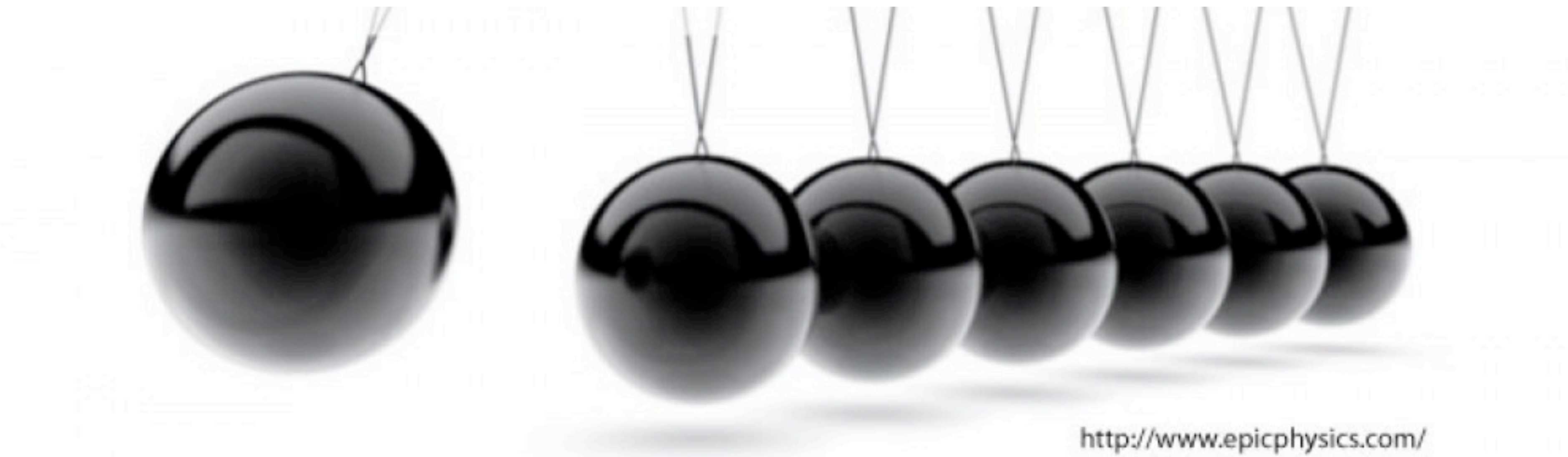
Welcome Back to Physics 211!



(General Physics I)

Thurs. Aug 30th, 2012

- Last time:
  - Syllabus, mechanics survey
  - Unit conversions
- Today:
  - Using your clicker
  - 1D displacement, velocity, acceleration graphs
- Next time:
  - More acceleration and free fall!

Web site

Course web site: https://jwlaiho.expressions.syr.edu

- Links to syllabus + course calendar
- Links to mastering physics + clicker registration

Clicker test: Enter Channel 41


Channel Setting for the
ResponseCard® RF
1. Press and release the "Ch" button.
2. While the light is flashing red and green
Enter 2 digit code.
(ie. channel 1=01, channel 21=21).
3. After the second digit is entered,
Press and release the "Ch" button.
LED Color Description:
Red - Response was not received
Green - Response was received
Yellow (Multiple Flash) - In the process of sending
Yellow (Single Flash) - Polling not open

There are two ways to set the channel on the ResponseCard NXT. One way is to use the Find Channels tool in the toolbox, as described in the previous section "The Toolbox," or you can manually set the channel. The steps below describe how to manually set the channel.

1. Press the Channel button.
2. Use the number pad to enter the new channel number.
3. Once the channel number has been entered, press the ⬬ button.

You must do this for

EVERY lecture

Clicker test: Channel 41

- What is today's date?

1. August 15th
2. August 28th
3. August 29th
4. Sept 1st

Kinematics-- describing motion

1D

The Particle Model

- Often motion of the object *as a whole* is not influenced by details of the object's size and shape.
- We only need to keep track of a single point on the object.
- So we can treat the object *as if* all its mass were concentrated into a single point.
- A mass at a single point in space is called a **particle**.
- Particles have no size, no shape, and no top, bottom, front or back.
- On the projector I draw the motion diagram of a car stopping, using the **particle model**.

