Lecture 2

Kinematics in One Dimension

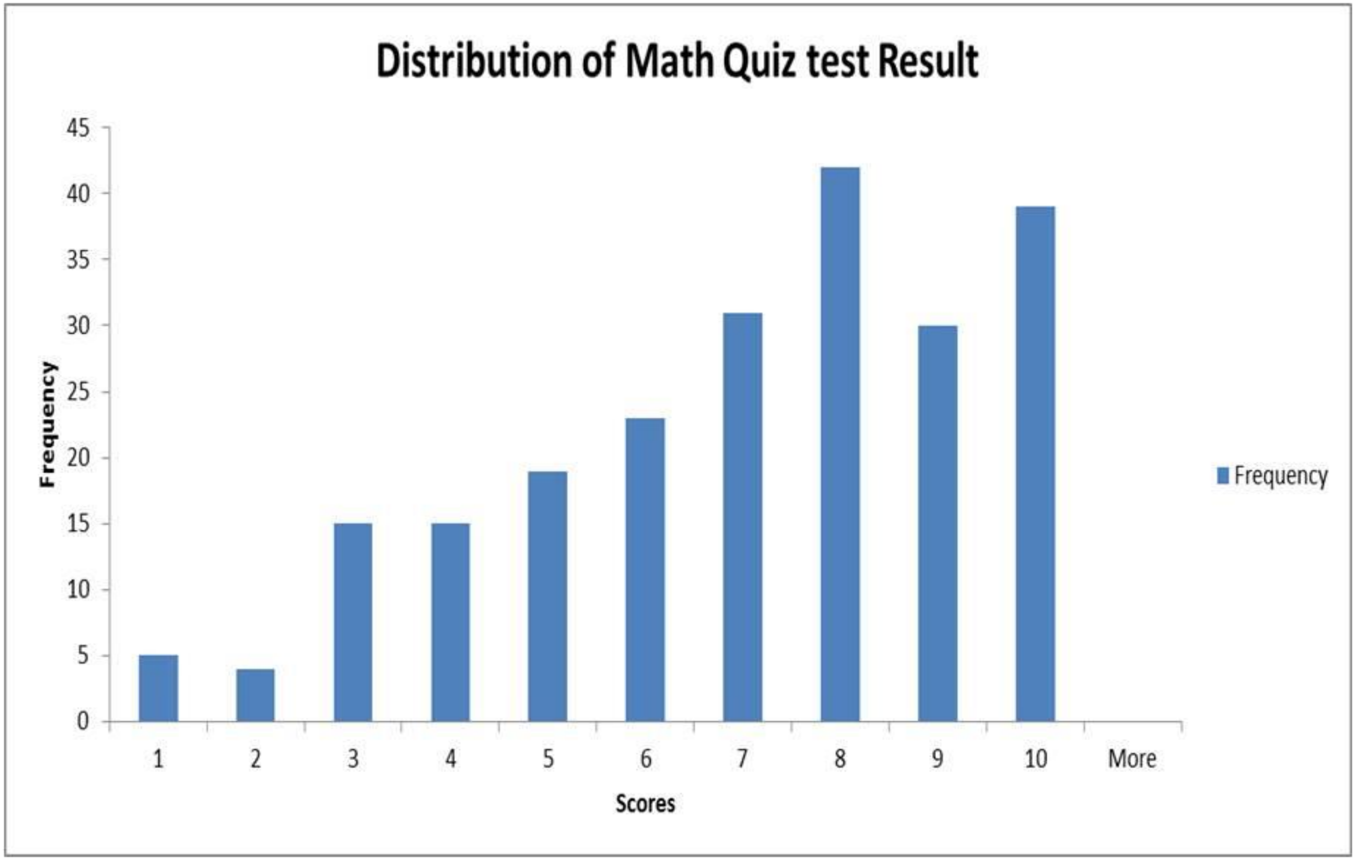
Course website:
http://faculty.uml.edu/Andriy_Danylov/Teaching/PhysicsI

Lecture (video)

