Announcements, Goals, and Reading

Announcements:

- HW01 due Tuesday Sep 20th, 11:59 pm on Mastering Physics
- HW00 grace period ends tonight
- **Help Resources: See next page**

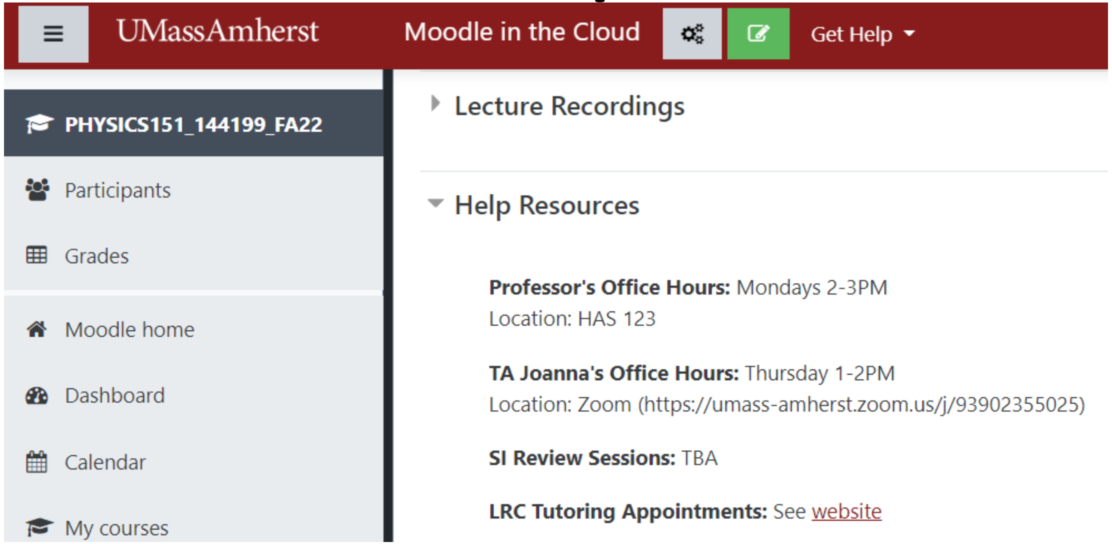
Goals for Today:

- Motion in 1-Dimension: Uniform Motion, Piecewise motion

Reading (Physics for Scientists and Engineers 4/e by Knight)

- Chapter 2: Kinematics in One Dimension

Help Resources



- ***Very important! These are opportunities for 1:1 instruction and tutoring that you can't always get in these big lectures.***
- ***Remember, receiving help is good! It is a skill and habit exercised by successful and smart people.***
- ***Some resources/people may be more helpful for you than others. If you don't feel sufficiently helped by one person/resource, try another. This is your learning, so you should take a level of responsibility for it.***

Drop in help in the Physics Help Room in Hasbrouck 115

Physics Help Room (HAS 115) - Fall 2022 Schedule

Help available for any 100-level Physics course from ANY GRADUATE TA
However, if you are looking for specific help, the course for which each TA is affiliated is listed

	Monday	Tuesday	Wednesday	Thursday	Friday
9am - 10am	Muldrow Etheredge 100	Esther Kalemba 131	Matthew Maroun 151	Sizhe Cheng 131	Robert Keane 151
			Siao-Fong Li 132	Nick Yazbek 131	Joanna Wuko 131
10am - 11am	Tao Wang 131	Jhih-Ying Su 151	Matthew Maroun 151	Sizhe Cheng 131	Robert Keane 151
	Shani Perera 151	Nick Pittman 152	Siao-Fong Li 132	Baji Jadhav 131/151	Sili Wu 151/131
11am - Noon		Nick Pittman 152	Yating Zhang 131	Esther Kalemba 131	Thisura 151
		Anthony Raykh 132	Joel Ponce 131/181	Prasanna More 181	Ryland Yurow 131
Noon - 1pm	Joel Ponce 131/181	Tanvir Ahmed Masum 131/597Q	Prasanna More 152	Joanna Wuko 131	Thisura 151
	Catherine McCarthy 131/281	Catherine McCarthy 131/281	Shani Perera 151	Sili Wu 151/131	
1pm - 2pm	Dyson Kennedy 131	Andrew Toler 151/281	Alexandria Nolan 131	Ryosuki Shiina 152	Hanzhe Xi 131
	Ed van Bruggen 151	Hannah Peltz Smalley 118	Justin Fagnoni 132	Ajit Kumar 131	Chenan Wei 131
2pm - 3pm	Tanvir Ahmed Masum 131/597Q	Mingyuan Wang	Ajit Kumar 131	Ryosuki Shiina 152	Hanzhe Xi 131
	Andrew Toler 151/281	Vivek Chakrabhavi 131	Justin Fagoni 132	Ajit Kumar 131	Joanna Wuko 151
3pm - 4pm	Chetan Yadav 131	Mingyuan Wang 131		Ed Van Bruggen 152	
	Hanzhe Xi 181	Aidan Morehouse 131		Owen Drescher 131	
4pm - 5pm	Aditya Kulkarni 131	Aiden Khelil 151	CLOSED FOR DEPARTMENTAL COLLOQUIUM	Zhiyu Yang 151	
	Chetan Yadav 131	Kripa Anand 132		Kripa Anand 132	
5pm - 6pm	Oluwafemi Akomolafe 132	Aiden Khelil 151		Arsh Chakraborty 132	
				Dang Tran 131	
6 pm - 7pm		Oluwafemi Akomolafe 132	Sofia Corba 181/132	Arsh Chakraborty 132	CLOSED
			Aman Aman 131	Ryosuke Shiina 131	
7pm - 8pm		Sofia Corba 181/132	Kerry O'Brien 151	Ryosuke Shiina 131	
			Pronay Dutta 131	Dang Tran 131	
8pm - 9pm		Sofia Corba 181/132	Charlie Veihmeyer 131		

