Chapter 2 - Kinematics

- Goal: Describe Motion
- Kinematics – 'How'
- Dynamics – 'Why' (Forces): Chapter 4

Displacement: a vector that points from an object's *initial* position to its *final* position.

- Position, Displacement, Velocity, Acceleration
  - **All vector quantities**
  - **3-d**

Reminders

- **Available online: Syllabus and Chapter 1 notes (PDF)**

- **HW#1 due *today* 6/20 at 11:59pm.**
- **HW#2 due Sunday 6/24 at 11:59pm.**

- **Math Quiz: Test your algebra/trigonometry skills**
  - Due Sunday 06/24 (40min to do it!) BUT
  use it as practice for HW #1 and #2…

- **Lab sessions: start today &Thursday.**
- **PRINT OUT Lab Report before going to labs**
  - Download lab report from LONCAPA website
  - Fill out the Pre-lab questions BEFORE going to lab!
- **CAPA sessions: Clippinger 036, M-Th, 1-5pm**

- **EXAM 1: Next Thursday (06/29).**
  - Topics: Chapters 1 and 2

Kinematics

- position, displacement
  - **Δ : change = final - initial**

- Ave. Speed = Distance traveled / Elapsed time
  - **no mention of direction**

- Ave. Velocity = Displacement / Elapsed time
  - **Vector**

average

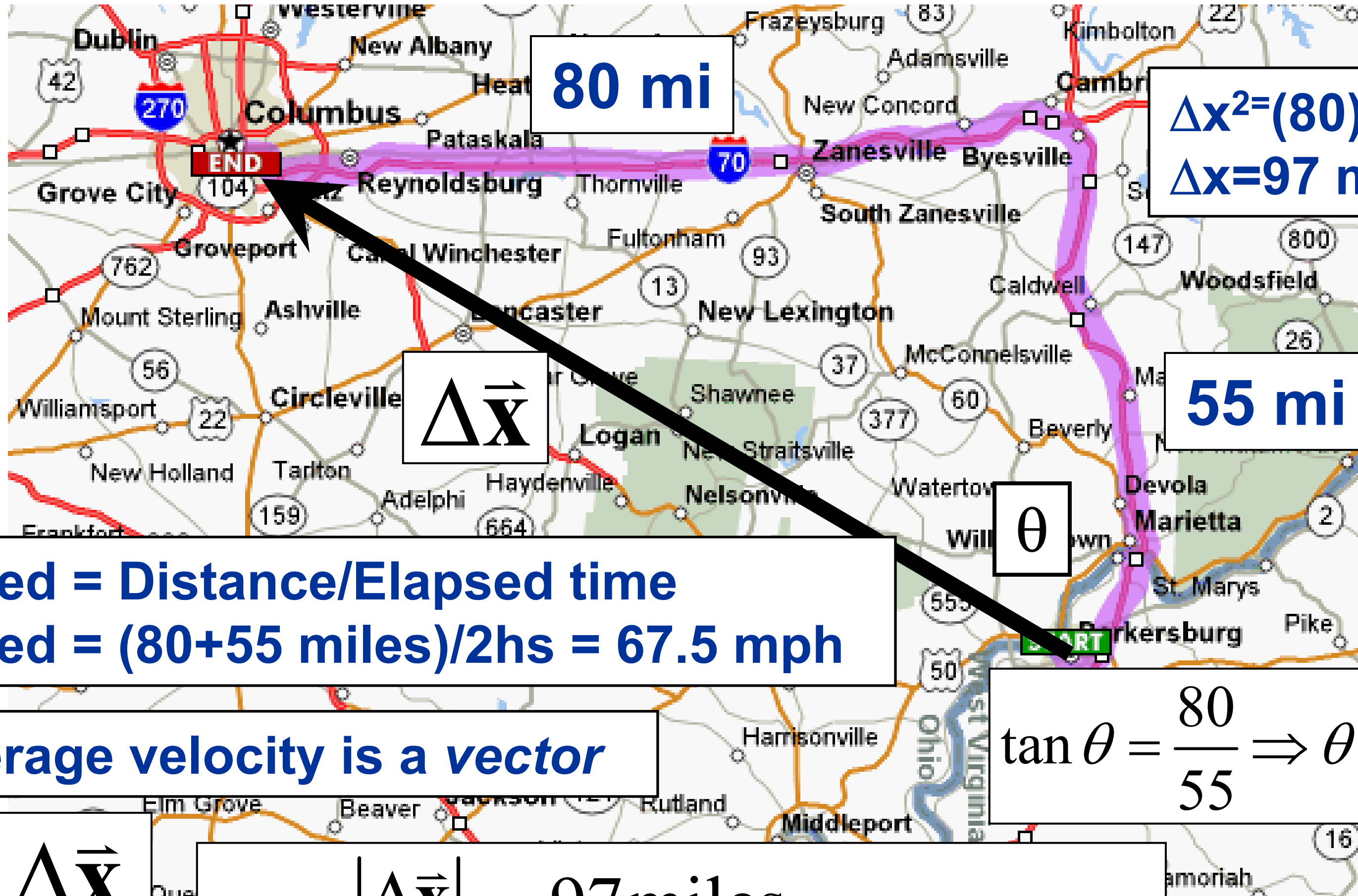
$$\bar{\vec{v}} = \frac{\vec{x} - \vec{x}_0}{t - t_0} = \frac{\Delta\vec{x}}{\Delta t}$$

