PHYS 1441 – Section 002
Lecture #4

Wednesday, Sept. 15, 2010

Dr. Jaehoon Yu

- One Dimensional Motion
  - Instantaneous Velocity and Speed
  - Acceleration
  - Motion under constant acceleration
  - One dimensional Kinematic Equations
  - How do we solve kinematic problems?
  - Falling motions

Announcements

- E-mail subscription
  - A test message was sent out yesterday!
    - Thanks for your replies!
    - If you haven't yet, please check your e-mail and reply ONLY TO ME!
  - 66/80 subscribed! ➔ Please subscribe ASAP
- 1st term exam
  - Non-comprehensive
  - Time: 1 – 2:20pm, Wednesday, Sept. 22
  - Coverage: Appendices A.1 – A.8 and CH1.1 – what we finish coming Monday, Sept. 20
- Quiz results
  - Class average: 8.3/16
    - Equivalent to 52/100
  - Top score: 16/16
- Colloquium at 4pm today in SH101
  - Physics faculty research expo!!

Physics Department
The University of Texas at Arlington

COLLOQUIUM

Physics Faculty Research Expo

Wednesday September 15, 2010
4:00 p.m. Rm. 101SH

SPEAKERS:

Dr. Chris Jackson
"Higgs in Space !"

Dr. Kaushik De
"What can we expect to discover at the LHC ?"

Dr. Wei Chen
"Nanotechnology for Health care and Homeland security"

Dr. Sangwook Park
"X-Ray Observations of Supernova Remnants and Neutron Stars"

Dr. Samar Mohanty
" What we did this summer at UTA Biophysics group! "

Refreshments will be served at 3:30 p.m. in the Physics Library

Reminder: Special Problems for Extra Credit

- Derive the quadratic equation for $yx^2-zx+v=0$ ➔ 5 points
- Derive the kinematic equation $v^2 = v_0^2 + 2a(x - x_0)$ from first principles and the known kinematic equations ➔ 10 points
- You must **show your OWN work in detail** to obtain the full credit
  - Must be in much more detail than in pg. 19 of this lecture note!!!
- Due Monday, Sept. 27

Displacement, Velocity and Speed

One dimensional displacement is defined as:

$$\Delta x \equiv x_f - x_i$$

Displacement is the difference between initial and final potions of the motion and is a vector quantity. How is this different than distance?

Unit? m

The average velocity is defined as: $v_x \equiv \frac{x_f - x_i}{t_f - t_i} = \frac{\Delta x}{\Delta t} \equiv \frac{\text{Displacement}}{\text{Elapsed Time}}$

Unit? m/s

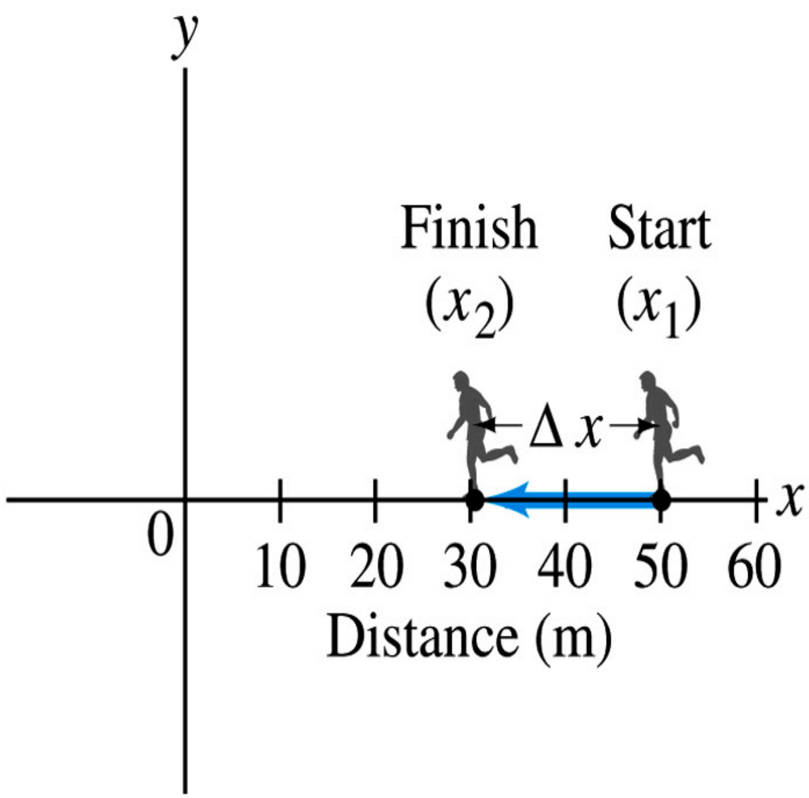
Displacement per unit time in the period throughout the motion