Motion diagram of a rocket launch

Clicker question 1-2.1

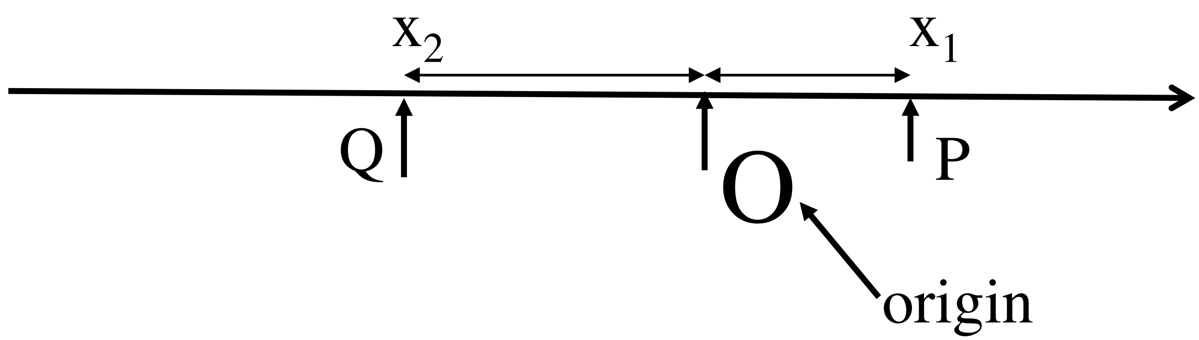
Three motion diagrams are shown. Which is a dust particle settling to the floor at constant speed, which is a ball dropped from the roof of a building, and which is a descending rocket slowing to make a soft landing on Mars?

A. (a) is dust, (b) is ball, (c) is rocket.
B. (a) is ball, (b) is dust, (c) is rocket.
C. (a) is rocket, (b) is dust, (c) is ball.
D. (a) is rocket, (b) is ball, (c) is dust.
E. (a) is ball, (b) is rocket, (c) is dust.

Position and Displacement

- Neglect shape of object and represent by point moving in space (1D)
- Position may be specified by giving distance to origin – x coordinate
- Choice of origin arbitrary! – many choices to describe same physical situation.
- Hence x-coordinate not unique

Displacement = change in position



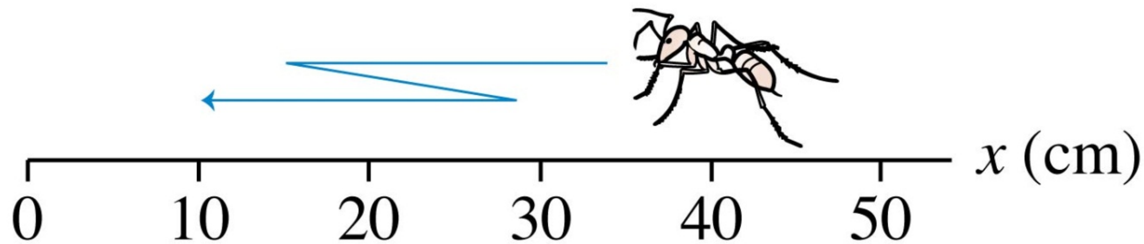
- Displacement (P→Q) = $x_2 - x_1 = \Delta x$
- Displacement does NOT depend on origin!

Displacement

- Displacement is ‘distance plus direction’
- Displacement Δx is a vector quantity – change in position (vector) of object
- In one dimension, this amounts to a sign
  - Displacement towards increasing x – *positive*
  - Displacement towards decreasing x – *negative*

Clicker question 1-2.2

An ant zig-zags back and forth on a picnic table as shown.



