



AI-AUGMENTED ENGINEERING DYNAMICS: A CONVERSATIONAL APPROACH

Taner Onsay, Ph.D

Author

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OBSERVE



IDEALIZE



MODEL



SOLVE / ANALYZE



VALIDATE



REPORT

How this course thinks — every week, every problem.

By Taner Onsay, PhD

CHAPTER - 1

PART 1 · ≈ 25 MIN

Introduction to Particle Kinematics

How do engineers describe motion?

OBSERVE



IDEALIZE



MODEL



SOLVE / ANALYZE



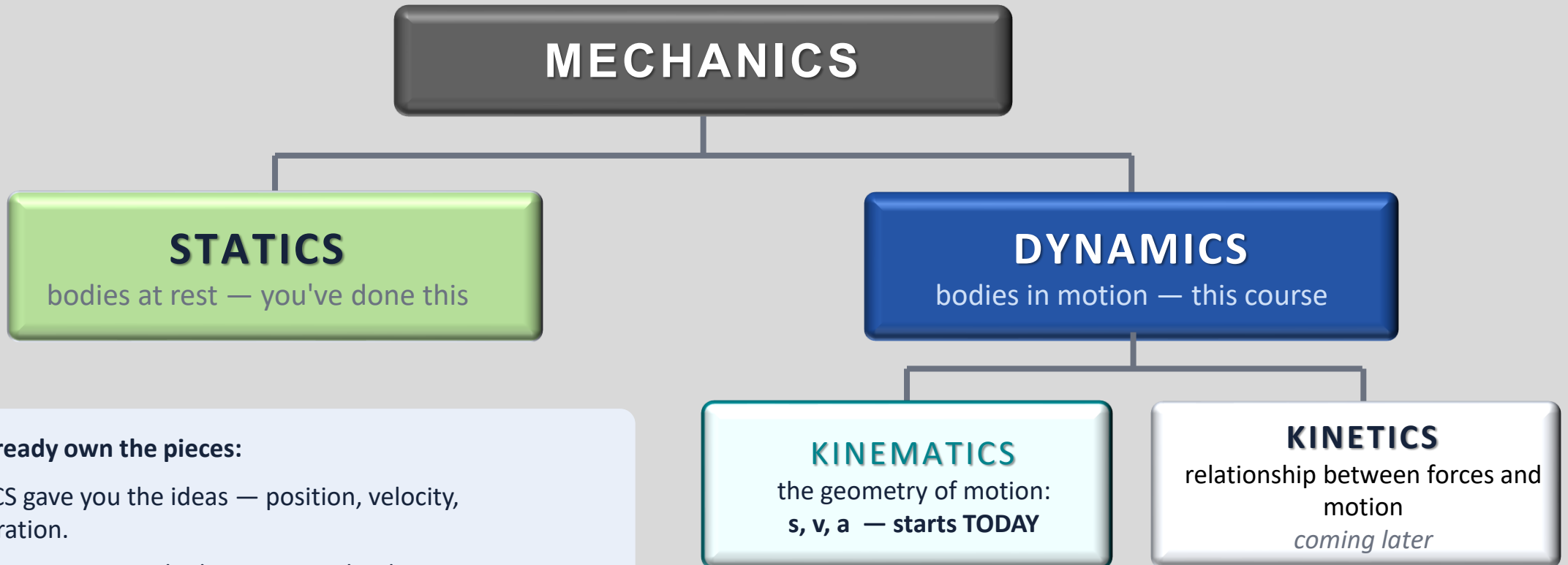
VALIDATE



REPORT



What Is Dynamics?



You already own the pieces:

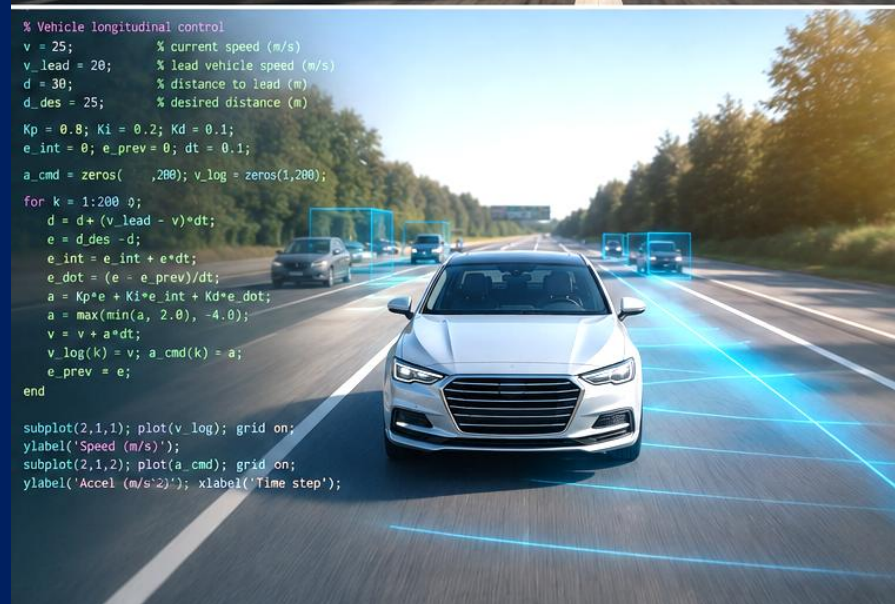
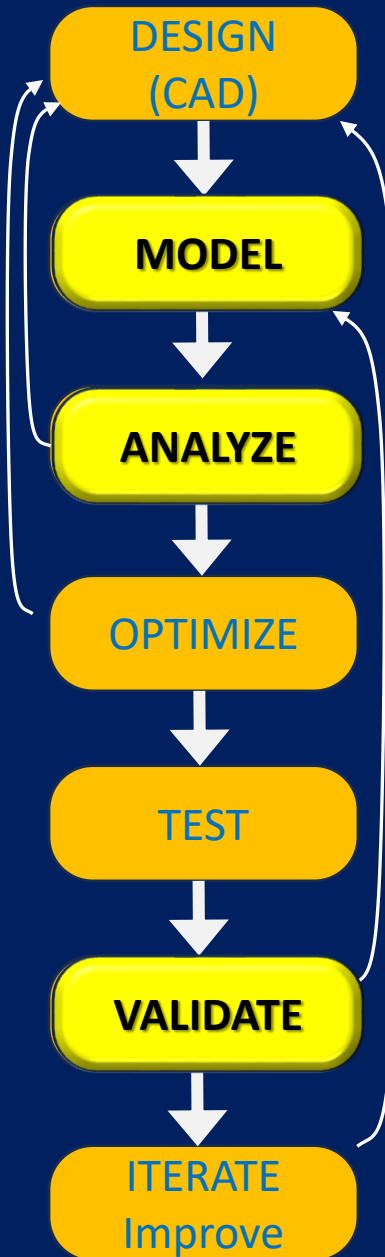
PHYSICS gave you the ideas — position, velocity, acceleration.

CALCULUS gives you the language — the derivative.

STATICS taught you to model — FBDs, assumptions, rigor.

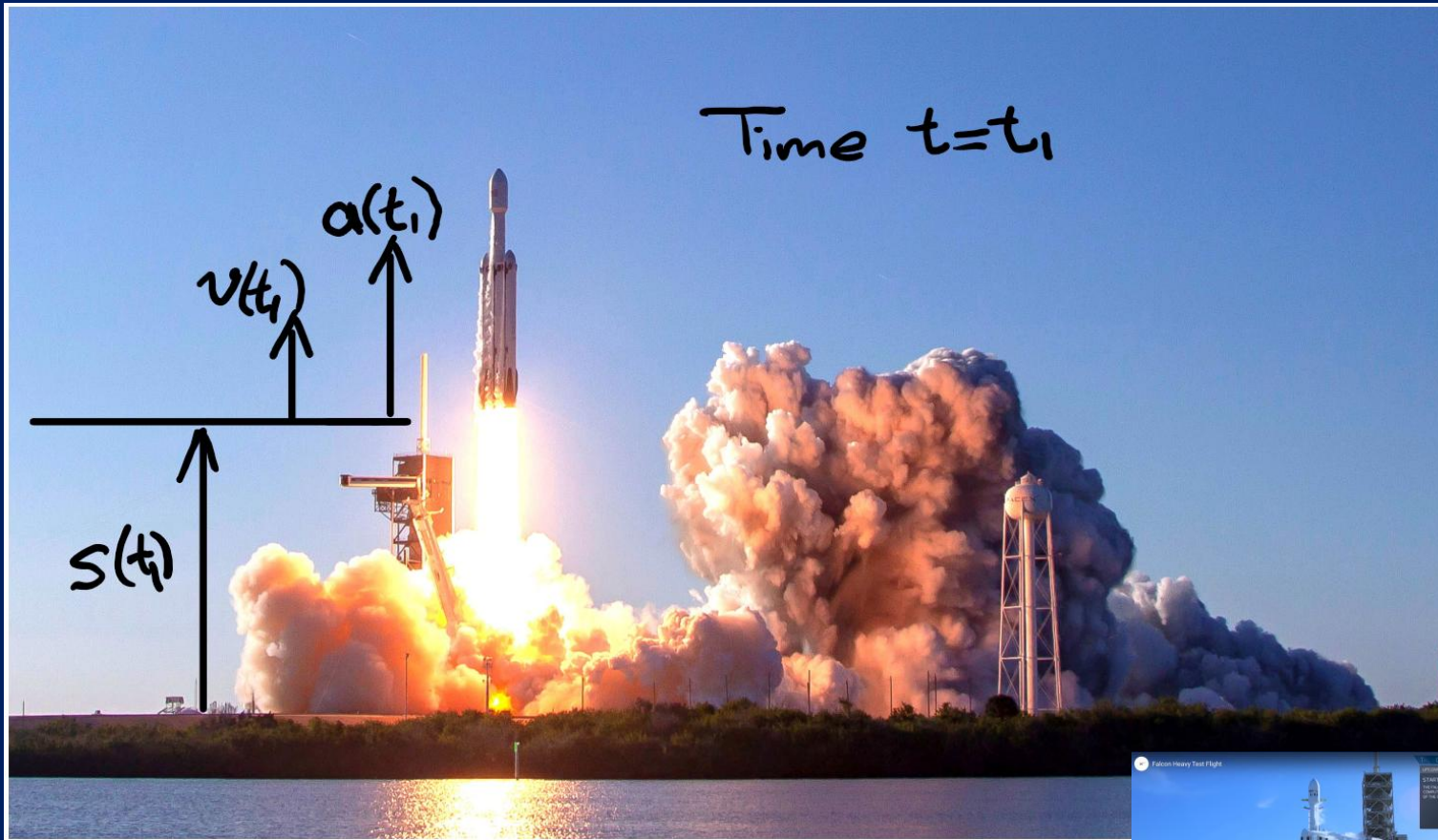
Dynamics puts them to work — systematically.