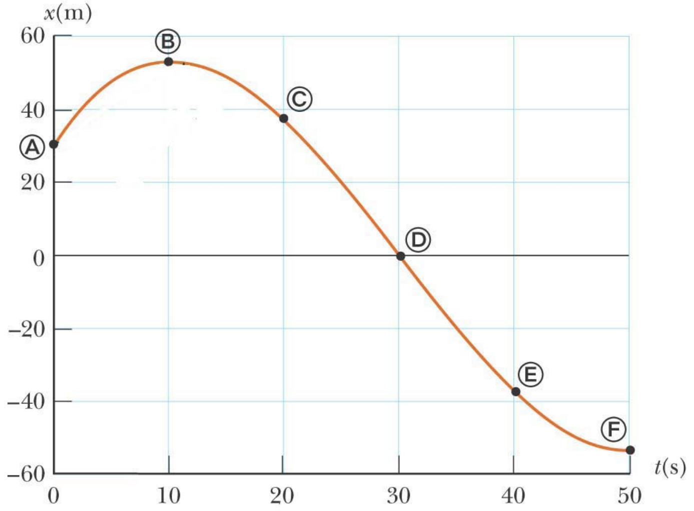
- ***Lots of Physics PhD students (<u>experts</u> in this material) available to help you all day, every weekday!***
- ***Our TAs will be there***
- ***This is a great opportunity that you should take advantage of.***

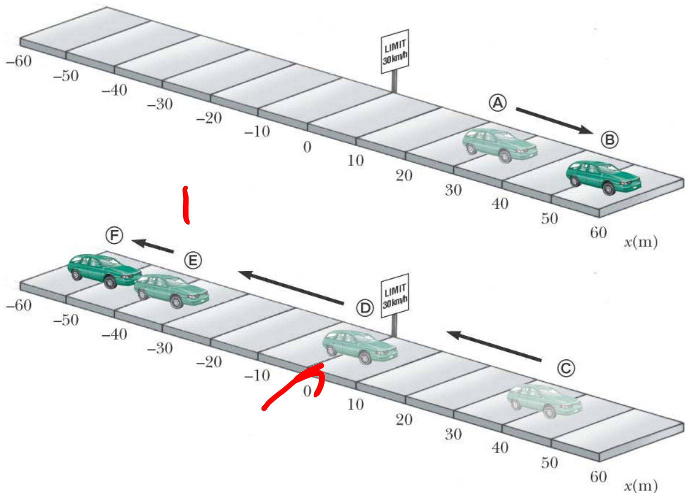
Kinematics in One Dimension

Kinematics – *Mathematical* study of motion without reference to forces that cause it

Motion described by position as function of time, e,g, **x(t)**

- Car moves forward then reverses
- Positions shown are at 10s intervals





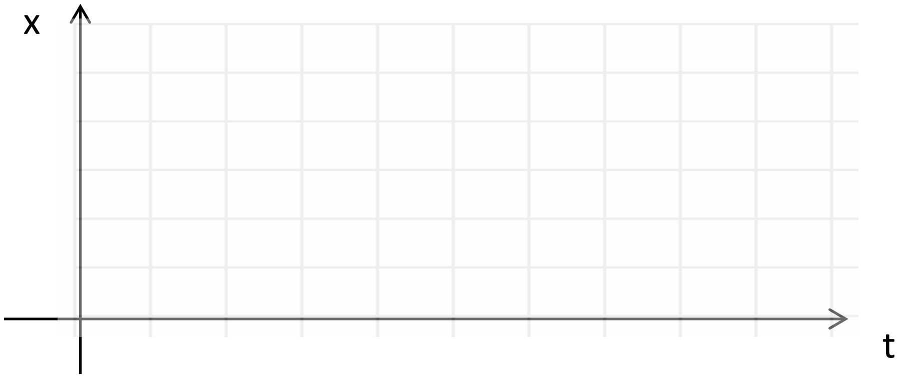
-Plot of car's motion contains more info than motion diagram