http://echo360.uml.edu/danylov2013/physics1fall.html

Register your i>clickers online at
http://www.iclicker.com/registration

Math Diagnostic Quiz Results



Outline

Chapter 2, Section 2.1-2.4

- Distance
- Displacement

- Speed
- Average velocity
- Instantaneous velocity

- Average Acceleration
- Instantaneous Acceleration

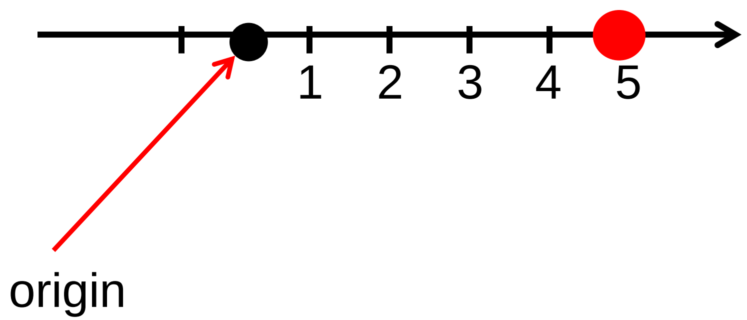
Kinematics

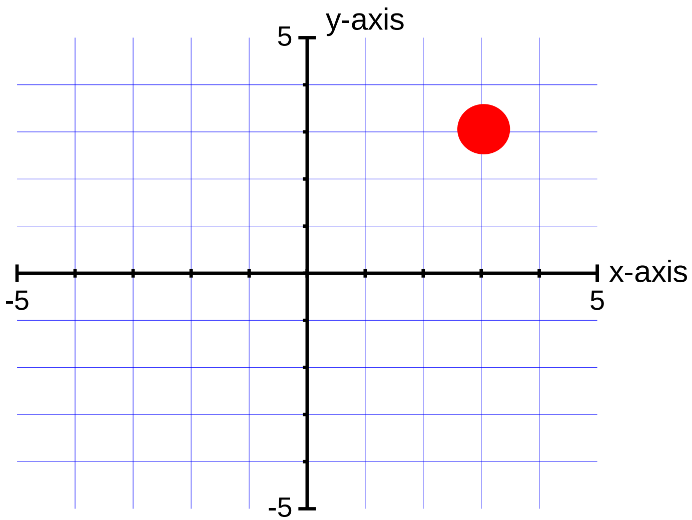
- There are three branches of Mechanics:
- Kinematics (Ch.2,3,10) Motion ~~Forces~~
- Statics (Ch.12) ~~Motion~~ Forces
- Dynamics (Ch.4,5,6) Motion Forces

<u>Kinematics describes motion of objects</u>

Frames of Reference (Position)

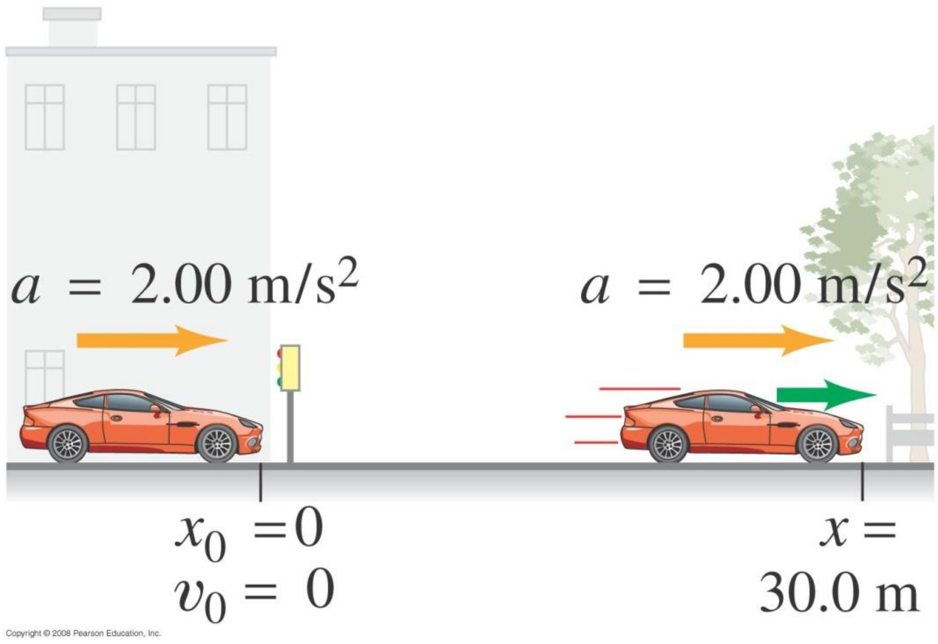
- Physics is all about describing and predicting the world around us.
- If you think about how we describe objects, one of the first things which should come to mind is POSITION.
- But position means nothing unless you know what the position is in reference to!
- In this class, we will base problems in a Cartesian coordinate system

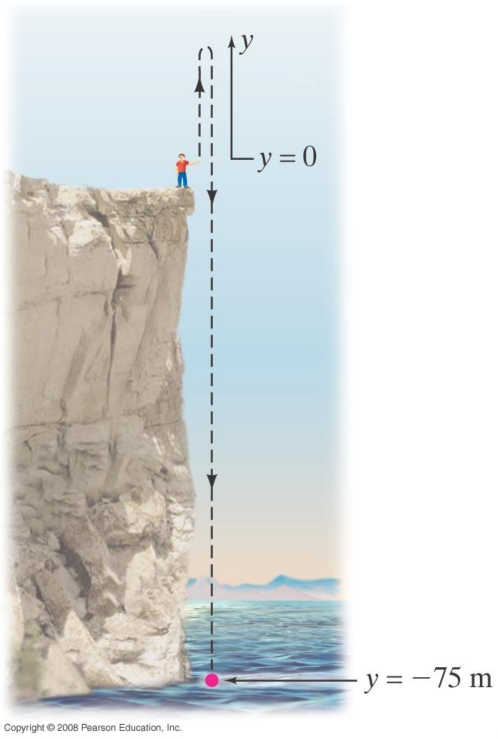




Frames of Reference (Motion)

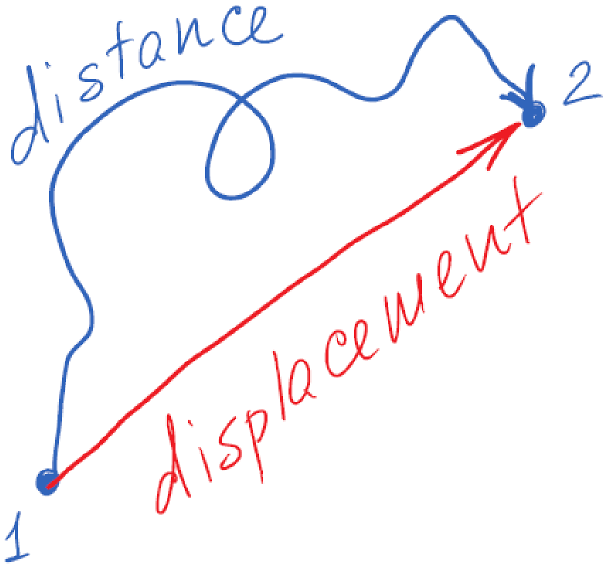
- With a frame of reference, we can now describe an object's motion.
- For 1 dimensional (1D) motion (motion in a straight line) we generally use the x-axis to describe the object's *position*.
- For falling bodies, we tend to describe position using the y-axis