IN THE INDUSTRY, WHERE DOES ENGINEERING DYNAMICS FIT?



OBSERVE — WATCH LIKE AN ENGINEER

First, just watch.



<https://www.youtube.com/watch?v=wbSwFU6tY1c>

While you watch, four engineering questions:

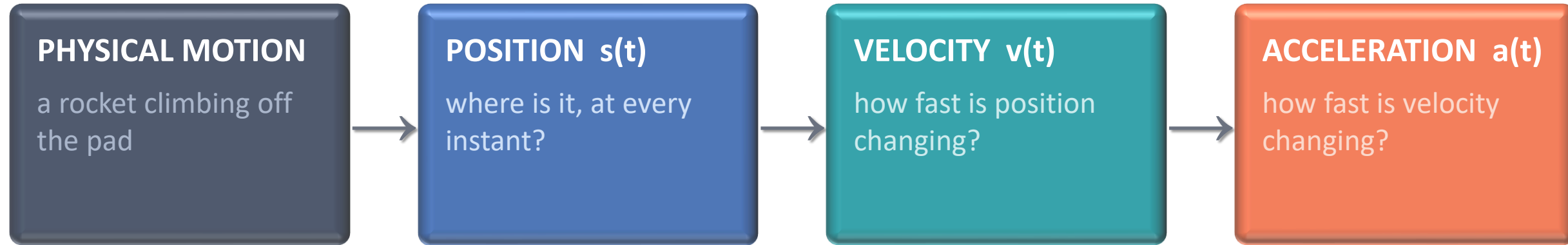
Where is the rocket at a particular instant?

How fast is it moving?

Is its velocity changing?

How could an engineer get these numbers from measurements?

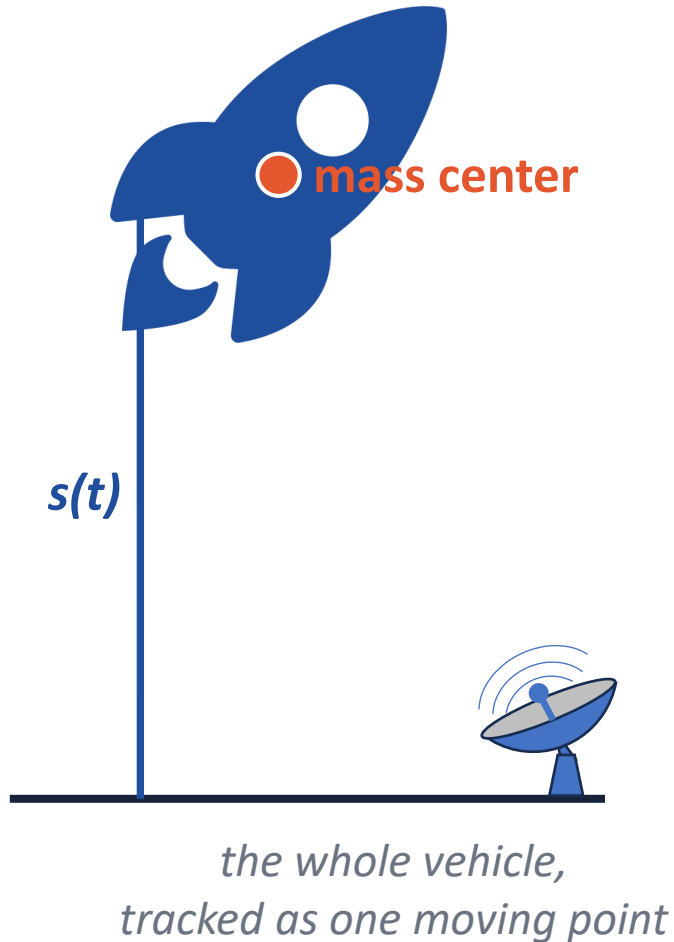
What Did We Just Observe?



Three functions. One motion. $s(t)$, $v(t)$, $a(t)$ are three descriptions of the SAME observed flight — and every one of them can be built from measurements of position over time.

Today's whole agenda: give these three ideas their precise mathematical meaning.

This Rocket Is Enormous. Why Can We Treat It as One Point?



A PARTICLE has mass, but negligible size and shape — *for the motion being studied.*

We follow the mass center and neglect any rotation of the body.

A particle is a MODEL — not necessarily a small object.



rocket



airplane



automobile



bicycle

*...all can be modeled as particles —
when the engineering question or interest is simply about where they go or
what is their overall motion.*

When Is a Car “Just a Point”?



“Where will the car be five seconds from now?”

PARTICLE MODEL: EXCELLENT

Only the location of the car matters — its size, shape, and rotation change nothing about the answer.