The average speed is defined as: $v \equiv \frac{\text{Total Distance Traveled}}{\text{Total Elapsed Time}}$

Unit? m/s

Example 2.1

The position of a runner as a function of time is plotted as moving along the x axis of a coordinate system. During a 3.00-s time interval, the runner's position changes from x_1=50.0m to x_2=30.5 m, as shown in the figure. What was the runner's average velocity? What was the average speed?



- Displacement:

$$\Delta x \equiv x_f - x_i = x_2 - x_1 = 30.5 - 50.0 = -19.5(m)$$

- Average Velocity:

$$v_x \equiv \frac{x_f - x_i}{t_f - t_i} = \frac{x_2 - x_1}{t_2 - t_1} = \frac{\Delta x}{\Delta t} = \frac{-19.5}{3.00} = -6.50(m/s)$$

- Average Speed:

$$v \equiv \frac{\text{Total Distance Traveled}}{\text{Total Time Interval}}$$

$$= \frac{50.0 - 30.5}{3.00} = \frac{+19.5}{3.00} = +6.50(m/s)$$

Example Distance Run by a Jogger

How far does a jogger run in 1.5 hours (5400 s) if his average speed is 2.22 m/s?

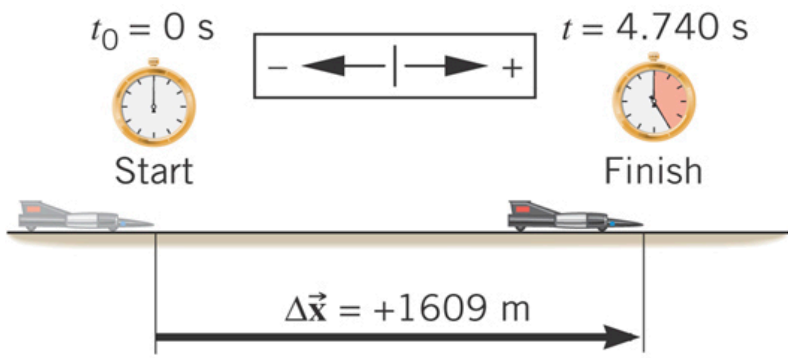
$$\text{Average speed} = \frac{\text{Distance}}{\text{Elapsed time}}$$

$$\text{Distance} = (\text{Average speed})(\text{Elapsed time}) =$$

$$= (2.22\ \text{m/s})(5400\ \text{s}) = 12000\ \text{m}$$

Example: The World's Fastest Jet-Engine Car

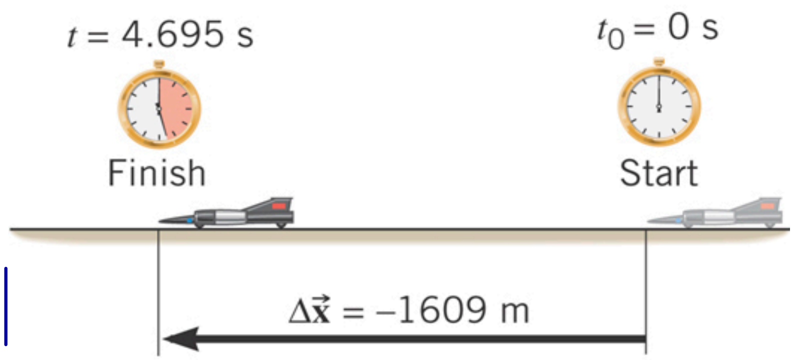
Andy Green in the car *ThrustSSC* set a world record of 341.1 m/s in 1997. To establish such a record, the driver makes two runs through the course, one in each direction to nullify wind effects. From the data, determine the average velocity for each run.