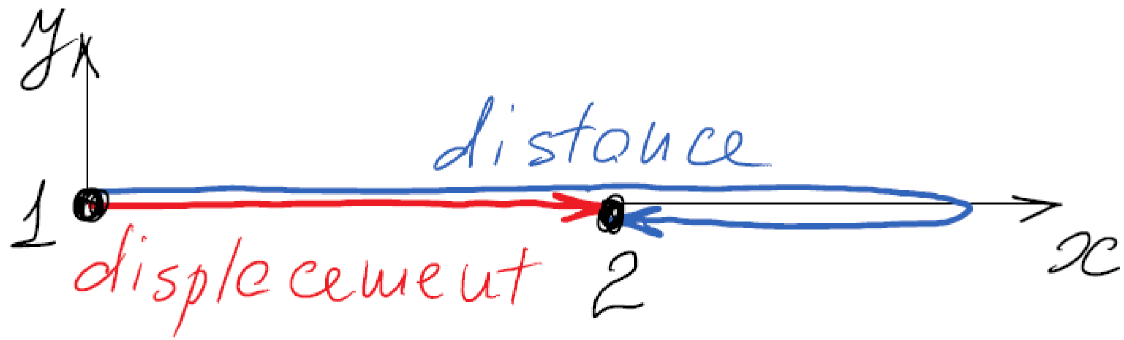




Distance vs. Displacement

Distance vs. Displacement





Distance (scalar):
  the total path length traveled by an object

Displacement (vector):
  how far an object is from its starting point

ConcepTest 1 Roller Coaster

What would be your displacement after a complete roller coaster?

ConcepTest 2 Walking the Dog

You and your dog go for a walk to the park. On the way, your dog takes many side trips to chase squirrels or examine fire hydrants. When you arrive at the park, do you and your dog have the same displacement?

A) yes

B) no

ConcepTest 2 Walking the Dog

You and your dog go for a walk to the park. On the way, your dog takes many side trips to chase squirrels or examine fire hydrants. When you arrive at the park, do you and your dog have the same displacement?

A) yes

B) no

Yes, you have the same displacement. Because you and your dog had the same initial position and the same final position, then you have (by definition) the same displacement.

Follow-up: have you and your dog traveled the same distance?

ConcepTest 3 Odometer

Does the odometer in a car measure distance or displacement?

A) distance

B) displacement

C) both

ConcepTest 3 Odometer

Does the odometer in a car measure distance or displacement?

A) distance

B) displacement

C) both

If you go on a long trip and then return home, your odometer does not measure zero, but it records the total miles that you traveled. That means the odometer records distance.

Follow-up: how would you measure displacement in your car?

Distance vs. Displacement (1D)