“Will the car roll over during this maneuver?”

PARTICLE MODEL: INSUFFICIENT

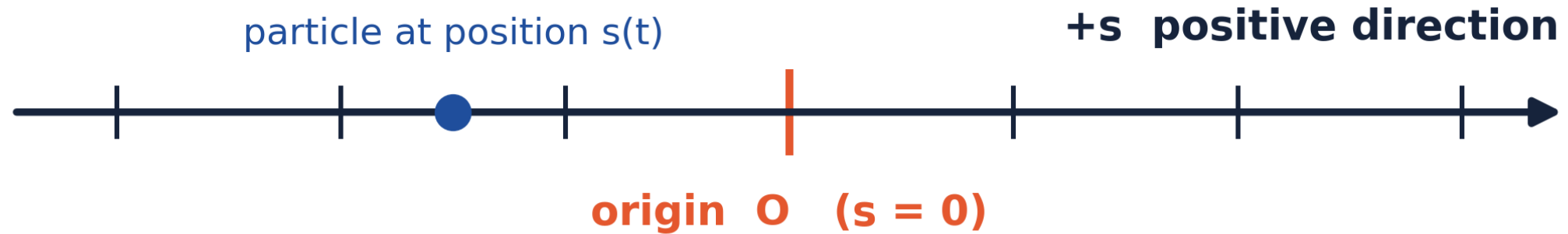
Rollover is ABOUT size, shape, and rotation — exactly what the particle model throws away.

THE MODEL DEPENDS ON THE QUESTION (Engineering Interest).

The same object can be a particle for one engineering question and not for another.

OPTIONAL AGENT 345 QUESTION *“How do engineers decide when a model is good enough?” — if it comes up, ask Agent 345 live and let the class critique the answer.*

Rectilinear Motion: One Straight Line, One Coordinate



ORIGIN O

you choose where $s = 0$ lives

POSITIVE DIRECTION

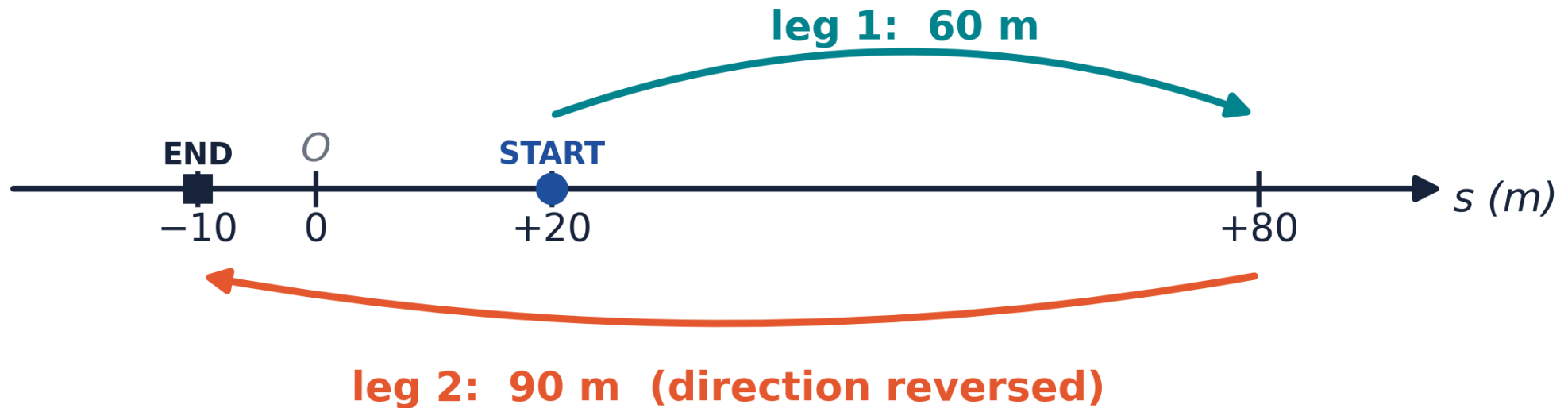
you choose which way + points

POSITION $s(t)$

signed coordinate of the particle
at time t (m or ft)

The coordinate system is the engineer's choice. The motion doesn't care — but every sign in today's lecture will.

One Journey, Three Different Questions



POSITION

Where are you?

$$s_{\text{end}} = -10 \text{ m}$$

DISPLACEMENT

Where did you end up, relative to where you started?

$$\Delta s = s_2 - s_1 = -10 - (+20) = -30 \text{ m}$$

TOTAL DISTANCE TRAVELED

How much motion occurred in total?

$$s_T = 60 + 90 = 150 \text{ m}$$

Because the car reversed: **distance traveled (150 m) $\neq$ |displacement| (30 m).** *Displacement carries a sign. Distance never does.*

LIVE DEMONSTRATION

Walking Along a Coordinate Axis



1) walk in the + direction

2) stop

3) reverse direction

4) wander through + and – territory

You call it, live, at every moment:

Is my position + or – right now?