(*a*)

$$\bar{\vec{\mathbf{v}}} = \frac{\Delta\vec{\mathbf{x}}}{\Delta t} = \frac{+1609\ \text{m}}{4.740\ \text{s}} = +339.5\,\text{m/s}$$

What is the speed? $v = \left|\bar{\vec{\mathbf{v}}}\right| = 339.5\,\text{m/s}$



(*b*)

$$\bar{\vec{\mathbf{v}}} = \frac{\Delta\vec{\mathbf{x}}}{\Delta t} = \frac{-1609\ \text{m}}{4.695\ \text{s}} = -342.7\,\text{m/s}$$

What is the speed? $v = \left|\bar{\vec{\mathbf{v}}}\right| = \left|-342.7\,\text{m/s}\right|$

$$= 342.7\,\text{m/s}$$

Instantaneous Velocity and Speed

- Can average quantities tell you the detailed story of the whole motion? **NO!!**
- Instantaneous velocity is defined as:
  - What does this mean?
    - Displacement in an infinitesimal time interval
    - Average velocity over a very short amount of time

$$v_x = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t}$$

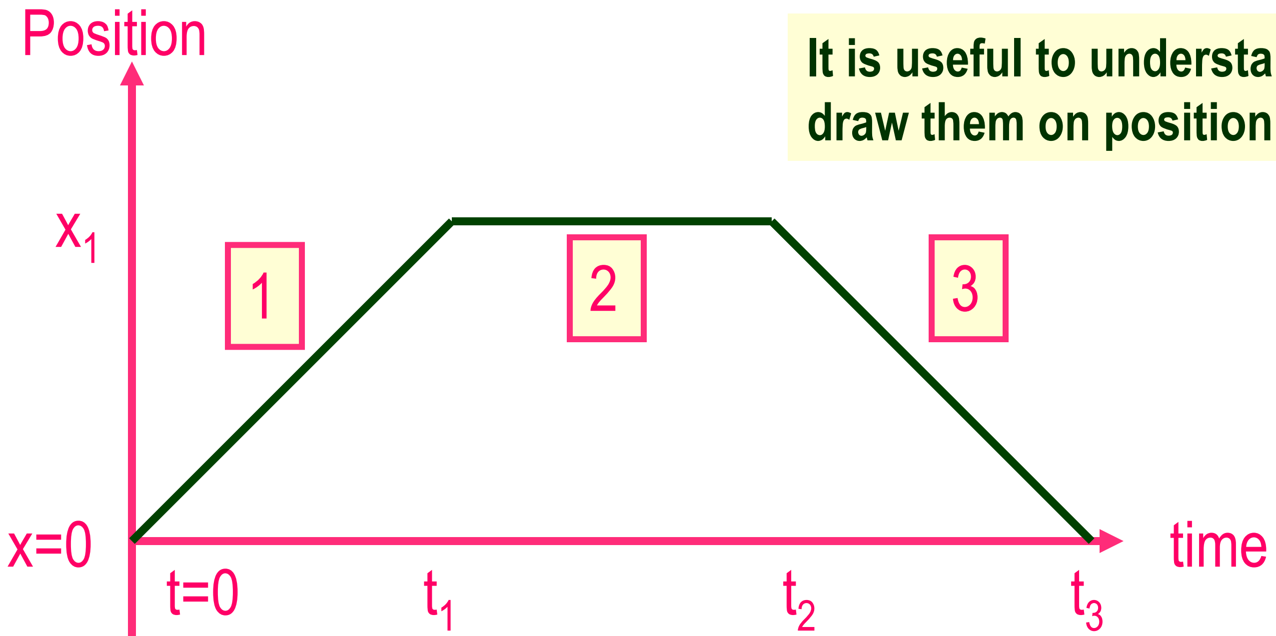
- Instantaneous speed is the size (magnitude) of the velocity vector:

$$|v_x| = \left| \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t} \right|$$