Distance is a scalar x

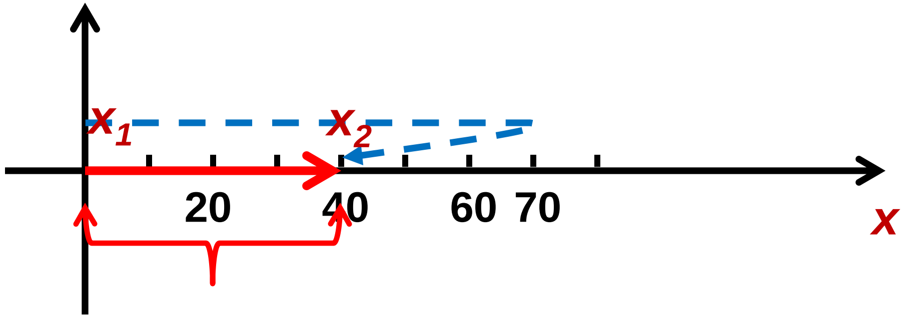
Displacement is a vector $\vec{x}$

– *A vector has both magnitude and direction (or sign in 1-D)*

Displacement = final position – initial position

$$\Delta x = x_2 - x_1.$$

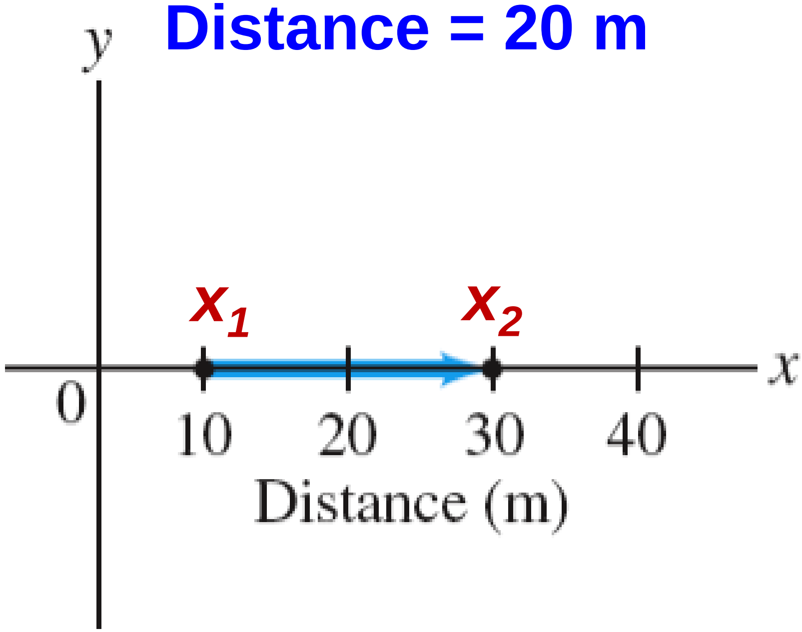
Distance = 70+30 =100 m



Displacement =x_2- x_1=+40 m

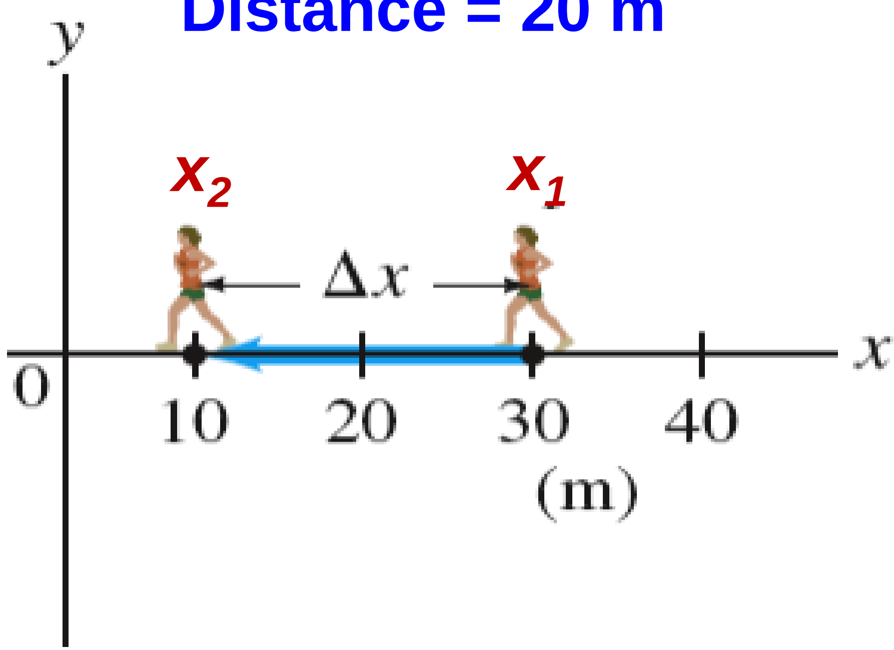
Distance vs. Displacement (1D)