  - **only depends on initial and final positions**
  - **same direction as displacement**

$$\vec{x} = \vec{x}_0 + \bar{\vec{v}}\Delta t$$

Average speed vs average velocity

You drive 55 miles north on 77 from Parkersburg. Then you take 70 and drive 80 miles west towards Columbus. The driving takes 2 hours. What is the average speed and average velocity?



80 mi

$\Delta x^2 = (80)^2 + (55)^2$

$\Delta x = 97$ miles (NW)

55 mi

$\Delta\vec{x}$

θ

Avg speed = Distance/Elapsed time

Avg speed = (80+55 miles)/2hs = 67.5 mph

$$\tan\theta = \frac{80}{55} \Rightarrow \theta = 55.5^o$$

The average velocity is a *vector*

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

$$\left|\bar{\vec{v}}\right| = \frac{\left|\Delta\vec{x}\right|}{\Delta t} = \frac{97\text{miles}}{2\text{ hs}} = 48.5\text{ mph}$$

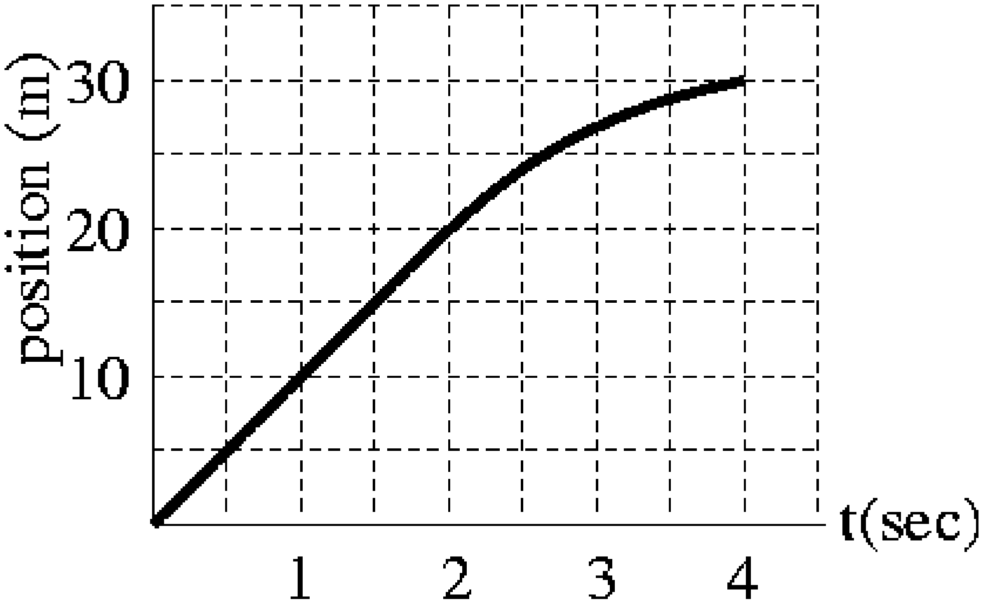
Average vs. Instantaneous

- Average – need beginning and end 'events' (times)
  - **'event' – time, place, velocity, acceleration**