-Shows position at all times 0s <t <50s

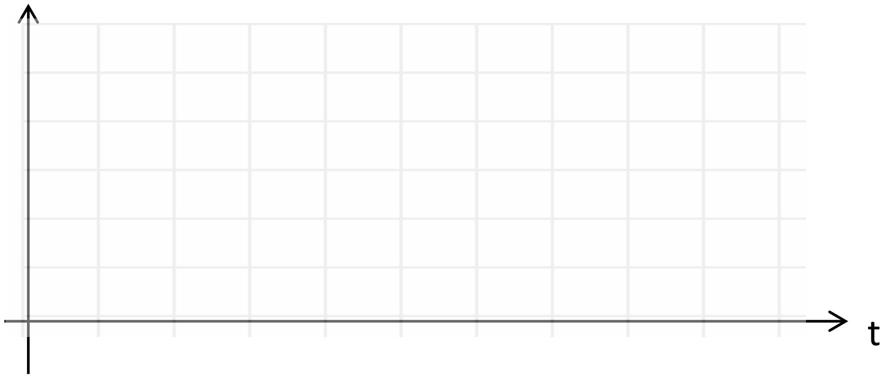
Uniform Motion in 1D

Don’t need full vector notation

Plot of x(t) (position vs time) for motion with constant speed and velocity>0



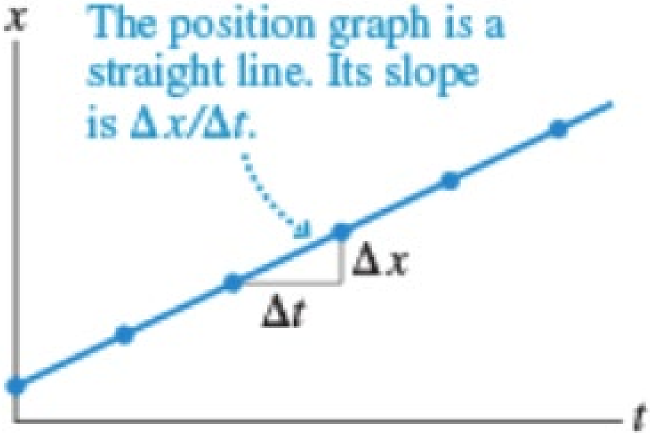
Plot of x(t) (position vs time) for motion with constant speed and velocity < 0



Constant velocity: Motion Diagram vs graphical representation

Motion diagram

Position vs Time graph



What about velocity vs time?

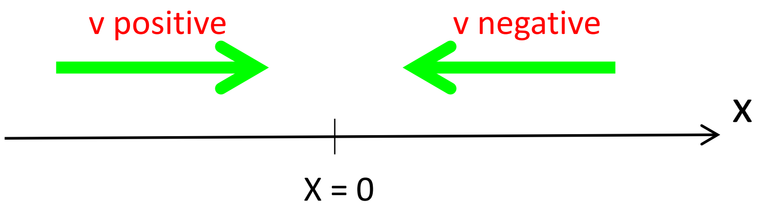
Uniform Motion in 1D

Motion with constant speed and velocity

Direction of motion indicated by sign of velocity

Motion to left → v negative

Motion to right → v positive



For example, an object has **speed** 5 m/s

Can have two possible **velocities**

$$v = +5m/s$$

or

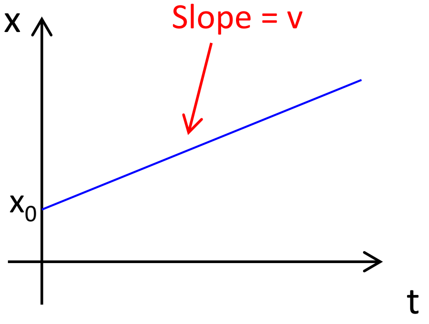
$$v = -5m/s$$

Uniform Motion in 1D

Motion with constant speed and velocity

Constant velocity motion is straight line motion on plot of position vs. time

$x(t) = x_0 + vt$ ⇔



Initial position

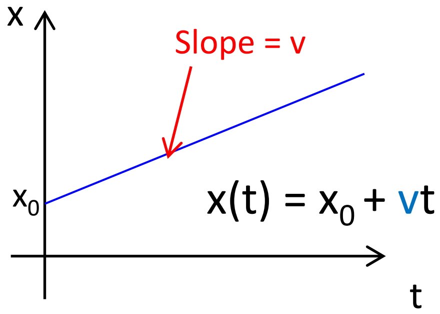
$t=0 \Rightarrow x(0) = x_0$

Compute average velocity between times t_1 and t_2

$$v_{avg} = \frac{\Delta x}{\Delta t} = \frac{x(t_2) - x(t_1)}{t_2 - t_1}$$

Computing Average Velocity

$$x(t) = x_0 + vt$$



Compute average velocity between times t_1 and t_2

$$v_{avg} = \frac{\Delta x}{\Delta t} = \frac{x(t_2) - x(t_1)}{t_2 - t_1}$$

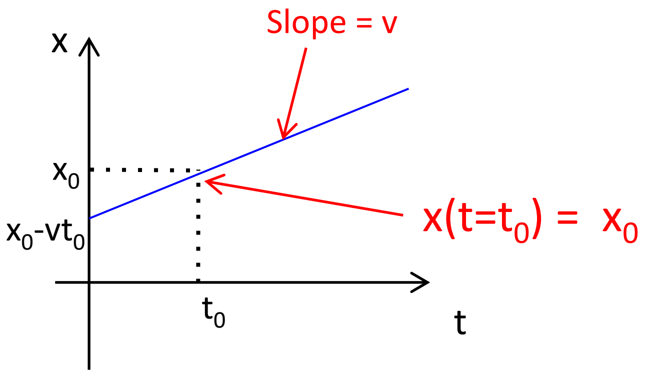
$$= \frac{(\cancel{x_0} + vt_2) - (\cancel{x_0} + vt_1)}{t_2 - t_1}$$

$$= \frac{vt_2 - vt_1}{t_2 - t_1} = \frac{v(t_2 - t_1)}{t_2 - t_1}$$

$$= v \checkmark$$

(1) Velocity is constant here (choice of t_2 and t_1 doesn't matter)
(2) Average velocity equals slope v