Distance = 20 m



Displacement = 30-10= + 20 m

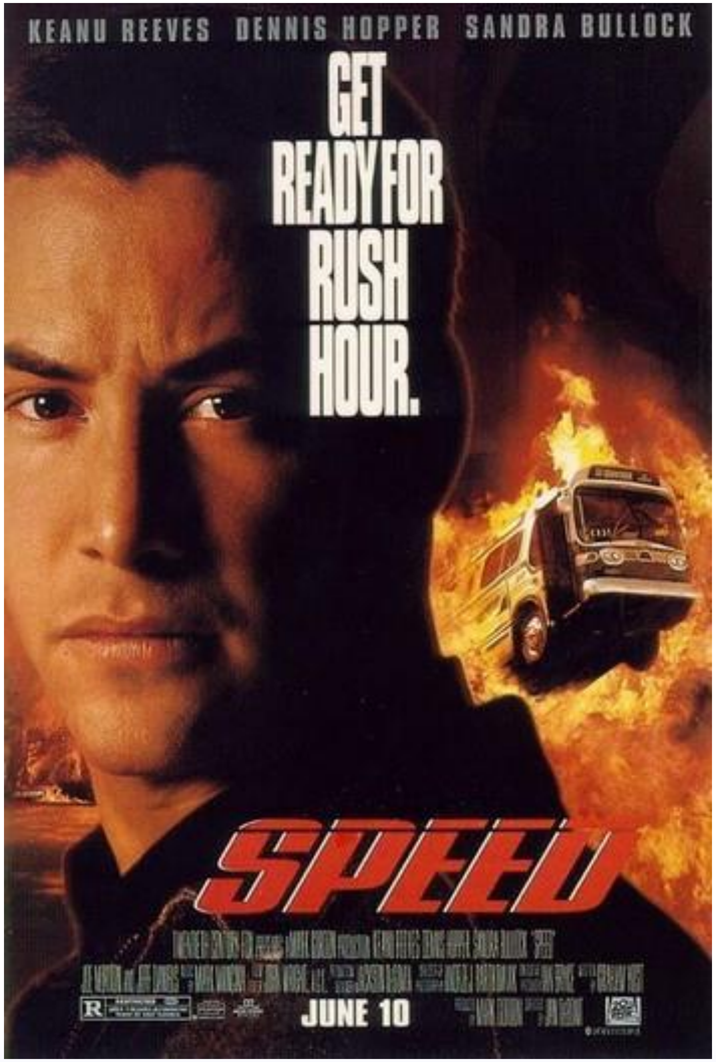
Distance = 20 m

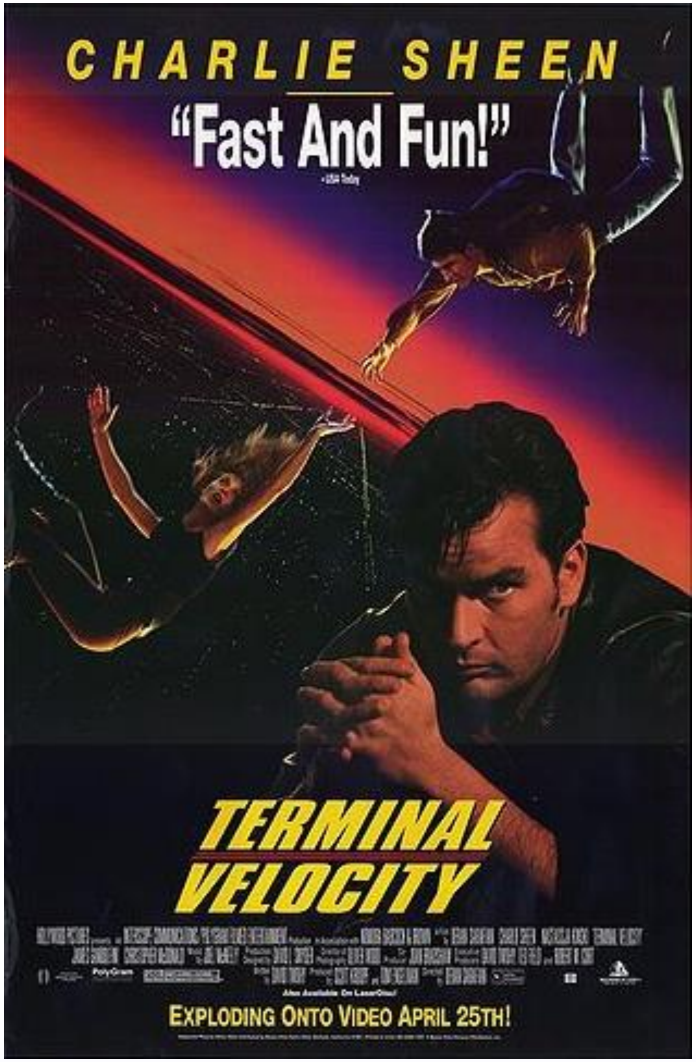


Displacement = 10-30= **-**20 m

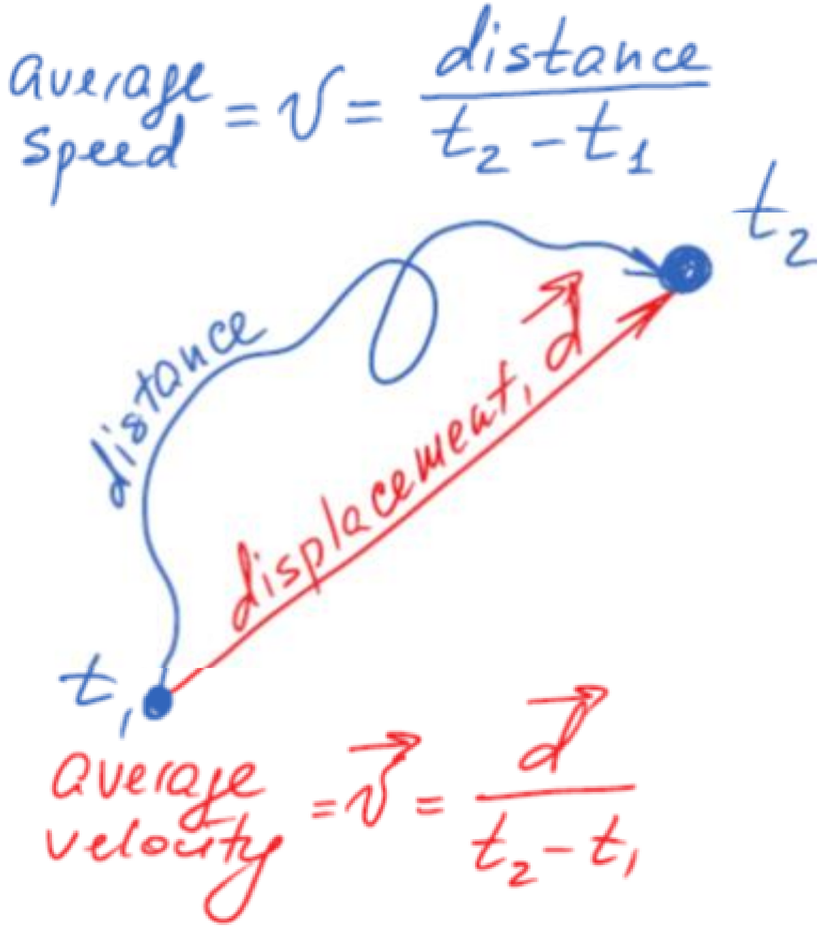
negative

Speed and Velocity





Average Speed and Velocity



Average Speed and Velocity

Displacement describes the position of an object.

Speed and Velocity describe the motion of the object

$$average\ speed = \frac{\text{distance travelled}}{\text{time elapsed}} \left[L/T \right]$$

Speed is a *scalar*

(Speed: Distance traveled per unit time interval)

$$average\ velocity = \frac{\text{displacement}}{\text{time elapsed}} \left[L/T \right]$$

Velocity is a vector

(Velocity: Displacement of an object per unit time interval)

ConcepTest 4 Speedometer

Does the speedometer in a car measure velocity or speed?

A) velocity

B) speed

C) both

D) neither

ConcepTest 4 Speedometer

Does the speedometer in a car measure velocity or speed?