- Instantaneous – *that* instant!
  - **shrink Δt to a very small interval**
  - ***Instantaneous speed* equals the magnitude of the instantaneous velocity**

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

- We can *graph* motion (1D)
  - **slope of the x vs t plot gives the velocity at every instant!**



Link:

http://www3.interscience.wiley.com:8100/legacy/college/cutnell/0471151831/concepts/index.htm

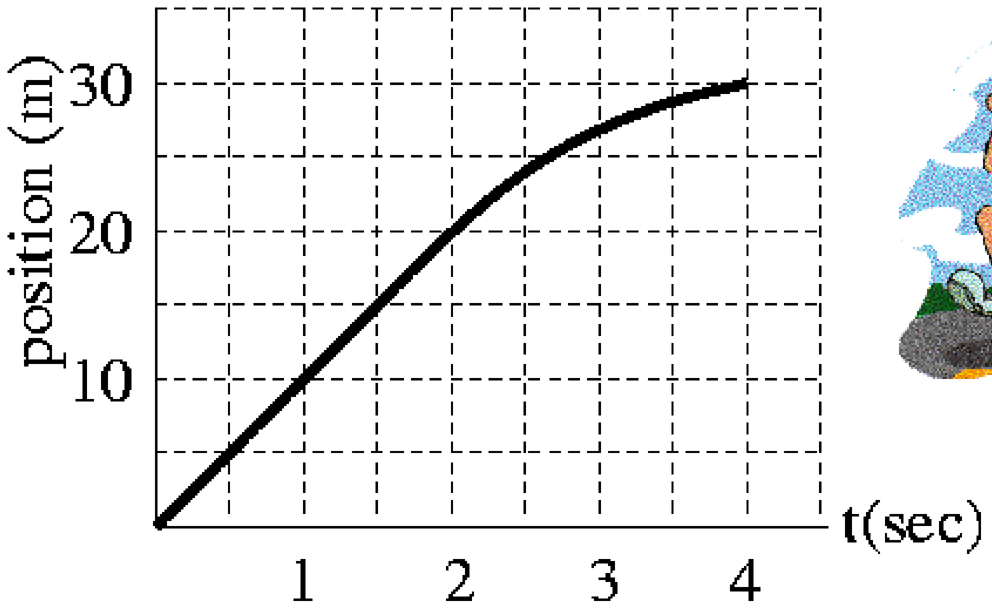
The plot represents the position of a runner as a function of time. What is the average velocity of the runner during the time interval from 1.0 to 4.0 sec?

(1) 5 m/s

(2) 6.7 m/s

(3) 7.5 m/s

(4) 10 m/s



$$\left|\vec{\mathbf{v}}\right| = \bar{v} = \frac{\Delta\vec{x}}{\Delta t} = \frac{\vec{x}-\vec{x}_0}{t-t_0} = \frac{30m-10m}{4s-1s} = 6.7m/s$$

The plot represents the position of a runner as a function of time. At what of the following times is the instantaneous velocity the largest?