Alternative form for line equation



$$\boxed{x(t) = x_0 + v\,(t-t_0)}$$

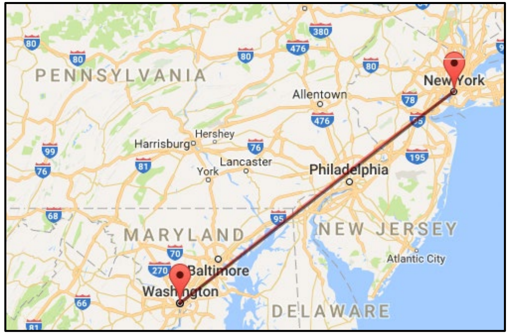
Equation is in Point-Slope form

Goes through point (t_0,x_0) with slope v

Most general equation to remember

Example…

Straight line distance from New York City to Washington DC is d=200 miles. Alice drives straight from NYC to DC at 50 miles/hour. Bob leaves 2 hours after Alice and drives along the same route at 75 miles/hour

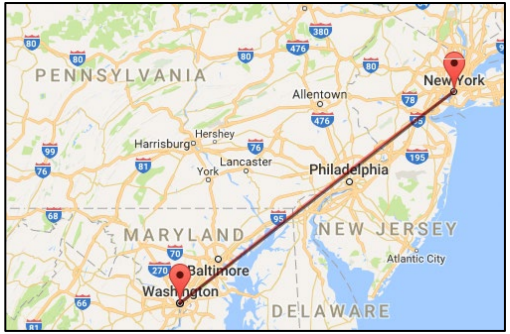


- Will Bob catch up with Alice before she reaches DC?
- If so, at what time?
- At what distance from NYC?

First step: Make formulas for Alice and Bob's position vs time $x(t) = x_0 + v\,(t - t_0)$

Example…

Straight line distance from New York City to Washington DC is d=200 miles. Alice drives straight from NYC to DC at 50 miles/hour. Bob leaves 2 hours after Alice and drives along the same route at 75 miles/hour



- Will Bob catch up with Alice before she reaches DC?
- If so, at what time?
- At what distance from NYC?

Applications: defend Earth from planet-killing asteroids, missile defense, car collision avoidance systems, ….

Start by writing formulas for Alice's and Bob's motions $x = x_0 + v\ (t - t_0)$

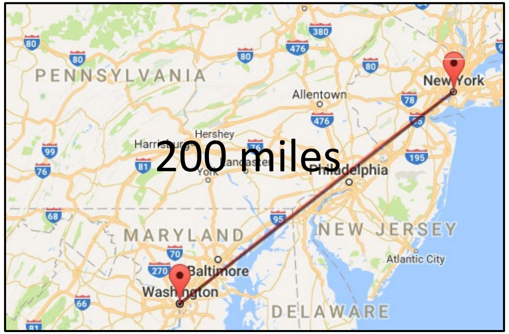
$x_A = v_A\ t$

$x_B\ (t) = v_B\ (t - t_0)$

- Let x be distance from NYC; $x_0 = 0$
- Assume Alice starts at t=0; for Alice $t_0 = 0$
- For Bob $t_0 = 2$ hour

Example…

- Will their paths cross before Alice reaches DC?
- If so, then at what time?
- And at what distance from NYC?



$x_A = v_A \; t$ $\qquad$ $x_B\,(t) = v_B\,(t - t_0)$

When will Alice get to DC?

d=200 miles
v_A= 50mph
v_B=75mph

$v_A\, t = d \;\Rightarrow\; t = d/\,v_A = 200\text{mi} \,/\, 50 \text{ mph} = 4 \text{ hours}$

Assume A's & B's paths cross at time t=T

$\Rightarrow x_A\,(T) = x_B(T)$

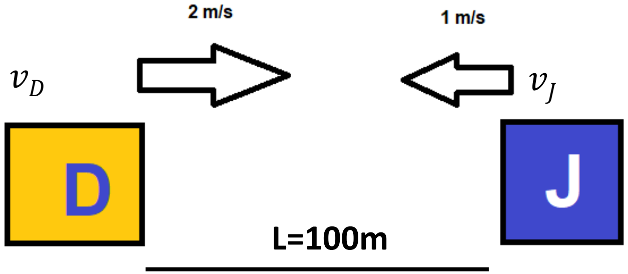
$\Rightarrow v_A\, T = v_B\,(T - t_0)$

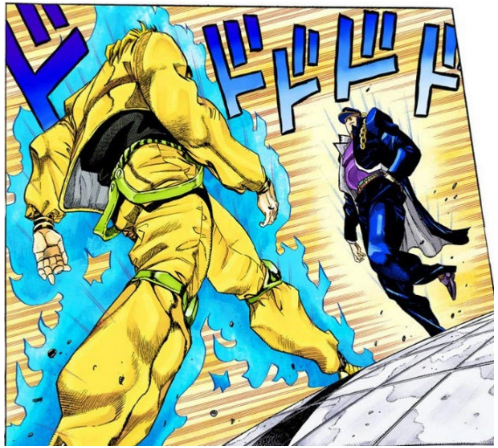
$\Rightarrow (v_B - v_A)\, T = v_B\, t_0 \;\Rightarrow\; T = (75/25)\, t_0 = 6 \text{ hours}$

But Alice has already reached Washington DC by then!