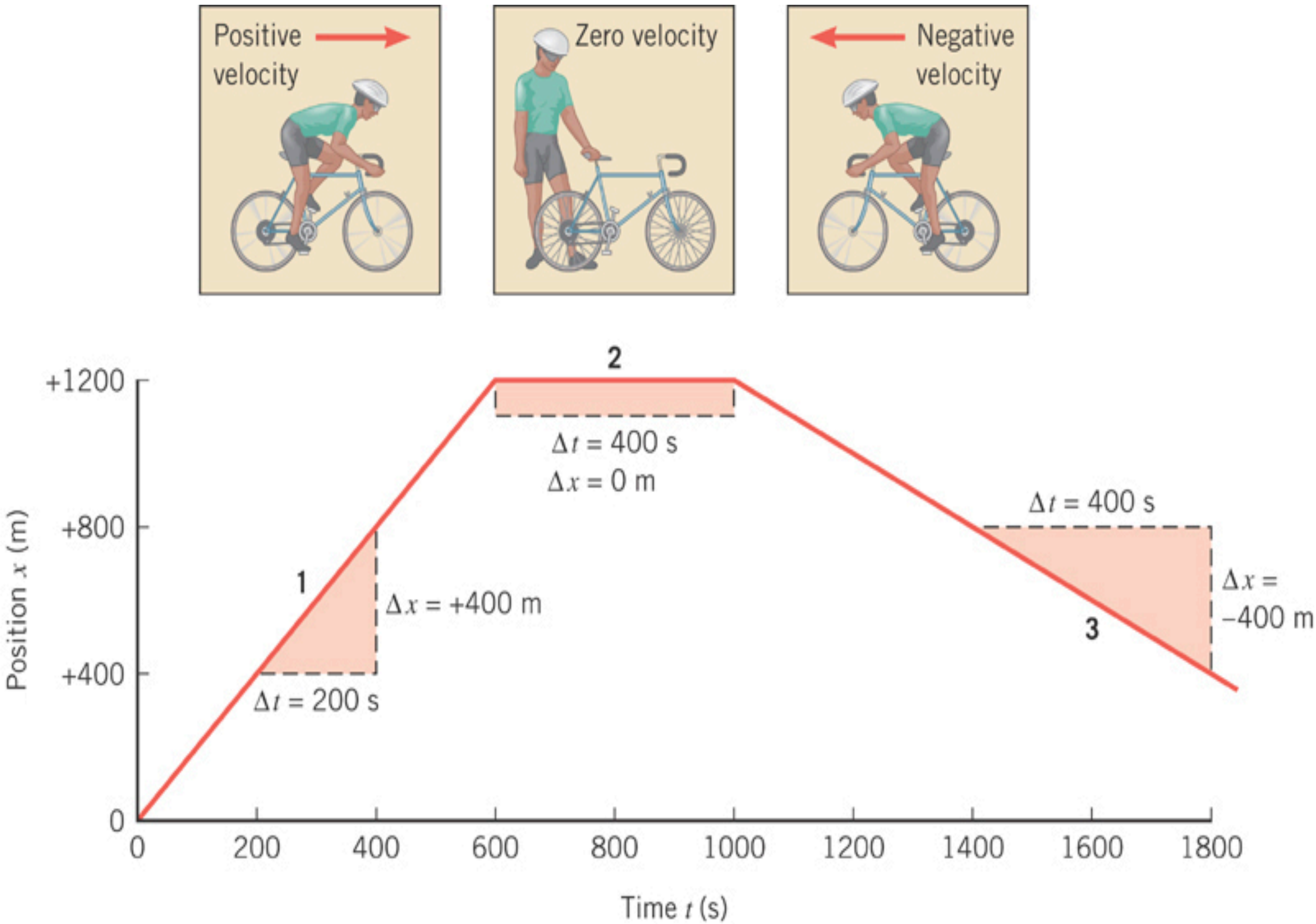
*Magnitude of Vectors are Expressed in absolute values

Position vs Time Plot

It is useful to understand motions to draw them on position vs time plots.