(1) 0.5 s (2) 1.5 s

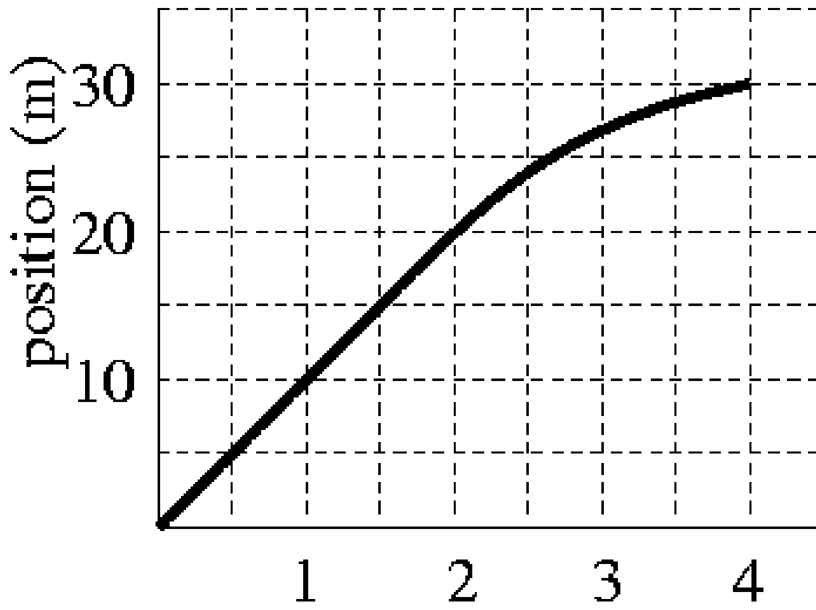
(3) 2.5 s (4) 3.5 s

(5) 4.5 s

(6) 0.5 and 1.5 s

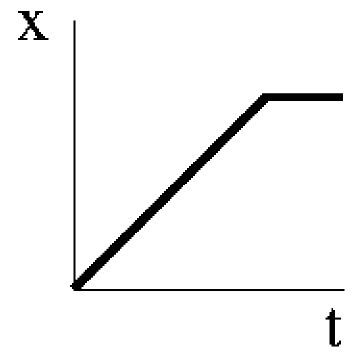
(7) 0.5, 1.5 and 2.5s

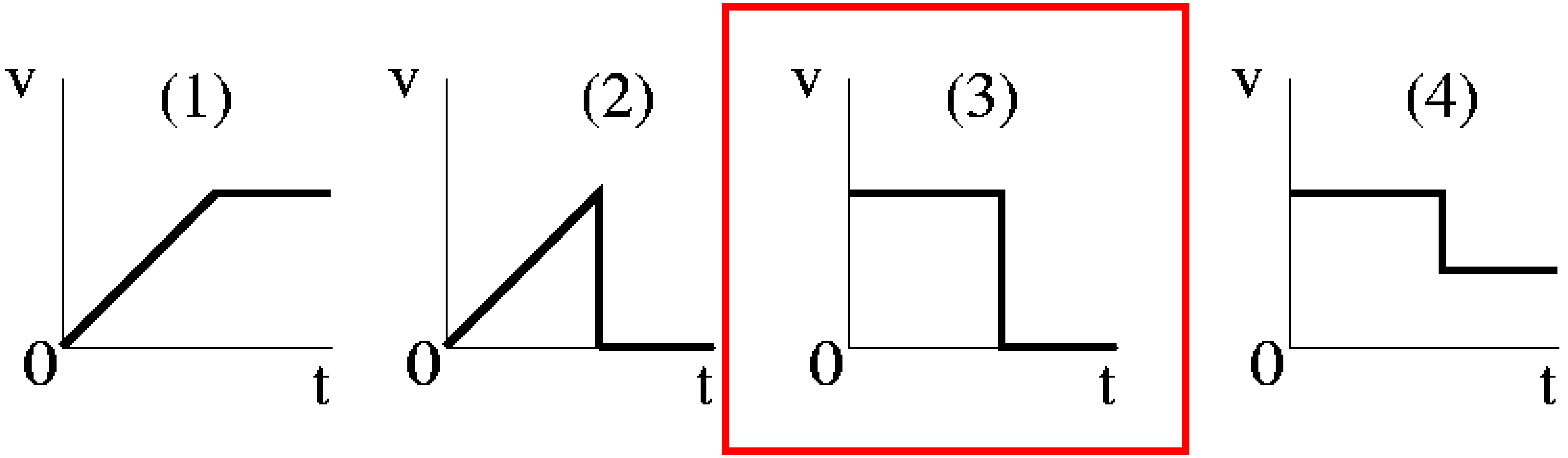
(8) same velocity at all times



Same slope from 0 to ~2sec, and it's the greatest slope.

Which velocity plot corresponds to the position plot to the right?





x vs t graph:

At first, constant, *positive* slope (means v>0 and constant).

Then *zero* slope (means v=0)

Acceleration

- Rate of change in velocity
- It's a vector

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

$$\vec{a} = \lim_{\Delta t \to 0} \frac{\Delta \vec{v}}{\Delta t}$$

$$\vec{v} = \vec{v}_0 + \overline{\vec{a}} \Delta t$$