If they kept going, they would meet at $x_A\,(T) = v_A\, T = 300$ miles

Another Example…





- Initial straight line distance L from Dio (left) to Jotaro (right) is 100m.
- At $t_0 = 0s$, Jotaro approaches Dio at $v_J = -1\frac{m}{s}$
- Dio walks briskly rightward toward Jotaro 10 seconds after Jotaro and approaches at $v_D = +2\frac{m}{s}$ until they collide for a friendly handshake.

  - Who will travel more distance by the time they collide?
  - How long will this take?

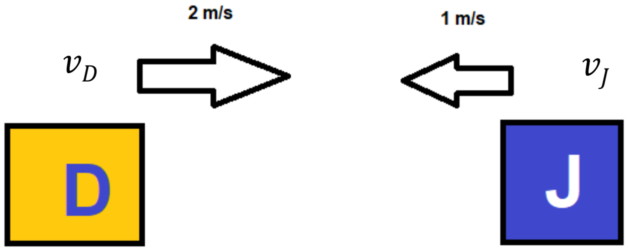
$x(t) = x_0 + v(t-t_0)$

Start by writing formulas for Jotaro's and Dio's motions

$$x_J(t) = L + v_J t = 100m + \left(-1\frac{m}{s}\right) * t$$

$$x_D(t) = v_{D(t-10s)} = 2\frac{m}{s}\,(t - 10s)$$
$$[when\ t >= 10s]$$

Notes…
- Let x be distance from Dio's starting position
- Jotaro starts from x_0=L=100m at t_0=0
- Dio starts from x_1=0 at t_1=10s



$$x_J(t) = L + v_J t = 100m + \left(-1\frac{m}{s}\right) * t$$

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$$[when\ t >= 10s]$$

- Who will travel more distance by the time they collide?
- How long will this take?

The time of collision t_c is where $x_J(t_c) = x_D(t_c)$: the time where they inhabit the same spatial position.*

Step 1: Set positions equal to one another

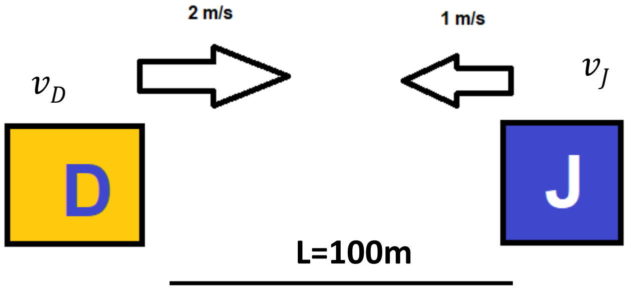
$$x_{J(t_c)} = xD_{(t_c)} \Rightarrow L + v_J t_c = vD_{(t_c - t_1)}$$

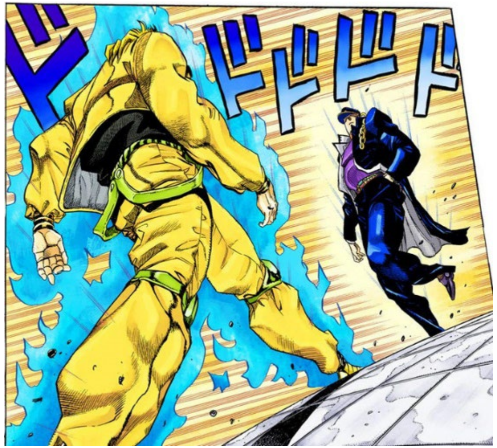
Step 2: Solve for t_c

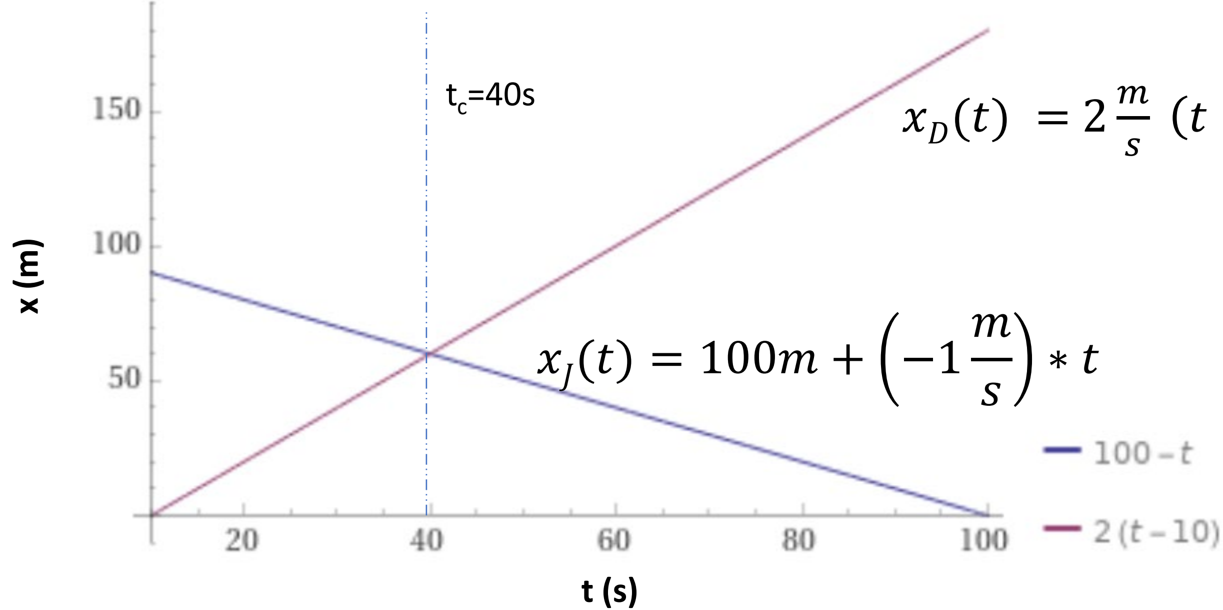
$$\Rightarrow t_c = \frac{L + vDt_1}{v_D - vJ} = \frac{100m + 2\frac{m}{s} * 10s}{2\frac{m}{s} - (-1\frac{m}{s})} = \frac{120m}{3\ m/s} = 40s$$