The ant's **distance traveled** and **displacement** are

A. 50 cm and 50 cm.
B. 30 cm and 50 cm.
C. 50 cm and 30 cm.
D. 50 cm and –50 cm.
E. 50 cm and –30 cm.

Velocity

- *Definition:*

Average velocity in some time interval Δt is given by

$$v_{av} = (x_2 - x_1)/(t_2 - t_1) = \Delta x/\Delta t$$

- Displacement Δx can be positive or negative – so can velocity – it is a vector, too
- **Average speed** is not a vector, just (distance traveled)/Δt
- Example of average velocity: Driving from Ithaca to Syracuse

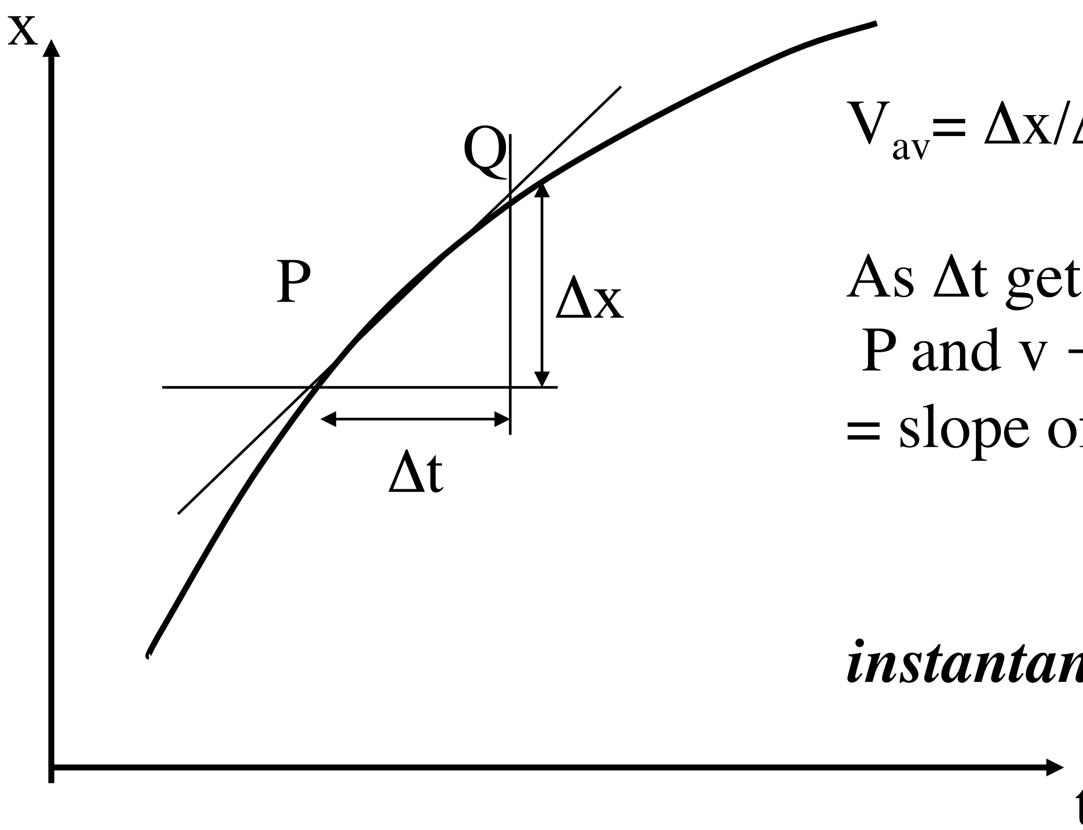
Instantaneous velocity

- But there is another type of velocity which is useful – **instantaneous velocity**

- Measures how fast my position (displacement) is changing at some **instant** of time

- Example -- nothing more than the reading on my car’s speedometer and my direction

Velocity from graph



$V_{av} = \Delta x / \Delta t$

As Δt gets small, Q approaches P and $v \rightarrow dx/dt$

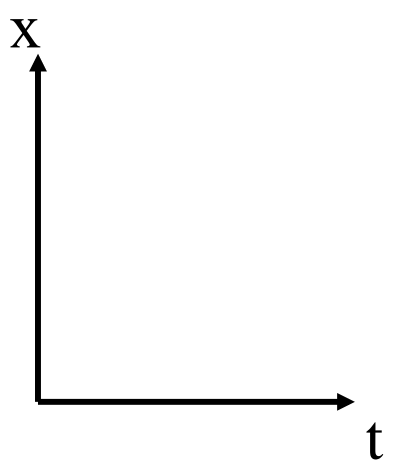
= slope of tangent at P

↓

instantaneous velocity

Interpretation

- Slope of x(t) curve reveals v_{inst} (= v)
- Steep slope = large velocity
- Upwards slope from left to right = positive velocity
- Average velocity = instantaneous velocity only for motions where velocity is constant



When does $v_{av} = v_{inst}$?