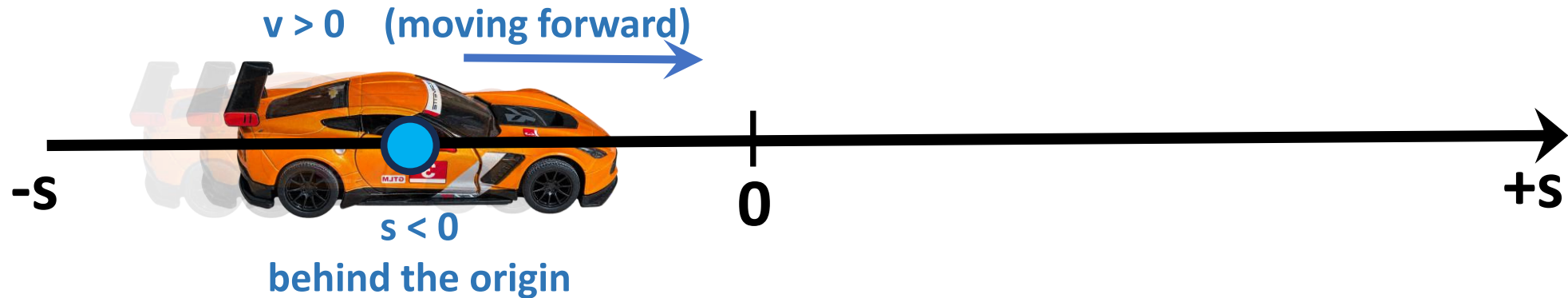
Is my velocity + or – right now?

When is my velocity ZERO?

If my position is negative, must my velocity be negative too?

What Did the Walking Demonstration Show?

Position and velocity are DIFFERENT quantities.



perfectly possible: $s < 0$ and $v > 0$ at the same instant

Position tells you where you are. Velocity tells you how your position is changing.

Velocity: The Rate Position Changes

over an interval — average:

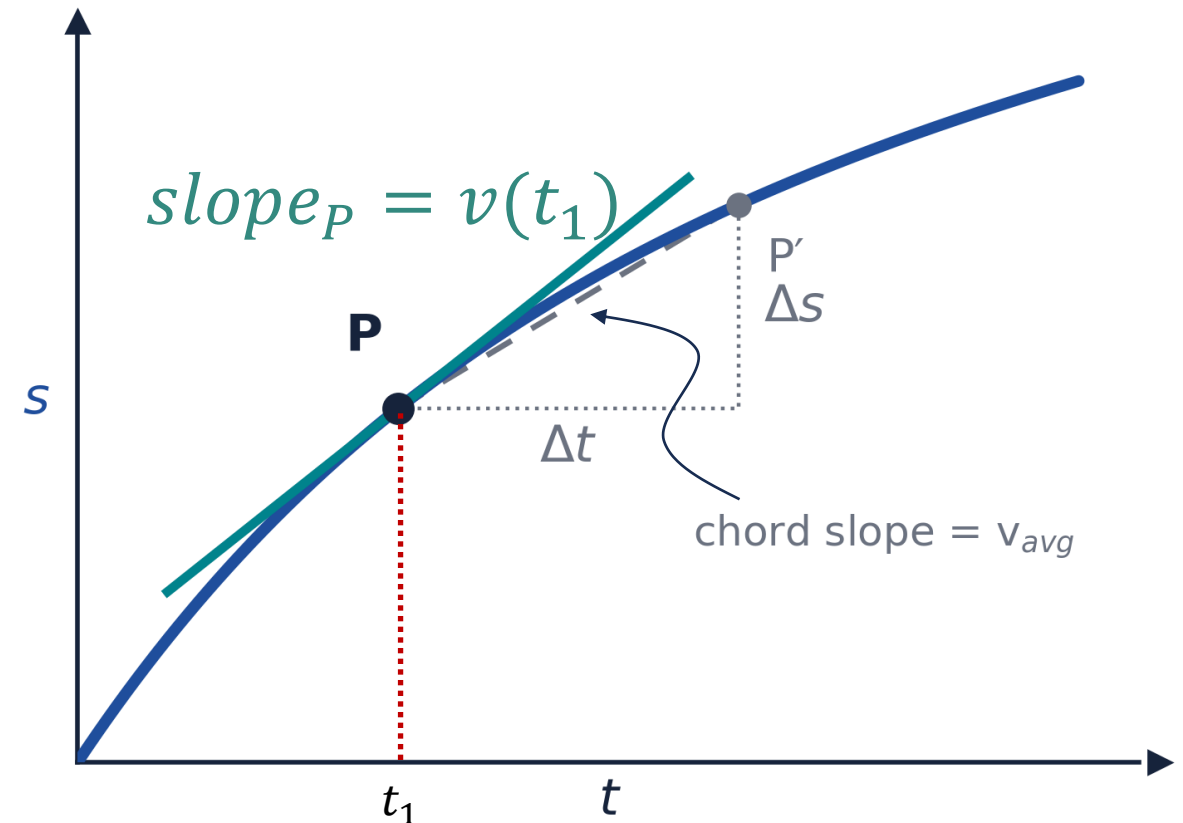
$$v_{avr} = \frac{\Delta s}{\Delta t}$$

shrink the interval — instantaneous:

$$v = \lim_{\{\Delta t \rightarrow 0\}} \frac{\Delta s}{\Delta t} = \frac{ds}{dt}$$

As $\Delta t \rightarrow 0$, the chord $P \rightarrow P'$ tips into the tangent at P.