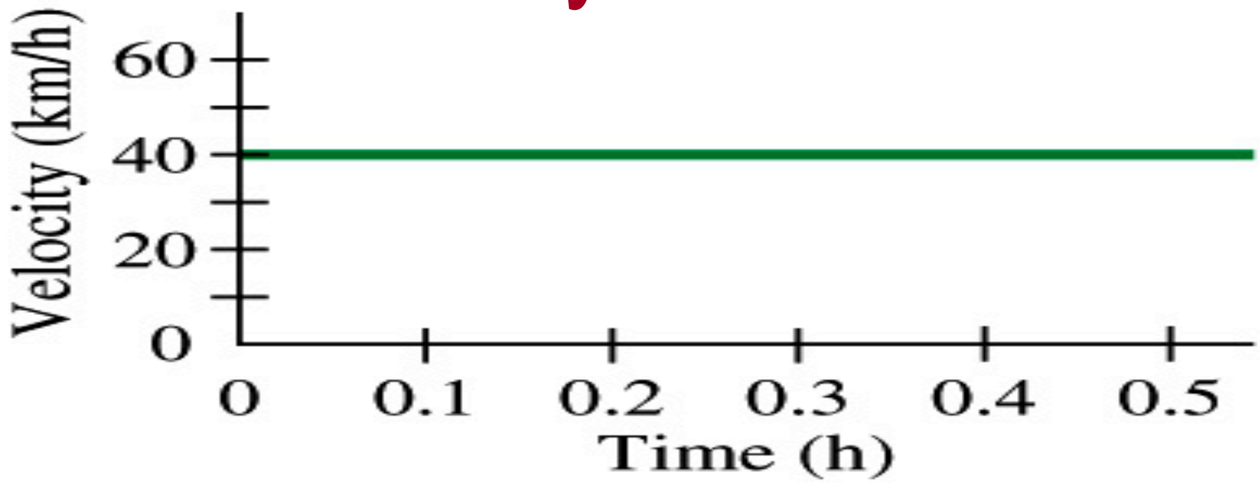


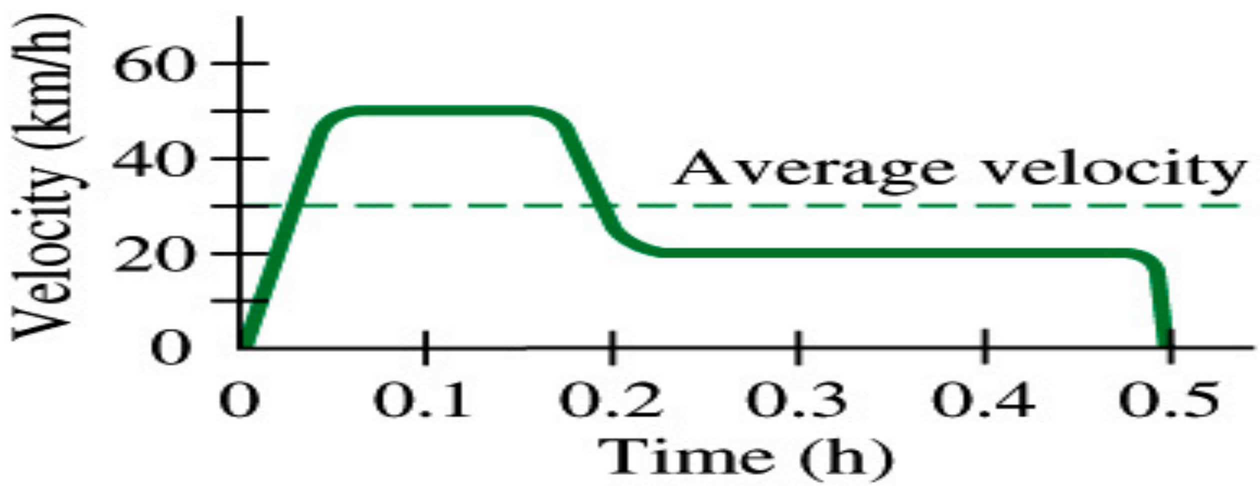
1. Running at a constant velocity (go from $x=0$ to $x=x_1$ in t_1, Displacement is $+ x_1$ in t_1 time interval)
2. Velocity is 0 (go from x_1 to x_1 no matter how much time changes)
3. Running at a constant velocity but in the reverse direction as 1. (go from x_1 to $x=0$ in t_3-t_2 time interval, Displacement is $- x_1$ in t_3-t_2 time interval)