- Same direction as **CHANGE** in velocity
- acceleration related to Force (a=F/m)
- If net force constant, acceleration is constant

$$\overline{\vec{v}} = \frac{\vec{x} - \vec{x}_0}{t - t_0} = \frac{\Delta \vec{x}}{\Delta t}$$

Note: acceleration would be the *slope* on **v vs. t** graph (link)

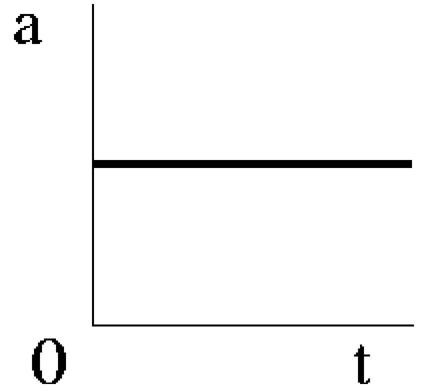
Two objects are accelerating over a period of 6 seconds. A toy rocket changes it's velocity from 140 m/s to 150 m/s. A bicyclist changes his velocity from 5 m/s to 15 m/s. Which has the greatest acceleration?

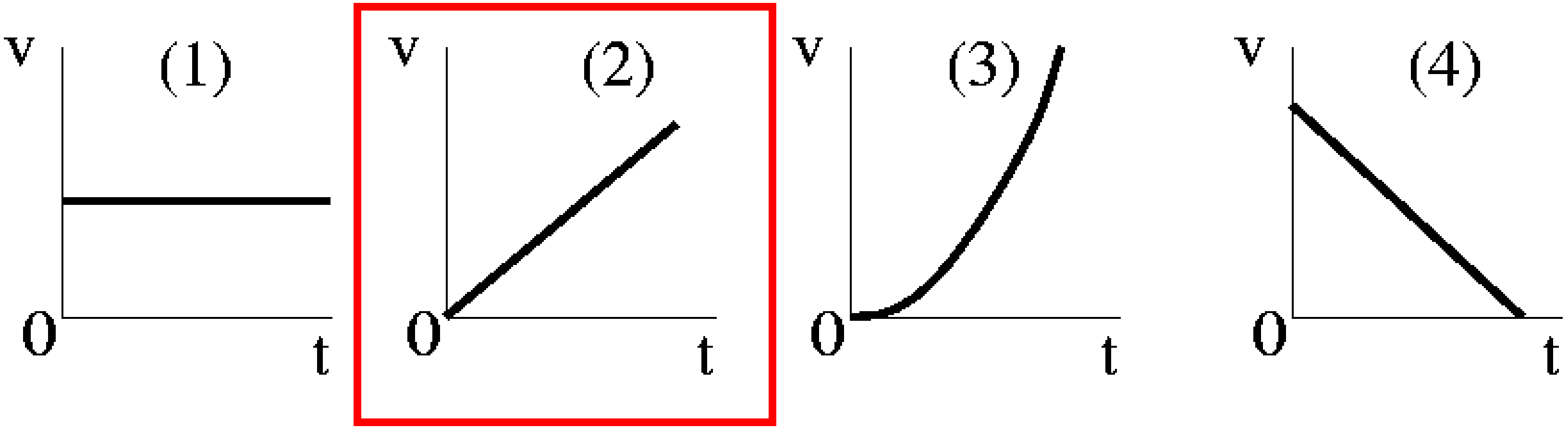
1. The bicyclist has the greater acceleration.
2. The rocket has the greater acceleration.
3. They both have the same acceleration.