Step 3: Find the position at t $= t_c = 40s$ $\quad x_{J(40s)} = 100m - 40m = 60m$

Dio will have traveled more distance from his initial position when they collide.





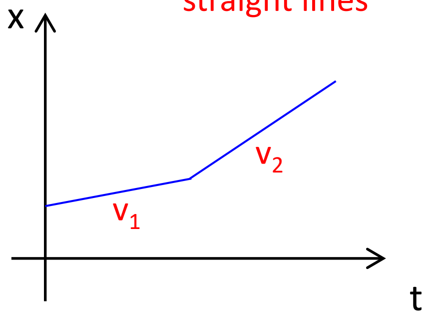


$$x_D(t) = 2\frac{m}{s}\,(t - 10s)$$

$$x_J(t) = 100m + \left(-1\frac{m}{s}\right) * t$$

Slightly more complicated motion…

Consider trips made up of multiple constant velocity segments



For example

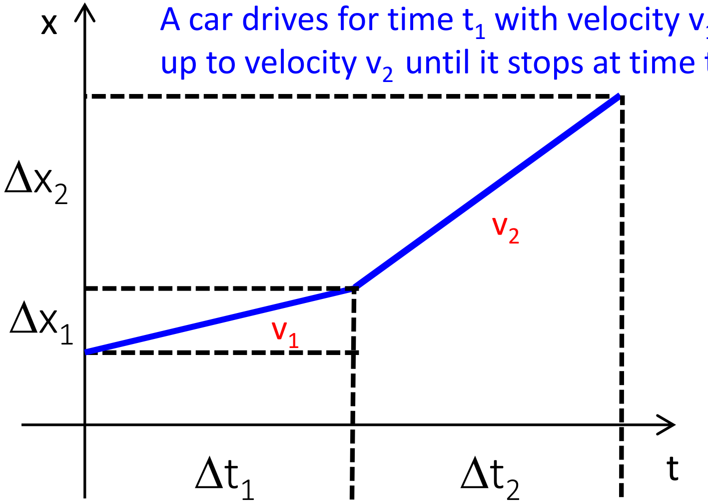
A car drives for time t_1 with velocity v_1 then speeds up to velocity v_2 until it stops at time t_2

Note: A car can't speed up instantaneously.
This is an idealization of a very short, but finite acceleration period

Looks innocent/innocuous
But leads to surprisingly tricky physics problems!

What is the average velocity for this trip? ➡ $v_{avg} = \dfrac{\Delta x_{\text{total}}}{\Delta t_{\text{total}}}$

A car drives for time t_1 with velocity v_1 then speeds up to velocity v_2 until it stops at time t_2.



$$v_{avg} = \frac{\Delta x_{total}}{\Delta t_{total}}$$

General solution

$$\Delta x_{total} = \Delta x_1 + \Delta x_2 = v_1 \Delta t_1 + v_2 \Delta t_2$$

$$\Delta t_{total} = \Delta t_1 + \Delta t_2$$

$$v_{avg} = \frac{v_1 \Delta t_1 + v_2 \Delta t_2}{\Delta t_1 + \Delta t_2}$$

Example: A car travels for time T/2 at velocity v_1 and then for time T/2 at velocity v_2. What is the average velocity?

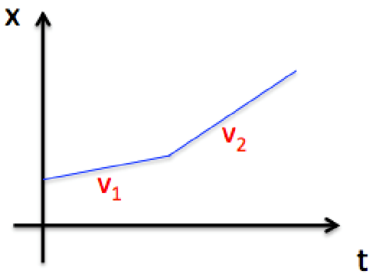
$$\Delta t_1 = \Delta t_2 = T/2 \qquad v_{avg} = \frac{v_1 T/2 + v_2 T/2}{T} = \frac{v_1 + v_2}{2}$$

Simple average of two velocities

Trips with multiple constant velocity segments

Compute average velocity for trip?

$$v_{avg} = \frac{\Delta x}{\Delta t}$$



Harder example: A car makes a trip of total distance D.
For the first D/2, it travels at v_1 and for the second D/2 it travels at v_2

$\Delta x = D$ No problem! But what is Δt? $\text{velocity} = \frac{\text{distance}}{\text{time}}$ ⟺ $\text{time} = \frac{\text{distance}}{\text{velocity}}$

$$\boxed{\Delta t_1 = \frac{D/2}{v_1} \quad \text{and} \quad \Delta t_2 = \frac{D/2}{v_2}}$$