Positive velocity
Zero velocity
Negative velocity
+1200
+800
+400
0
Position x (m)
2
Δt = 400 s
Δx = 0 m
1
Δx = +400 m
Δt = 200 s
Δt = 400 s
Δx =
−400 m
3
0
200
400
600
800
1000
1200
1400
1600
1800
Time t (s)

Velocity vs Time Plot





Displacement, Velocity and Speed

Displacement $$\Delta x \equiv x_f - x_i$$

Average velocity $$v_x \equiv \frac{x_f - x_i}{t_f - t_i} = \frac{\Delta x}{\Delta t}$$

Average speed $$v \equiv \frac{\text{Total Distance Traveled}}{\text{Total Time Spent}}$$

Instantaneous velocity $$v_x = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t}$$

Instantaneous speed $$|v_x| = \left| \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t} \right|$$

Acceleration

Change of velocity in time (what kind of quantity is this?)

Vector!

•Average acceleration:

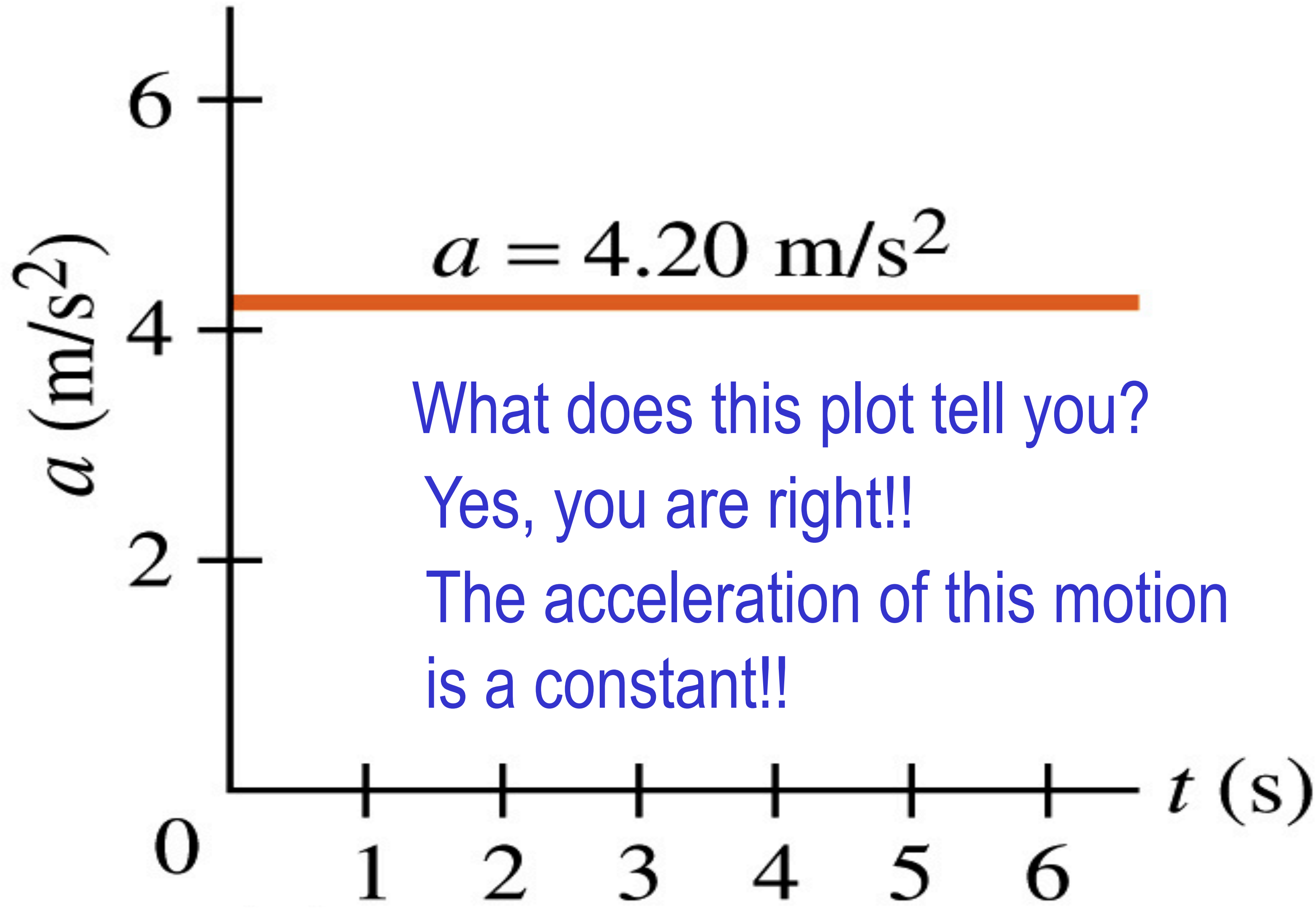
$$a_x \equiv \frac{v_{xf} - v_{xi}}{t_f - t_i} = \frac{\Delta v_x}{\Delta t}$$ analogs to $$v_x \equiv \frac{x_f - x_i}{t_f - t_i} = \frac{\Delta x}{\Delta t}$$