The derivative is just this limiting slope.



Instantaneous velocity is the SLOPE of the position–time graph.

Speed and Velocity Are Not Synonyms

$$\text{speed} = |v|$$

*speed is the **magnitude** of velocity — it forgets direction*

AVERAGE VELOCITY

uses displacement: $\Delta s / \Delta t$

our journey: -30 m over the trip time →
NEGATIVE — the sign reports net direction

AVERAGE SPEED

uses total distance traveled: $s_T / \Delta t$

our journey: 150 m over the SAME trip time
→ positive, and much larger

Same car. Same journey. Same clock. Two honest answers — because they answer different questions.

PREDICT → WATCH → COMPARE

Two Roads, Same Car — What Should $s(t)$ Look Like?

Before we press play: sketch the SHAPE of the position–time graph for each motion (slope?). Which one is performing a rectilinear motion?

30 fps



30 fps



120 fps
SloMo



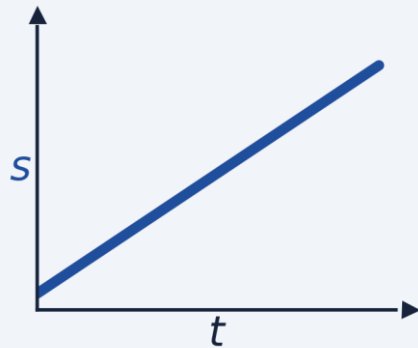
120 fps
SloMo



Same Road. Same Car. Three Different Motions.



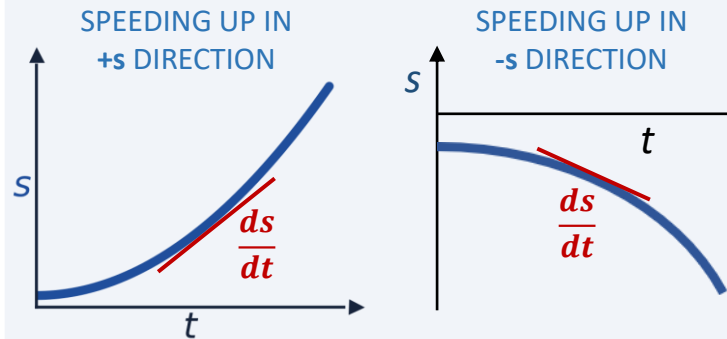
(A)



CONSTANT SPEED

straight line: the slope never changes $\rightarrow v$ is constant

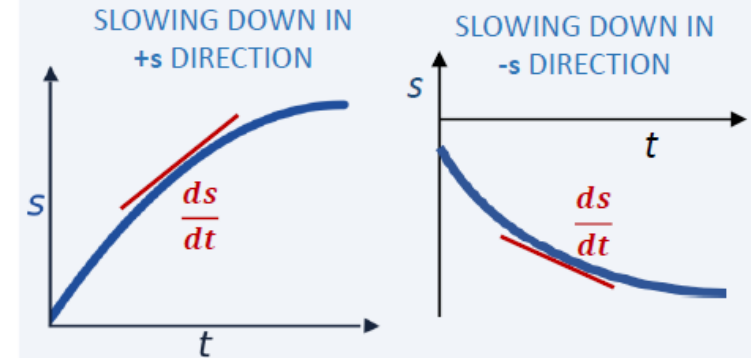
(B)



SPEEDING UP (ACCELERATING)

the magnitude of the slope grows $\rightarrow |v|$ increases

(C)



SLOWING DOWN (DECELERATING)

the magnitude of the slope shrinks $\rightarrow |v|$ decreases

conceptual sketches — not measured data (that comes later in the course)

The slope of $s(t)$ tells us $v(t)$.

ONE MORE OBJECT

Now It's a Bicycle.



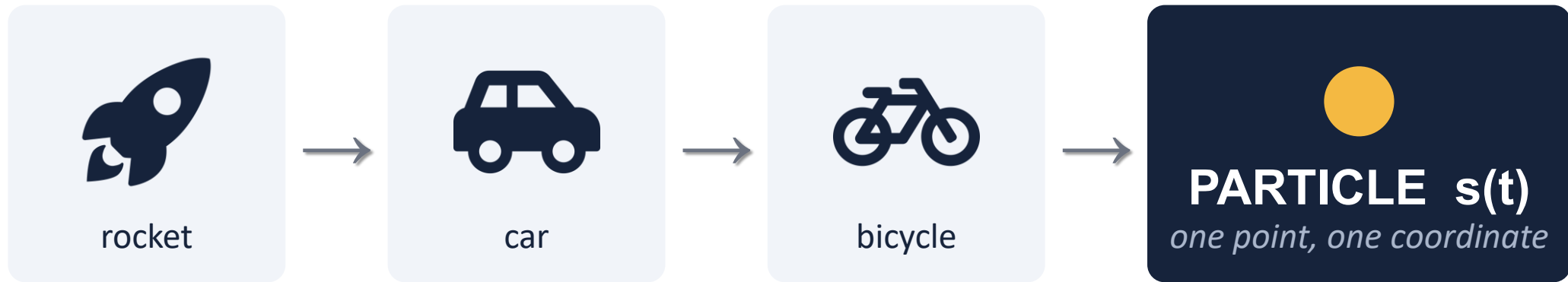
[INSERT INSTRUCTOR-RECORDED BICYCLE MOTION VIDEO]

steady speed · accelerating · decelerating — instructor file, placeholder only



***Does the mathematics change
because the object is now a bicycle
instead of a car?***

Different Object — Same Kinematics



The physical systems are wildly different. The kinematic language is identical: $s(t)$, $v(t)$, $a(t)$.
That is exactly why the particle model earns its keep.