Here Δt=sum of $(\Delta t_1 + \Delta t_2)$ $\quad v_{avg} = \frac{\Delta x}{\Delta t}$

$$\Delta t = \frac{D}{2}\left(\frac{1}{v_1} + \frac{1}{v_2}\right) = \frac{D}{2}\frac{v_1 + v_2}{v_1 v_2} \Rightarrow \boxed{v_{avg} = \frac{2v_1 v_2}{v_1 + v_2}}$$

A car makes a trip of total distance D.
For the first D/2, it travels at v_1 and for the second D/2 it travels at v_2

$$\boxed{v_{avg} = \frac{2v_1 v_2}{v_1 + v_2}}$$

Check to see that it makes sense.

A scientist has to check a complicated answer whether it makes sense in simple limited cases!

What if $v_1 = v_2 = v$. We expect the final answer to be v as well.
Plugging into our results gives…

$$\Rightarrow \quad \boxed{v_{avg} = v} \quad \checkmark$$

A car makes a trip of total distance D.
For the first D/2, it travels at v_1 and for the second D/2 it travels at v_2

$$\boxed{v_{avg} = \frac{2v_1 v_2}{v_1 + v_2}}$$

Check to see that it makes sense.

A scientist has to check a complicated answer whether it makes sense in simple limited cases!

What if v_1 goes to zero? It will never get to halfway point.

$$\Delta t_1 = \frac{D/2}{v_1}$$

Expect $\boxed{\lim_{v_1 \to 0} v_{avg} = 0}$

$$\boxed{\lim_{v_1 \to 0} \Delta t = \infty}$$

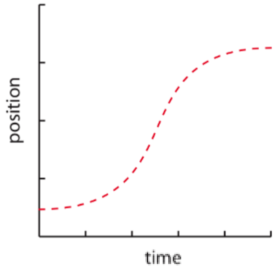
Both easily checked from results!

$$\boxed{v_{avg} = \frac{2v_1 \cancel{v_2}}{\underbrace{v_1}_{0} + \cancel{v_2}}}$$

✓

Position vs. time plots (not every plot is legitimate!)

Which of these graphs might represent the motion of a real object (e.g. a bike)?



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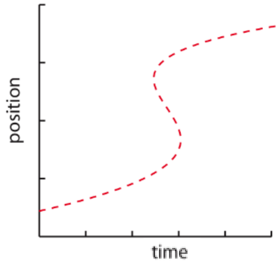
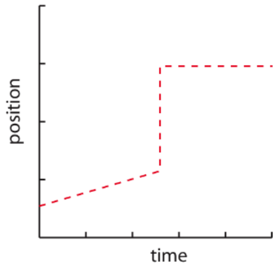


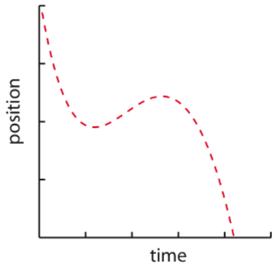
X

Goes backwards in time!



X

Changes position instantaneo usly

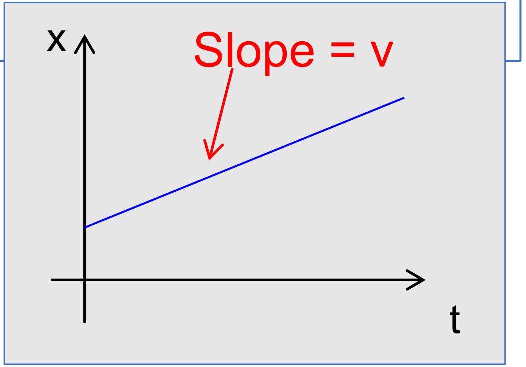


✓

1D motion non-constant velocity ➔ Instantaneous velocity

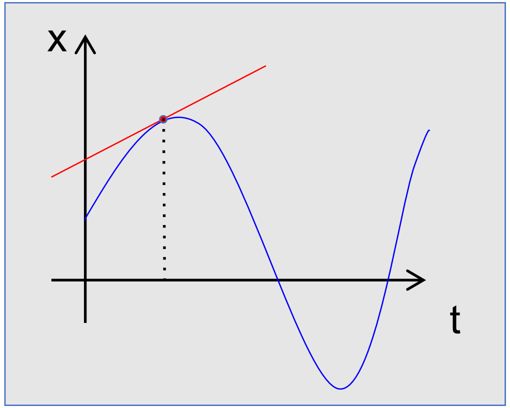
Constant velocity motion

- Straight line motion diagram
- Velocity equals slope of line



More generally

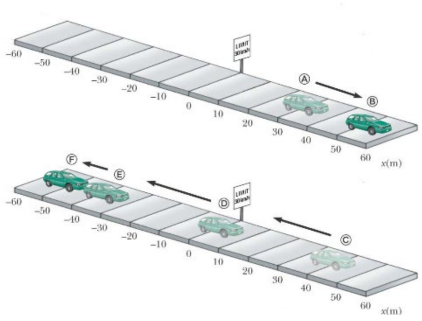
- Velocity changes with time
- **Instantaneous velocity** is slope of line tangent to curve
- Can compute this slope by taking limit of average velocity over shorter and shorter time intervals
- Velocity is the **derivative** of the position curve

