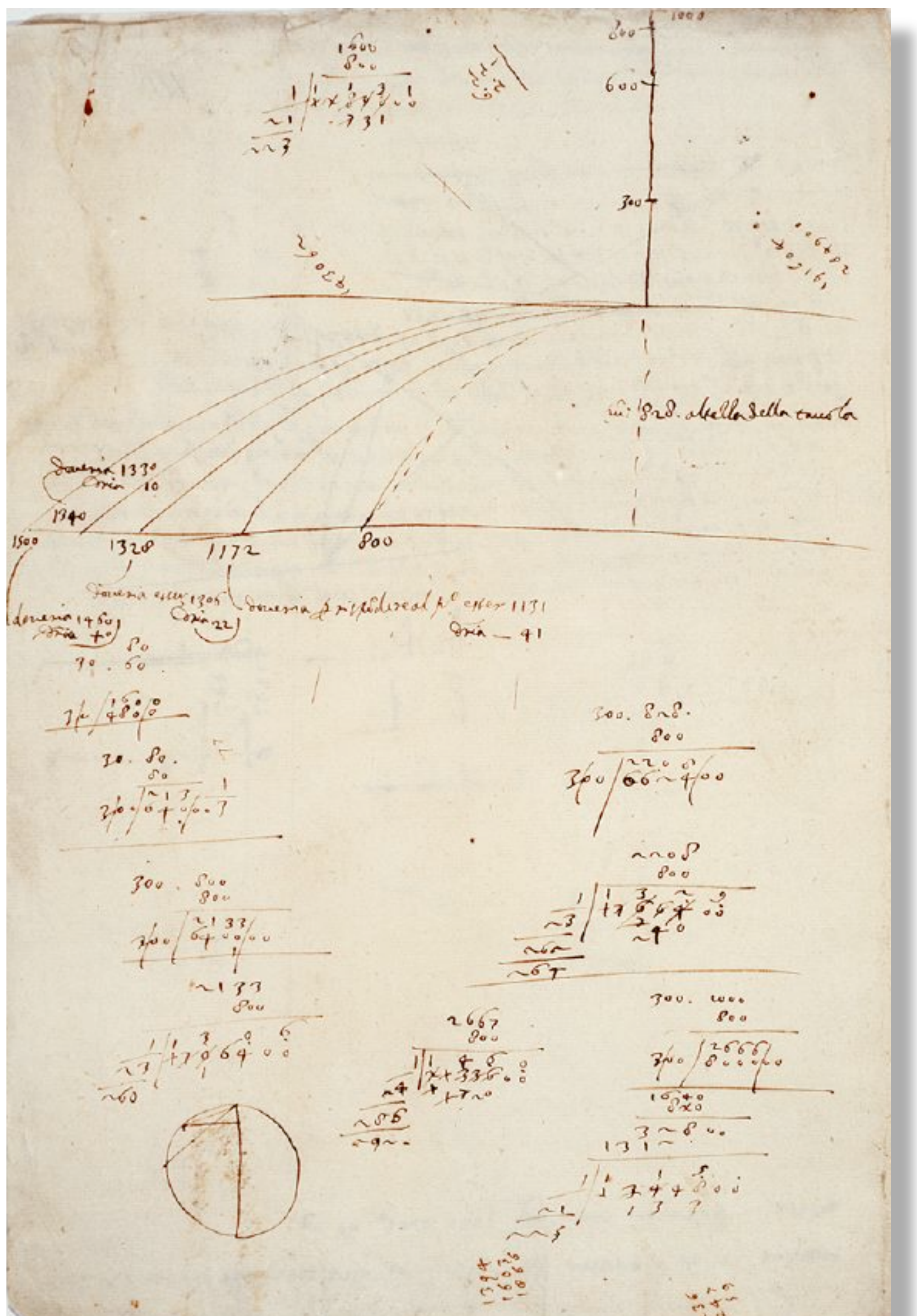


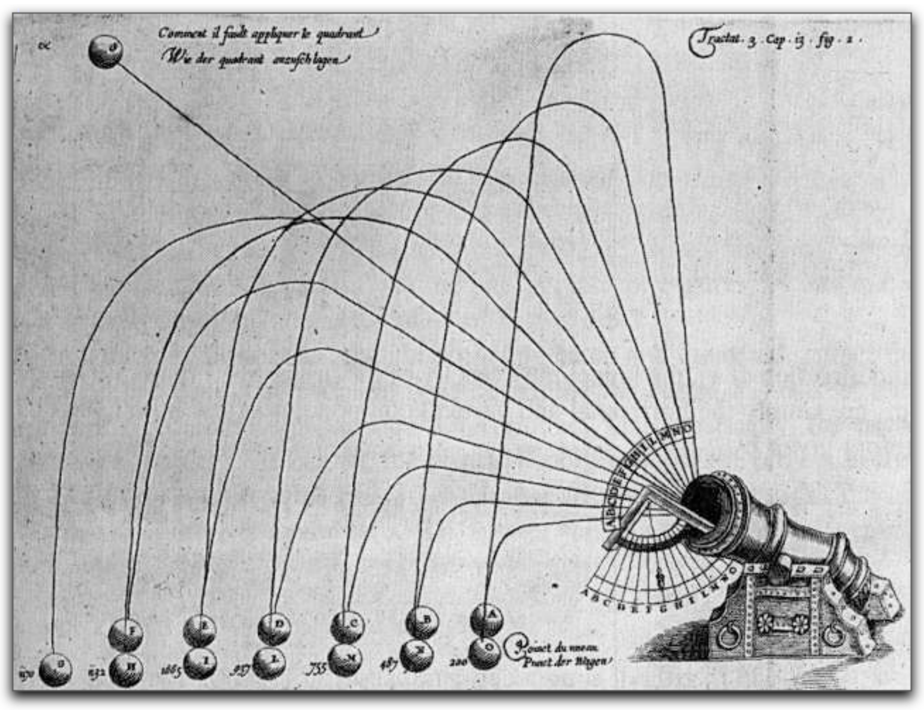
two separate motions

vertical: acceleration happens @ g

horizontal: no acceleration







From a 17C book on artillery

Galileo did something else

He started Physics

You'll read that he was the first experimental scientist

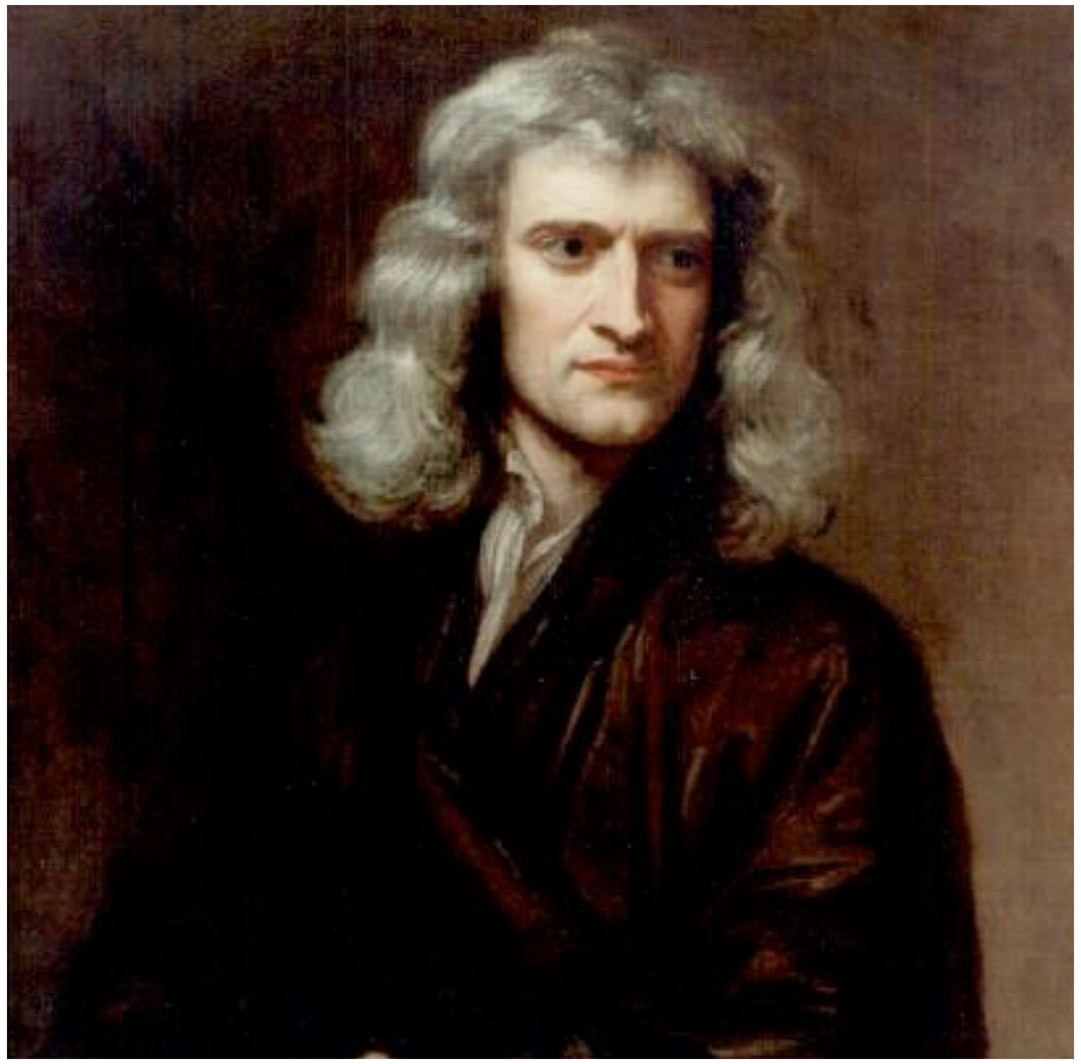
not true…there were others doing recognizably scientific experiments - William Gilbert in Britain, for example

His Platonism. That was key.

we observe phenomena…but the rules that nature follows are …"underneath" what's observable

also the insistence on studying nature as independent of religious dogma

Isaac Newton



1643-1727

da'man.

Isaac Newton

mathematician, physicist, alchemist

two nervous breakdowns…then

politician, administrator, religious heretic/zealot

Newton = mechanics

impenetrable book:

Philosophiae naturalis principia mathematica

aka: “The Principia”

Definitions, Axioms (Laws), Propositions, Lemmas (assumptions), Corollaries and Scholia (notes)

the big Mo'

First, relevant definitions:

mass: "The quantity of matter is the measure of the same, arising from its density and bulk conjointly..."

not very satisfying...

"**quantity of motion**": "The quantity of motion is the measure of the same, arising from the velocity and quantity of matter conjointly..."

in modern terms:

momentum = mass times velocity $p = mv$

$$p = m v$$

momentum:

English**:** **slugs-ft/s**

metric: kg-m/s

mass:

English: slugs

metric: kilogram,kg

velocity:

English: ft/sec

metric: meters/sec = m/s

momentum

the “quality” that moving objects have

`motion is not for free`

you have to push it

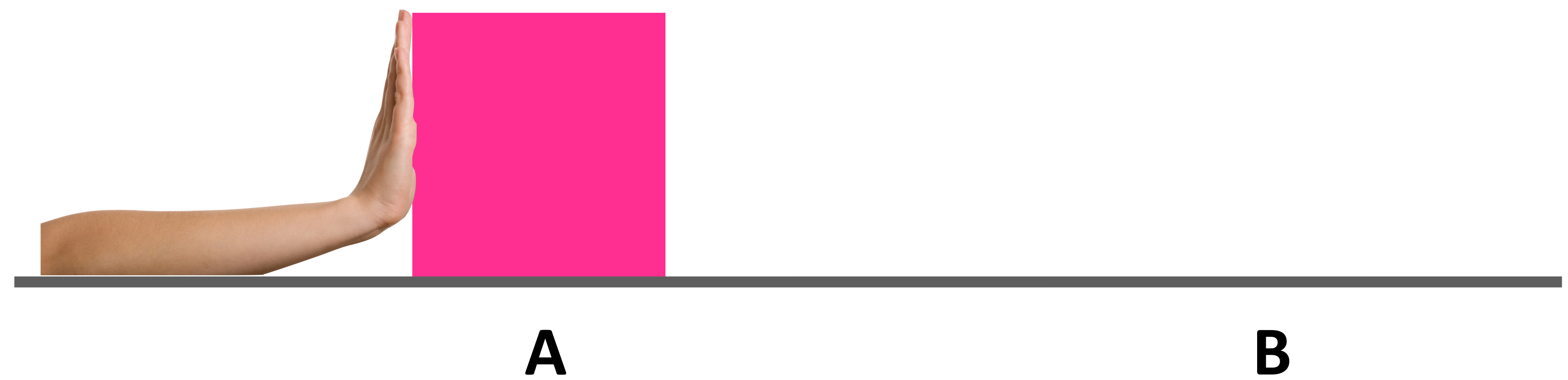
apply a force

make something move?

a force

More **F**, more speed

So, apply a force for some period of time:



We'll just use arrows for force, F.

If F acts for

a) a short time...or — means Δt small

b) a long time — means Δt large

which makes the box go faster, at **B**?

compare

If same F acts for same Δt

...say 100 pounds for 1 minute:

a) Wagon faster at **B**?

b) Beetle faster at **B**?

Sure. The size - or better, the MASS of the object matters.

$$F\Delta t = mv$$

mass is a quantitative measure of inertia

resistance to motion

is **Inertia**

$$F\Delta t = mv$$

fix force & time

$F\Delta t$ is fixed, say 100 pound-seconds...

Then...since $F\Delta t = mv$

shared between m and v

$$F\Delta t = \boldsymbol{m} \times v$$

or

$$F\Delta t = m \times \boldsymbol{v}$$

fix mass and velocity

$$mv = F \times \Delta t$$

or

$$mv = F \times \Delta t$$

fancier

initial and final "states"

$$F\Delta t = \left(\overset{\text{final}}{mv} - \overset{\text{initial}}{m_0 v_0}\right) \equiv \overset{\text{the change}}{\Delta mv}$$

remember?
I'll use the little "0" subscript to mean "initial"

This quantity is the "impulse"

Controlling Impulse governs superior athletic accomplishment!

- "sweet spot"
- "good contact"

change the momentum?

whack it.

With Newton's definition:

$$p = mv$$

$$F\Delta t = mv - m_0 v_0 \equiv \Delta mv$$

$$F\Delta t = p - p_0 = \Delta p$$

rearrange: $F = \dfrac{\Delta p}{\Delta t} = \dfrac{\Delta(mv)}{\Delta t}$

better known as: "Newton's Second Law"

$$F = \frac{\Delta p}{\Delta t} = \frac{\Delta(mv)}{\Delta t}$$

suppose the mass doesn't change?

$$\Delta(mv) = m(\Delta v)$$

$$F = \frac{m\Delta(v)}{\Delta t}$$

usually called
"Newton's Second Law"

$$F = ma$$

about force:

If a body **experiences a force**, it **accelerates**.
it can go faster, or slower... (accelerates or decelerates)

If a body **is accelerating**, then a force **is being applied** to it.

If an applied **force is removed**, the object will **continue to move in a straight line at a constant velocity**.

you have an intuitive

feel for force.

$$F = m\ a$$

English system: pounds, lbs

Metric system: Newtons, N

English system: slugs

Metric system: kilograms, kg

English system: ft/s^2

Metric system: m/s^2

So: 1 N = 1 kg m/s^2