Dimension? [LT^{-2}] Unit? m/s^2

•Instantaneous acceleration: Average acceleration over a very short amount of time.

$$a_x \equiv \lim_{\Delta t \to 0} \frac{\Delta v_x}{\Delta t}$$ analogs to $$v_x \equiv \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t}$$

Acceleration vs Time Plot



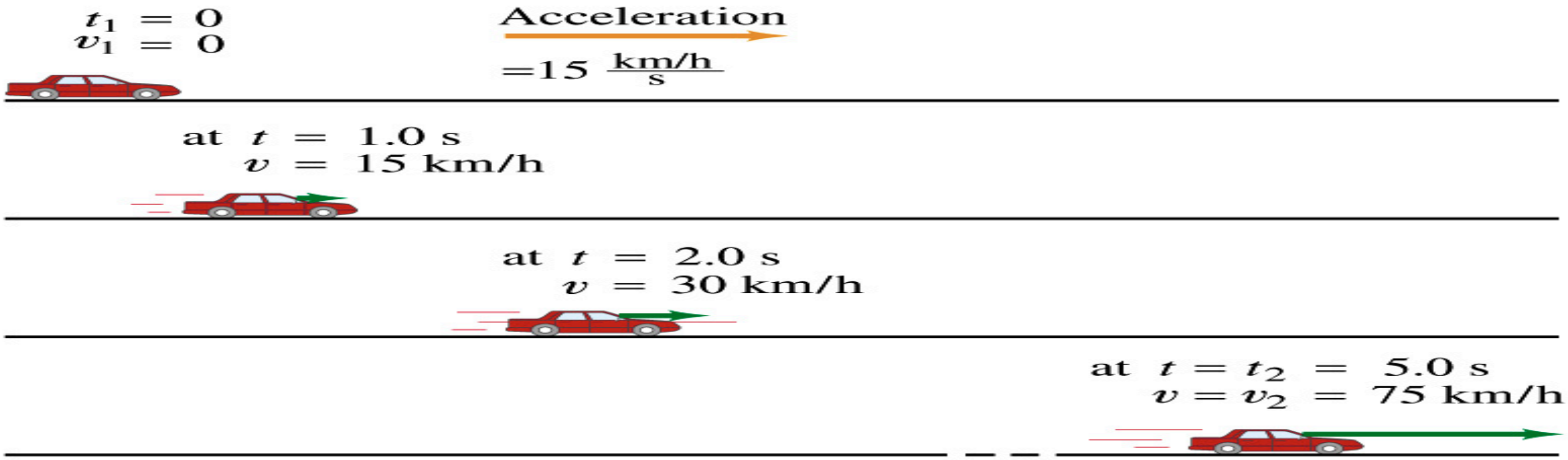
What does this plot tell you?

Yes, you are right!!

The acceleration of this motion is a constant!!