Acceleration: The Rate Velocity Changes

over an interval — average:

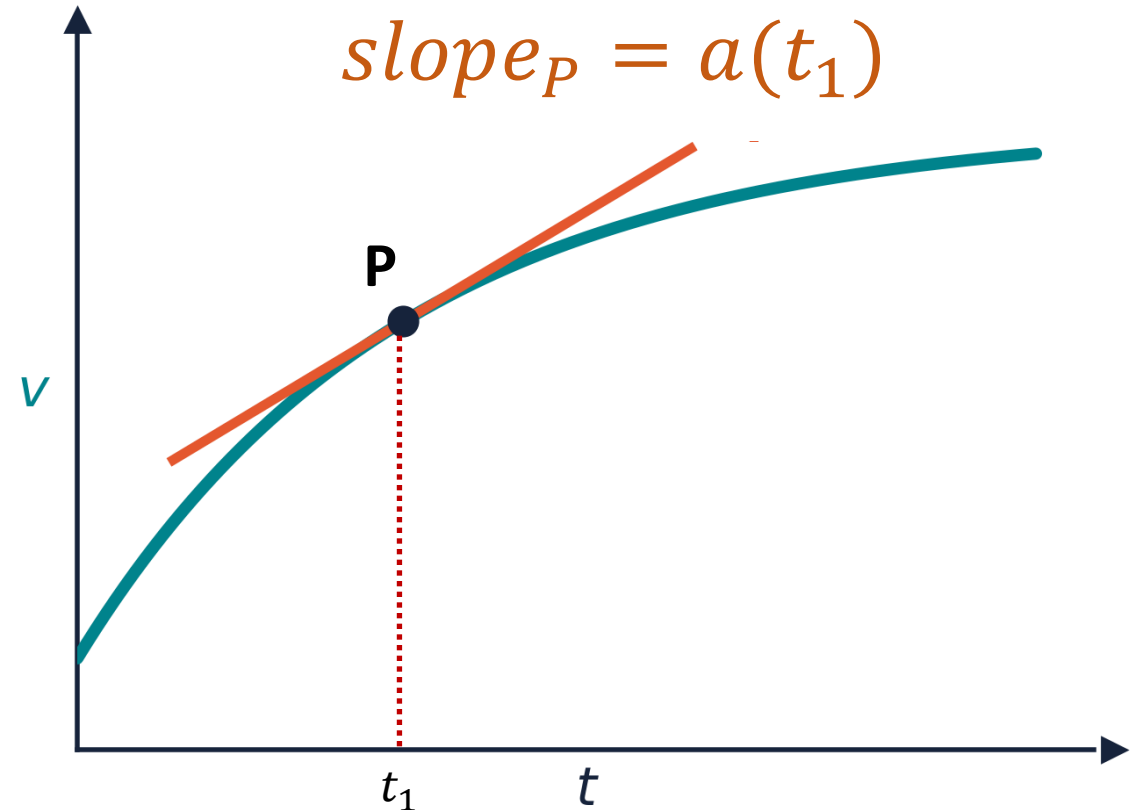
$$a_{avr} = \frac{\Delta v}{\Delta t}$$

instantaneous — and as a second derivative of position:

$$a = \frac{dv}{dt} = \frac{d^2s}{dt^2}$$

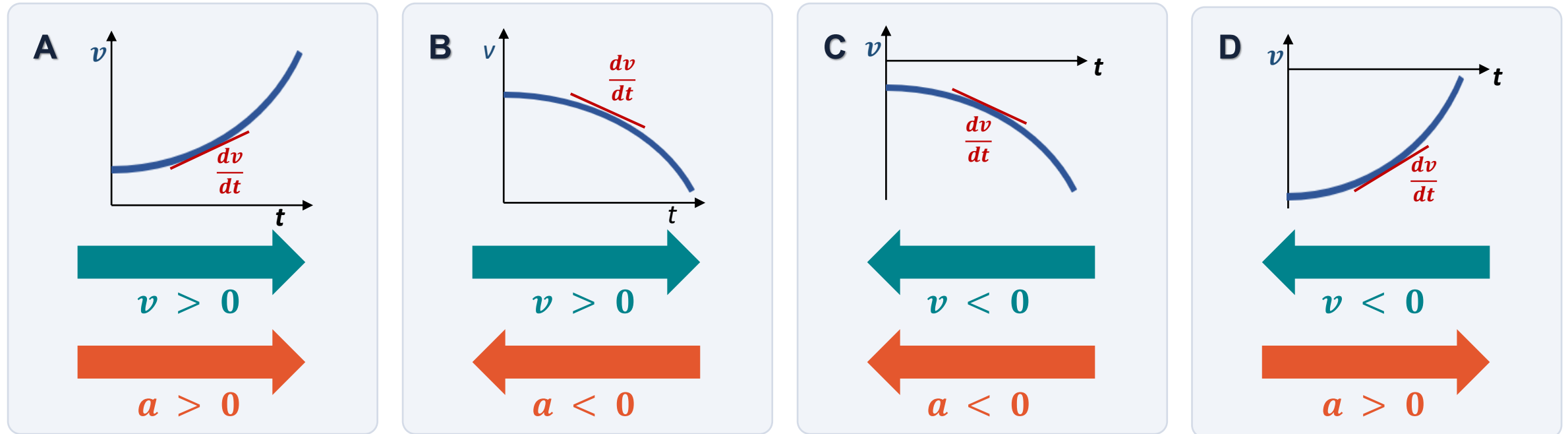
⚠ CAREFUL: the sign of a alone does NOT tell you “speeding up” or “slowing down.”