A) velocity

B) speed

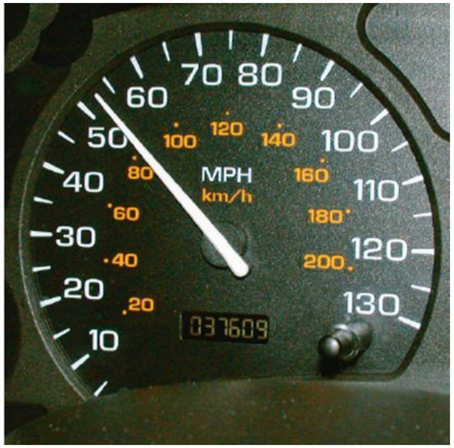
C) both

D) neither

The speedometer clearly measures speed, not velocity. Velocity is a vector (depends on direction), but the speedometer does not care what direction you are traveling.

Follow-up: how would you measure velocity in your car?

Instantaneous Velocity



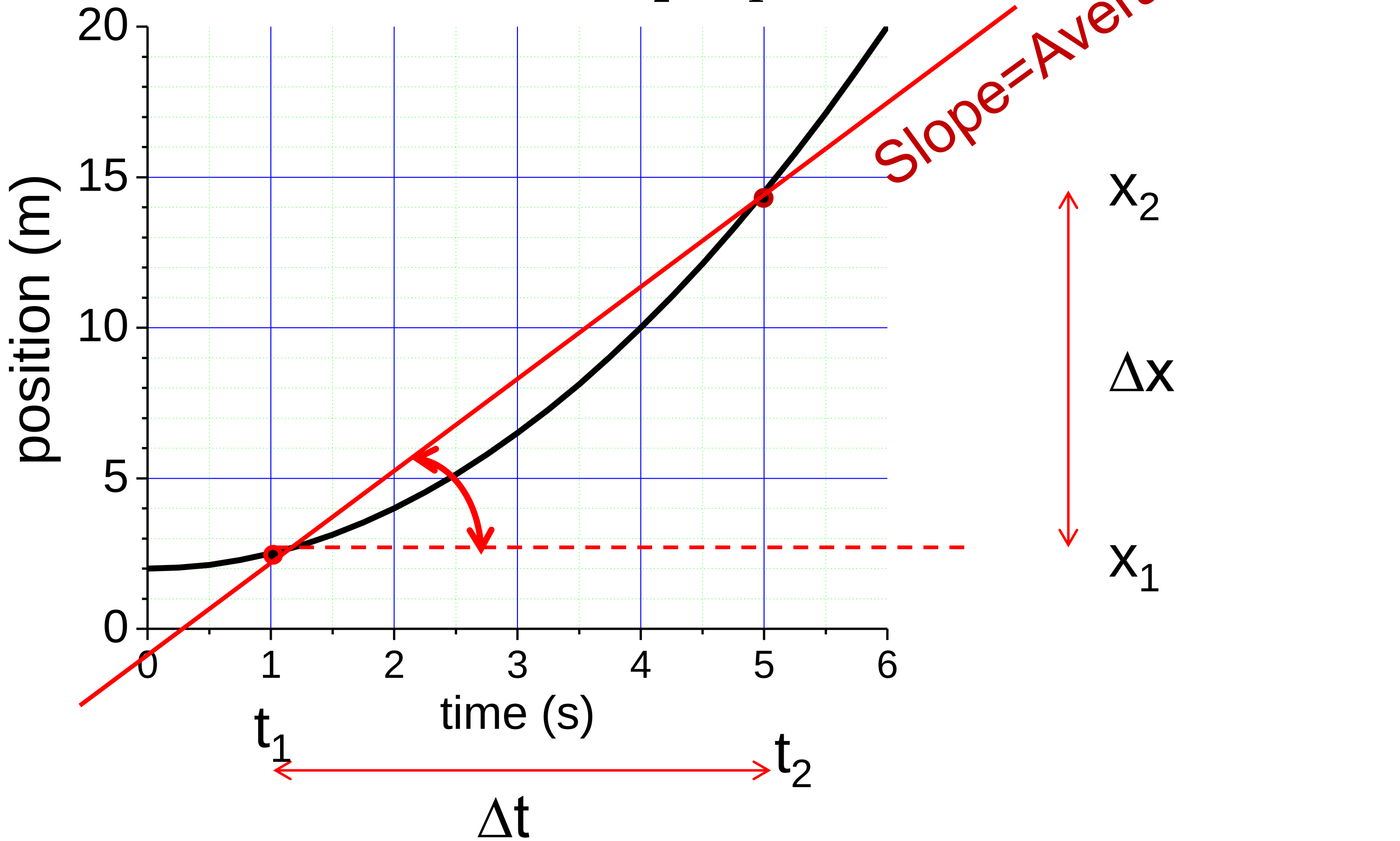
Average velocity does not tell the whole story…

e.g., if the MassPike timed your 55 mile travel between two exits to be 1 hr, they could calculate your average velocity to be 55 mph, but they couldn't tell if you speeded in between.

Thus, we need instantaneous velocity….