Same Δv, same Δt,

means $\mathbf{a=\Delta v/\Delta t}$ is *the same* for both.

Which **velocity** plot corresponds to the acceleration plot to the right?

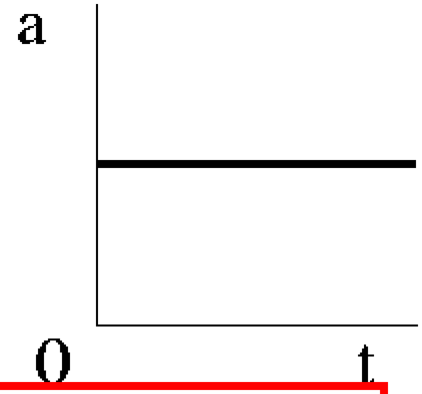


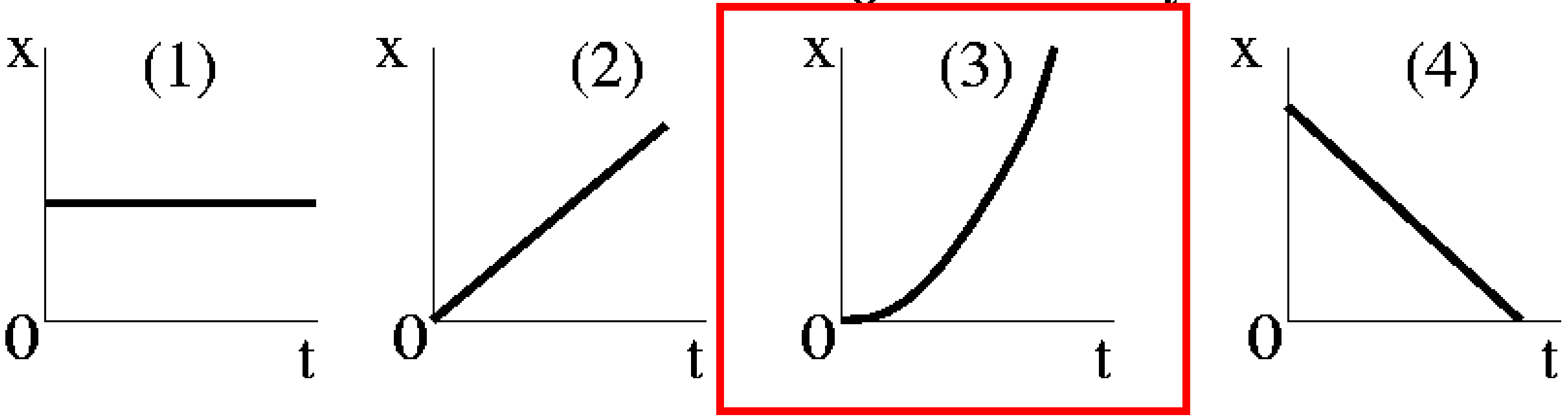


Accel constant, slope of v vs. t plot must be constant

Accel >0, slope of v vs. t plot must be *positive.*

Which **position** plot corresponds to the acceleration plot to the right?