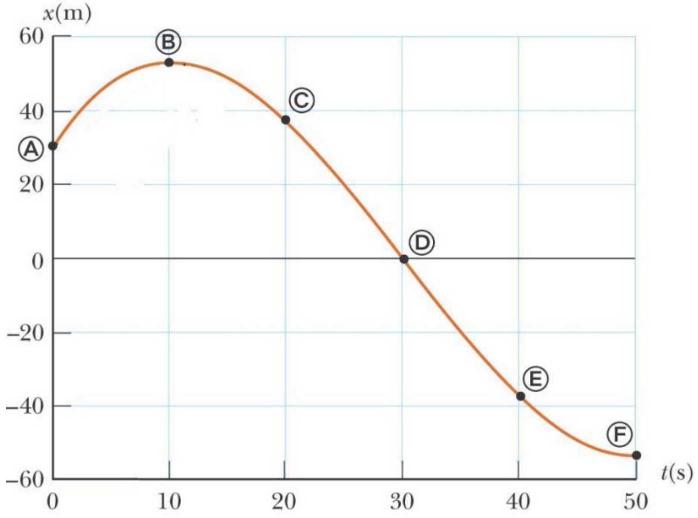


1D motion with non-constant velocity

Before "instantaneous velocity" return to…
Average velocity vs. Average speed

The relationship becomes
more important when you can
back up…
Cover more distance, without
necessarily getting anywhere



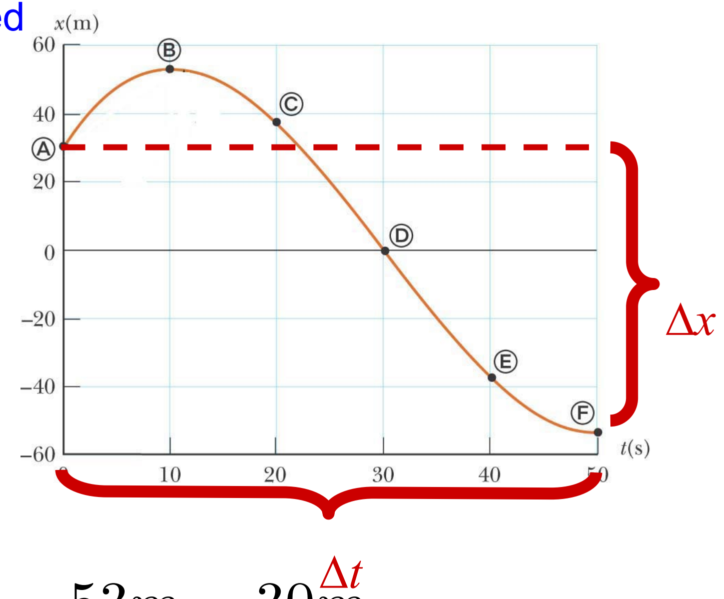


Is the velocity zero anywhere? How
can
you tell?
Where is the velocity the greatest?
How can you tell?

Average Velocity: based on...

Displacement = **Net distance** traveled

Position of the Car at Various Times		
Position	**t(s)**	**x(m)**
Ⓐ	0	30
Ⓑ	10	52
Ⓒ	20	38
Ⓓ	30	0
Ⓔ	40	−37
Ⓕ	50	−53



$$v_{avg} = \frac{\Delta x}{\Delta t} = \frac{x(t_f) - x(t_i)}{t_f - t_i} = \frac{-53m - 30m}{50s - 0s} = -1.7m/s$$

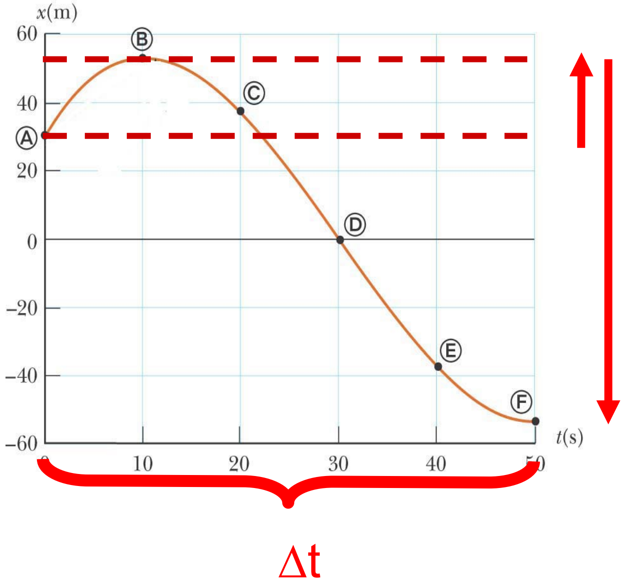
Magnitude is 1.7 m/s; direction is -*x*

Average Speed:

Based on **total distance** travelled

Position of the Car at Various Times

Position	t(s)	x(m)
Ⓐ	0	30
Ⓑ	10	52
Ⓒ	20	38
Ⓓ	30	0
Ⓔ	40	−37
Ⓕ	50	−53



$$s_{avg} = \frac{\text{total distance}}{\text{total time}} = \frac{22m + 105m}{50s} = 2.5m/s$$

> No direction and no sign associated with speed.
> Never negative, or smaller than |v|.