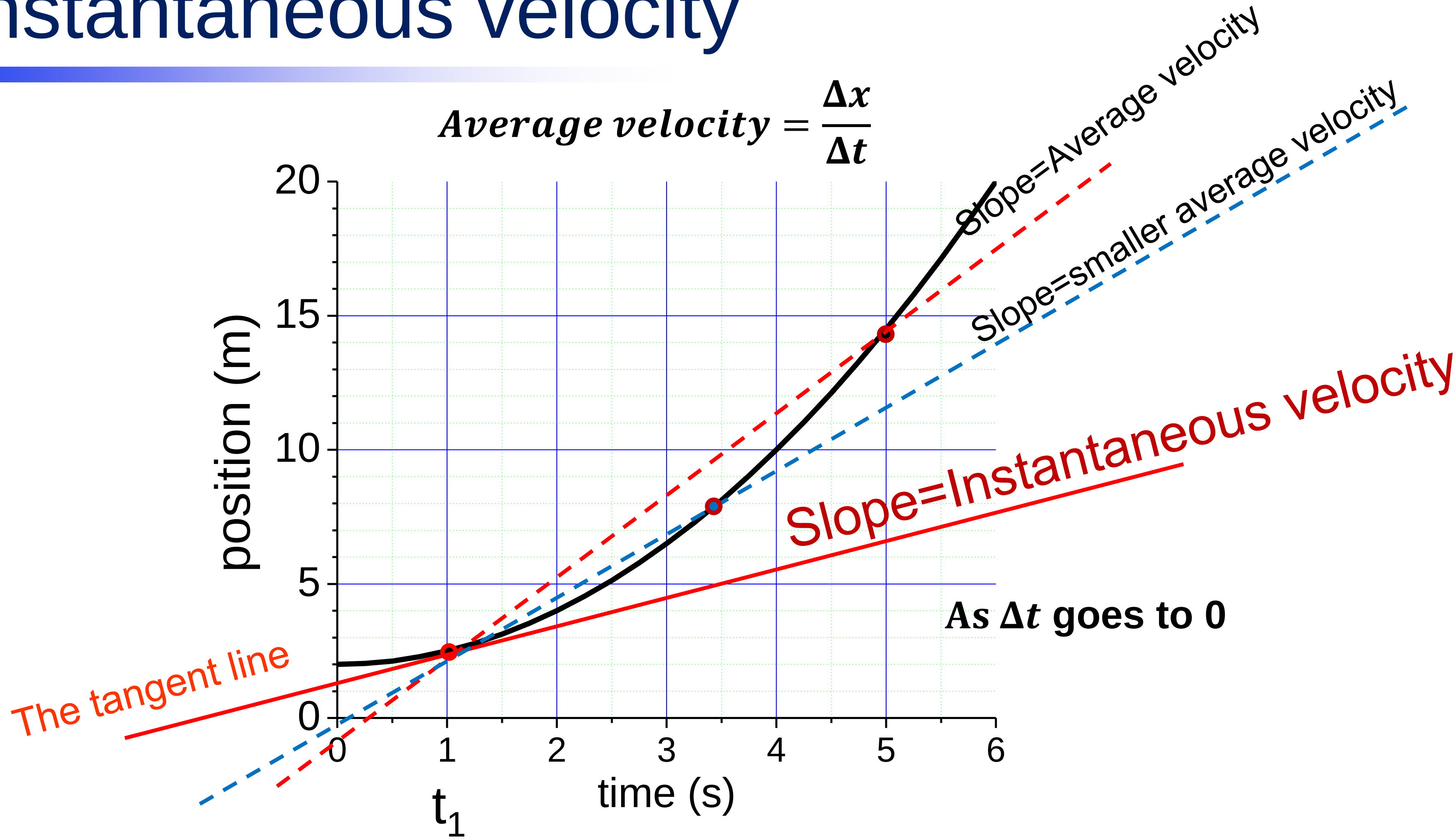
Graphs: Average velocity

$$Average\ velocity = \frac{x_2 - x_1}{t_2 - t_1} = \frac{\Delta x}{\Delta t}$$



Instantaneous velocity

$$Average\ velocity = \frac{\Delta x}{\Delta t}$$



Instantaneous velocity $v(t) = \lim_{\Delta t \to 0} \frac{x(t + \Delta t) - x(t)}{\Delta t} = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t} = \frac{dx}{dt}$

Instantaneous velocity

- Graphically, instantaneous velocity is the slope of the x vs t plot at a single point
- Mathematically, the instantaneous velocity is the *derivative* of the position function

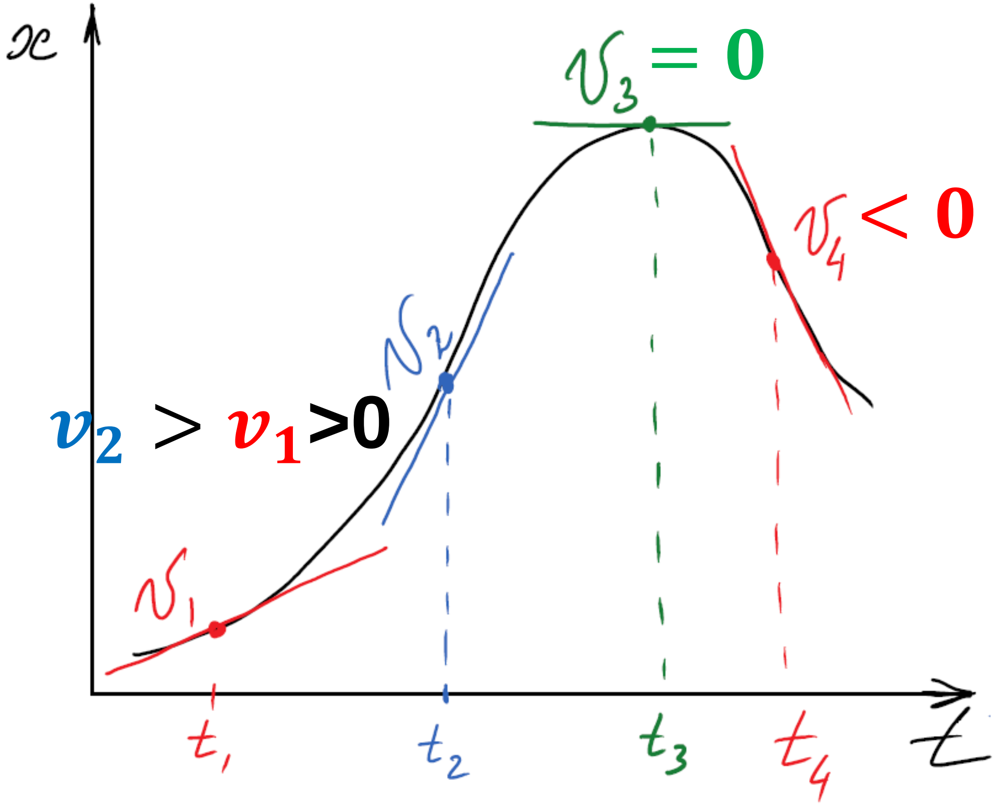
For a function which gives position (x) as a function of time (t), we can find the function of velocity as a function of time by taking the derivative of the position function