Velocity increases at each time

slope of x vs. t should *increase* at each instant

(see animation in link)

Constant Acceleration

- Const net force → Const acceleration

$$\Delta\vec{x} = \bar{\vec{v}}\,\Delta t$$

$$\Delta\vec{v} = \bar{\vec{a}}\,\Delta t$$

If $\vec{a} = \text{const},\ \bar{\vec{a}} = \vec{a}$

$$\vec{v}_f = \vec{v}_i + \vec{a}(t_f - t_i)$$

$$\vec{v} = \vec{v}_0 + \vec{a}t$$

Simplification:

$t_i = 0$ restart clock

$x_i = 0$ origin at start

i→0 initial becomes t=0

x, v, a at time t (final event)

$$\Delta\vec{x} = \frac{1}{2}\left(\vec{v}_0 + \vec{v}\right)t$$

$$\Delta\vec{x} = \vec{v}_0 t + \frac{1}{2}\vec{a}t^2$$

$$v^2 = v_0^2 + 2ax$$

ONLY IF ACCEL IS CONSTANT !

Problem Solving – Basic Outline

- Read it – Read it – Read it again!
- Draw/Image – lay out coordinate system
- What you know? Don't know? Want to know?
- Physical Processes? Laws? Conditions?
- Valid Relationships/Formulas
- Solve

Example:

A car accelerates uniformly from rest to a speed of 25 m/s in 8.0s.

1. Find the distance the car travels in this time and
2. the constant acceleration of the car.

(Define the +x direction to be in the direction of motion of the car.)

$x = ?$

$v_0 = ?$

$v = ?$

$a = ?$

$t = ?$

$$x = \frac{1}{2}(v_0 + v)t$$

x = 100 m

$$v = v_0 + at$$

a = 3.1 m/s^2

$$v = v_0 + at$$

$$x = \frac{1}{2}(v_0 + v)t$$

$$x = v_0 t + \frac{1}{2}at^2$$

$$v^2 = v_0^2 + 2ax$$

Example: Plane Landing

A jet plane lands with a velocity of +100m/s and with full brakes on can accelerate at a rate of -5.0m/s^2.

- From the instant it touches the runway, what is the minimum time needed before it can come to rest?

t = 20s

- Can this plane land on a small island airport where the runway is 0.80km long?

x = 1000m. No, it cannot.

- Read it – Read it
- Draw/Image – lay out coordinate system
- What know? Don't know? Want to know?
- Physical Processes? Laws? Conditions?
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Free-fall

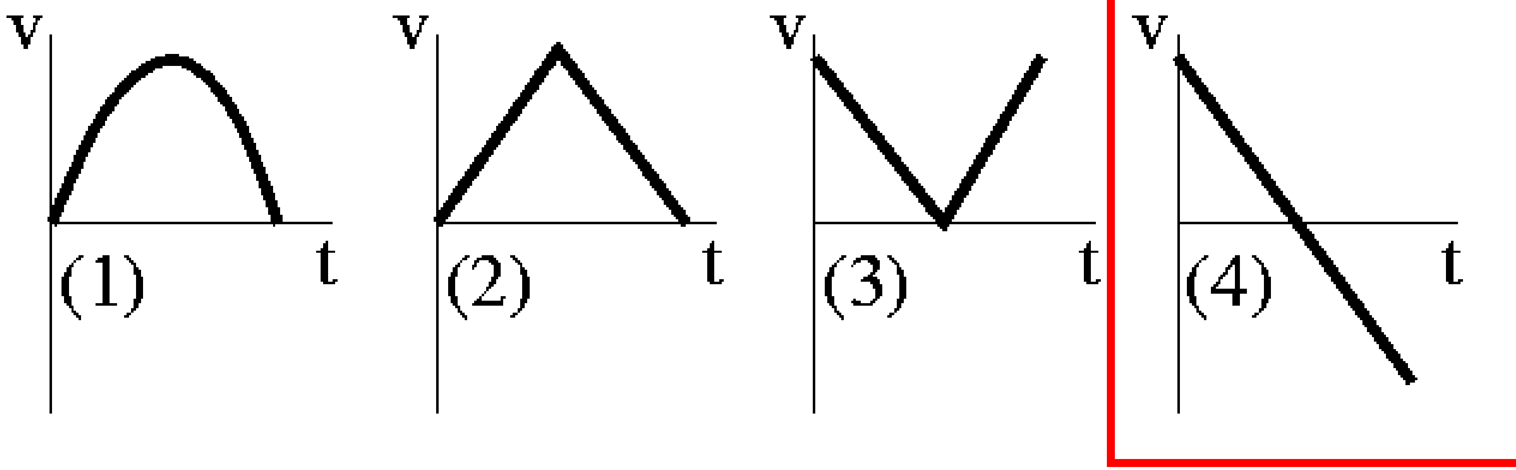
- An object is in free-fall when the only force acting on the object is gravity