Example 2.3

A car accelerates along a straight road from rest to 75km/h in 5.0s.



What is the magnitude of its average acceleration?

$$v_{xi} = 0\ m/s$$

$$v_{xf} = \frac{75000m}{3600s} = 21\ m/s$$

$$\bar{a}_x = \frac{v_{xf} - v_{xi}}{t_f - t_i} = \frac{\Delta v_x}{\Delta t} = \frac{21-0}{5.0} = \frac{21}{5.0} = 4.2(m/s^2)$$

$$= \frac{4.2 \times (3600)^2}{1000} = 5.4 \times 10^4 (km/h^2)$$

Few Confusing Things on Acceleration

- When an object is moving in a constant velocity ($v=v_0$), there is no acceleration ($a=0$)
  - Is there any acceleration when an object is not moving?
- When an object is moving faster as time goes on, ($v=v(t)$), acceleration is positive ($a>0$).
  - Incorrect, since the object might be moving in negative direction initially
- When an object is moving slower as time goes on, ($v=v(t)$), acceleration is negative ($a<0$)
  - Incorrect, since the object might be moving in negative direction initially
- In all cases, velocity is positive, unless the direction of the movement changes.
  - Incorrect, since the object might be moving in negative direction initially
- Is there acceleration if an object moves in a constant speed but changes direction?

The answer is YES!!

One Dimensional Motion

- Let's focus on the simplest case: acceleration is a constant ($a=a_0$)
- Using the definitions of average acceleration and velocity, we can derive equations of motion (description of motion, velocity and position as a function of time)

$$\bar{a}_x = a_x = \frac{v_{xf} - v_{xi}}{t_f - t_i}$$ (If $t_f=t$ and $t_i=0$) $$a_x = \frac{v_{xf} - v_{xi}}{t} \Rightarrow v_{xf} = v_{xi} + a_x t$$

For constant acceleration, average velocity is a simple numeric average

$$\bar{v}_x = \frac{v_{xi} + v_{xf}}{2} = \frac{2v_{xi} + a_x t}{2} = v_{xi} + \frac{1}{2} a_x t$$

$$\bar{v}_x = \frac{x_f - x_i}{t_f - t_i}$$ (If $t_f=t$ and $t_i=0$) $$\bar{v}_x = \frac{x_f - x_i}{t} \Rightarrow x_f = x_i + \bar{v}_x t$$

Resulting Equation of Motion becomes

$$x_f = x_i + \bar{v}_x t = x_i + v_{xi} t + \frac{1}{2} a_x t^2$$

One Dimensional Motion cont'd

Average velocity $\bar{v}_x = \frac{v_{xi} + v_{xf}}{2}$ ⇒ $x_f = x_i + \bar{v}_x t = x_i + \left(\frac{v_{xi} + v_{xf}}{2}\right)t$

Since $a_x = \frac{v_{xf} - v_{xi}}{t}$ **Solving for t** ⇒ $t = \frac{v_{xf} - x_{xi}}{a_x}$

Substituting t in the above equation,

$$x_f = x_i + \left(\frac{v_{xf} + v_{xi}}{2}\right)\left(\frac{v_{xf} - v_{xi}}{a_x}\right) = x_i + \frac{v_{xf}^2 - v_{xi}^2}{2a_x}$$

Resulting in

$$v_{xf}^2 = v_{xi}^2 + 2a_x\left(x_f - x_i\right)$$

Kinematic Equations of Motion on a Straight Line Under Constant Acceleration

$$v_{xf}(t) = v_{xi} + a_x t$$

Velocity as a function of time

$$x_f - x_i = \frac{1}{2}\bar{v}_x t = \frac{1}{2}\left(v_{xf} + v_{xi}\right) t$$

Displacement as a function of velocities and time

$$x_f = x_i + v_{xi} t + \frac{1}{2} a_x t^2$$

Displacement as a function of time, velocity, and acceleration

$$v_{xf}^2 = v_{xi}^2 + 2a_x\left(x_f - x_i\right)$$

Velocity as a function of Displacement and acceleration

You may use different forms of Kinetic equations, depending on the information given to you for specific physical problems!!