Next slide: you vote on four cases.



Acceleration is the SLOPE of the velocity–time graph.

Four Particles. Which Are Speeding Up?



Which particles are speeding up? Which are slowing down? Commit to an answer for all four.

OPTIONAL AGENT 345 QUESTION “Can an object have negative acceleration while speeding up?” — ask Agent 345 after the vote; make it defend its answer against case C.

REVEAL

Compare the Signs — of v AND a Together

**SAME signs of v and a
→ SPEEDING UP**

**OPPOSITE signs of v and a
→ SLOWING DOWN**

**A) $v > 0, a > 0$
SPEEDING UP**

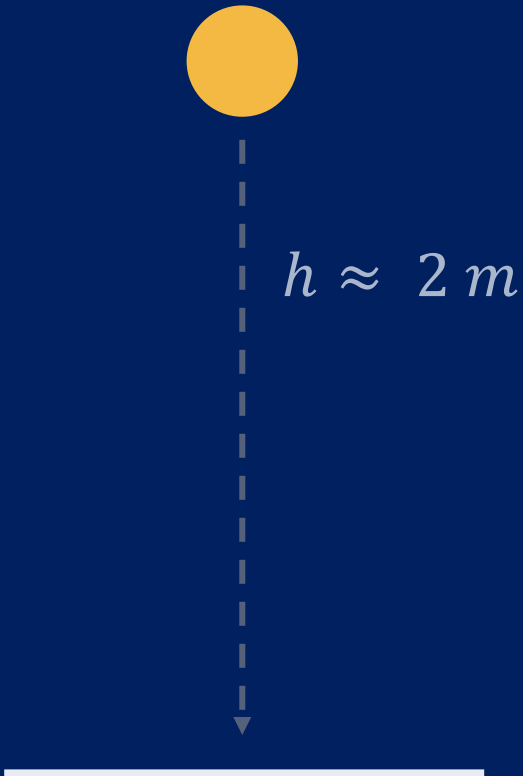
**B) $v > 0, a < 0$
SLOWING DOWN**

**C) $v < 0, a < 0$
SPEEDING UP**

**D) $v < 0, a > 0$
SLOWING DOWN**

“Negative acceleration” does not mean “slowing down.”
Case C: $v < 0$ and $a < 0$ — and the particle is speeding up.

LIVE DEMONSTRATION — Ball Drop from $\approx 2\text{ m}$



Before I let go — predict:

What is the ball's velocity immediately before release?

What happens to its velocity after release?

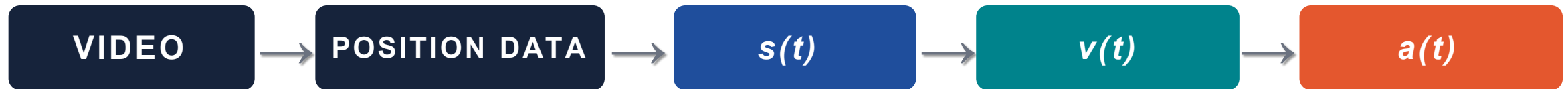
What can we say about its acceleration on the way down?



WE RECORD THE DROP. You will analyze this exact classroom footage later — not a textbook video, ours.

We Saw It. Now Can We Measure It?

Can we determine $s(t)$, $v(t)$, and $a(t)$ from the video we just recorded?



TRACKER — the idea, not the tutorial

Free video-analysis software: click the ball's location frame by frame → a table of position vs time. From that table, the rest of today's lecture follows.

Measurement, not magic.

EXTENDED ACTIVITY

Analyze ball-drop video in Tracker and compare the measured motion with the predictions you just made out loud.

Did reality agree with you?



Position → Velocity → Acceleration



One operation — the derivative — walks the whole chain, left to right.

(Could we ever walk it backwards, from a to v to s ? Hold that thought until Chapter 1-PART 2.)

You Just Learned the Language of Motion

OBSERVE

Observe physical motion — a rocket, a car, a person pacing the front of the room.

IDEALIZE

Ask “What is the engineering question or interest?”

MODEL

Represent the object as a particle — because the question allows it.

ANALYZE

$s(t) \rightarrow v(t) \rightarrow a(t)$ — *each the rate of change of the one before.*

VALIDATE

Compare the mathematical description with measured reality.

“Would I put my name on this answer as an engineer?”