$$v = x'(t) = \frac{dx}{dt}$$

$$x = 2 + \frac{1}{2}t^2$$

$$v = \frac{dx}{dt} = \frac{d}{dt}\left(2 + \frac{1}{2}t^2\right) = t$$

Instantaneous velocity



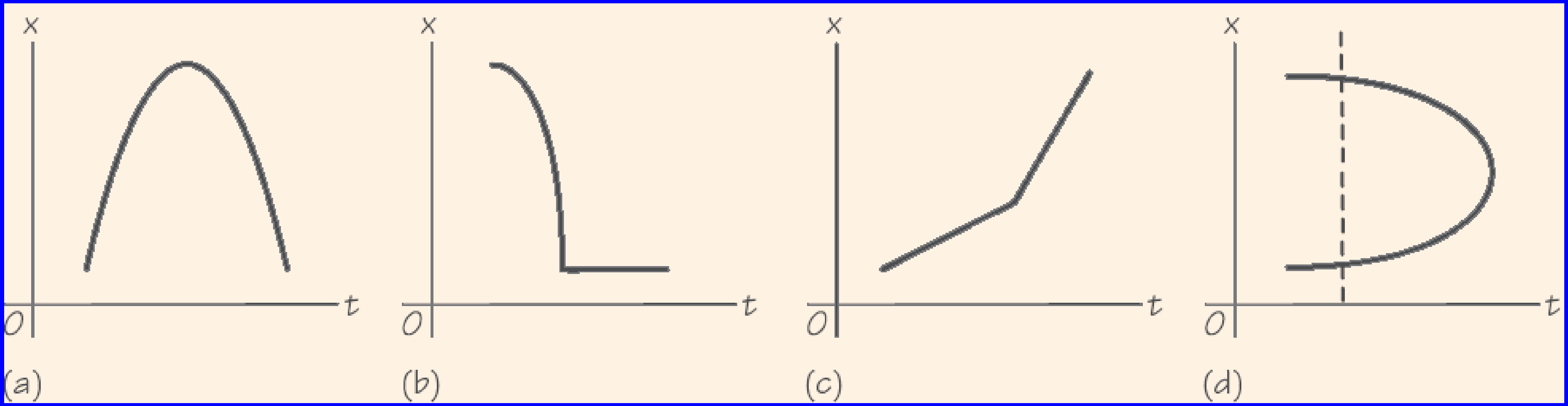
don't be afraid of negative

Gentler slope ≡ lower velocity

Steeper slope ≡ higher velocity

ConcepTest 5 Relay baton

Which one of the following *x-vs-t* graphs could be a reasonable representation of the motion of a baton in a relay race being passed from one runner to the next?



Acceleration

Velocity can also change with time: acceleration

$$average\ acceleration = \frac{\text{change of velocity}}{\text{time elapsed}}\left[L/T\!\!\diagup_{T}\right] \qquad \bar{a} = \frac{v_2 - v_1}{t_2 - t_1}$$

Instantaneous acceleration $$a = \lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t} = \frac{dv}{dt}$$

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

If we are given x(t), we can find both velocity v(t) and acceleration a(t) as a function of time

Speeding up: acceleration Slowing down: deceleration

Example 2-7: Acceleration given $x(t)$.

One D motion

$0 \longrightarrow x$

$$\boxed{x(t) = 2 \cdot t^2 + 3}$$

- $v(t) = \frac{dx}{dt} = \frac{d}{dt}(2t^2+3) = 4 \cdot t \ (m/s)$

$v(2s) = 4 \cdot 2 = 8\ m/s$

$v(1s) = 4 \cdot 1 = 4\ m/s$

A particle is moving in a straight line so that its position is given by the relation

$$x = (2\ \mathrm{m/s^2})t^2 + (3\ \mathrm{m}).$$

Calculate

(a) its average acceleration during the time interval from $t_1 = 1$ s to $t_2 = 2$ s,

(b) its instantaneous acceleration as a function of time.

average acceleration

- $\bar{a} = \frac{v_2 - v_1}{t_2 - t_1} = \frac{(8-4)\ m/s}{(2-1)\ s} = \frac{4}{1}\ m/s^2 = 4\ m/s^2$

- Instantaneous acceler.

$a(t) = \frac{dv}{dt} = \frac{d}{dt}(4t) = 4\ m/s^2 = \text{const}$

Summary

Distance
Displacement

Speed
Average velocity
Instantaneous velocity

Average acceleration
Instantaneous acceleration

The End

See you on Wednesday