- Accel due to gravity = g = 9.80 m/s^2 downward
  - **(Sign applied after define coordinates)**

- 'g' fairly constant on Earth's surface.
  - **Depends predominantly on distance from center of Earth and mass of Earth**
  - **Change 'g': dramatically different altitude, different planet**

- Const Force, Const Accel – straight up/down – can use kinematic equations in 1-d

I toss a ball into the air. Assume the +y direction to be upwards. Which plot best represents the VELOCITY versus time of this graph?



Velocity starts upward (+), then transitions to downward (-).

Velocity is vector, will have direction (in 1-d represented by sign)

I toss a ball into the air. Think about the direction of the acceleration as the ball is traveling upward and as it is traveling downward.

1. acceleration is upward when ball traveling up; downward when traveling down
2. acceleration is downward when ball traveling up; downward when traveling down
3. acceleration is upward when ball traveling up; upward when traveling down
4. acceleration is downward when ball traveling up; upward when traveling down

Gravity always points downward.

Reminders

- **Review session on Chaps 1&2 moved to next Wed. (before the Exam)**
- **PDFs online: Syllabus (updated) and Chapter 2 notes**

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- **HW#3 due *Tuesday* 6/26, 11:59pm.**

- **Math Quiz: Test your algebra/trigonometry skills**
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  - Topics: Chapters 1 and 2 **(including related Lab material)**

I toss a ball into the air. Think about the velocity and acceleration at the point when the ball reaches maximum height.

1. the velocity is zero and the acceleration is zero
2. the velocity is non-zero and the acceleration is zero
3. the velocity is zero and the acceleration is non-zero
4. the velocity is non-zero and the acceleration is non-zero

Even though velocity is zero right at max height, it is constantly changing.

Gravity doesn't 'turn off' for split second.

Example: Deer in the Road

You are driving home at night along US-50 traveling at 30m/s when a deer jumps out in the road 150m ahead. The deer freezes in your headlights.

After a reaction time of t, you apply the brakes to produce a constant acceleration $-4.0 m/s^2$.

What is the maximum reaction time allowed in order not to hit the deer?

Braking distance = 112.5 m

Reaction time: t=1.25 s

Example: Stones and Rafts

A woman on a bridge 75.0 m high sees a raft floating at a constant speed on the river below. She drops a stone from rest in an attempt to hit the raft. The stone is released when the raft has 7.00 m more to travel before passing under the bridge. The stone hits the water 4.00 m in front of the raft.

Find the speed of the raft.

Time for stone to hit water = 3.91s

v_{raft} = 0.77 m/s

- Example: The ball is moving and its position is recorded every 1 s:
  - http://capa2.phy.ohiou.edu/res/ohiou/physlets/1dkinematics/four_opt.html
- Now, what about the acceleration?
  - http://capa2.phy.ohiou.edu/res/ohiou/physlets/1dkinematics/accel_prs.html
- Constant velocity vs. Constant acceleration
  - http://www3.interscience.wiley.com:8100/legacy/college/cutnell/0471151831/concepts/index.htm
- 1D constant acceleration
  - http://www3.interscience.wiley.com:8100/legacy/college/cutnell/0471151831/concepts/index.htm