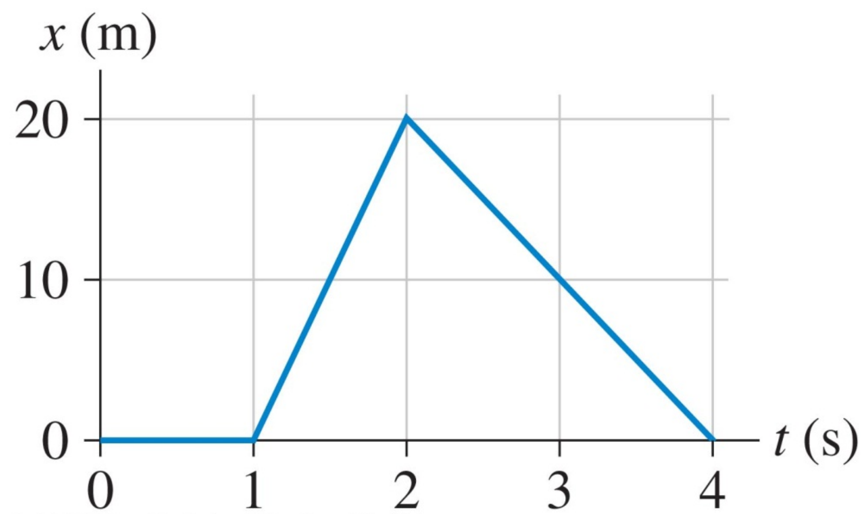
When does $v_{av} = v_{inst}$?

- When x(t) curve is a **straight line**
  - Tangent to curve is same at all points in time

- We say that such a motion is a constant velocity motion
  - we'll see that this occurs when no **forces** act

Clicker question 1-2.3

Here is a position graph of an object:

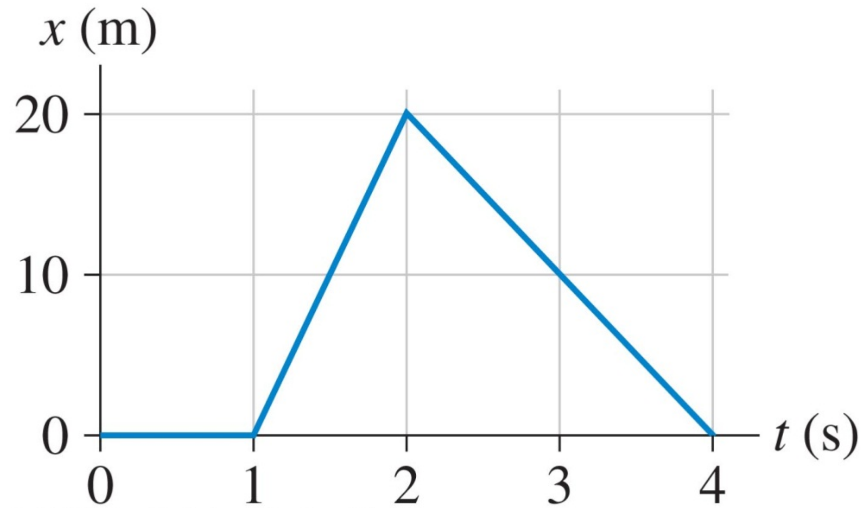


At t = 1.5 s, the object's velocity is

A. 40 m/s.
B. 20 m/s.
C. 10 m/s.
D. –10 m/s.
E. None of the above.

Clicker question 1-2.4

Here is a position graph of an object:



At t = 3.0 s, the object's velocity is

A. 40 m/s.
B. 20 m/s.
C. 10 m/s.
D. –10 m/s.
E. None of the above.

Summary of terms

- Positions: x_{initial}, x_{final}
- Displacements: $\Delta x = x_{\text{final}} - x_{\text{initial}}$
- Instants of time: t_{initial}, t_{final}
- Time intervals: $\Delta t = t_{\text{final}} - t_{\text{initial}}$
- Average velocity: $v_{av} = \Delta x/\Delta \mathrm{t}$
- Instantaneous velocity: $v = \mathrm{d}x/\mathrm{dt}$
- Instantaneous speed: $|v| = |\mathrm{d}x/\mathrm{dt}|$

Acceleration

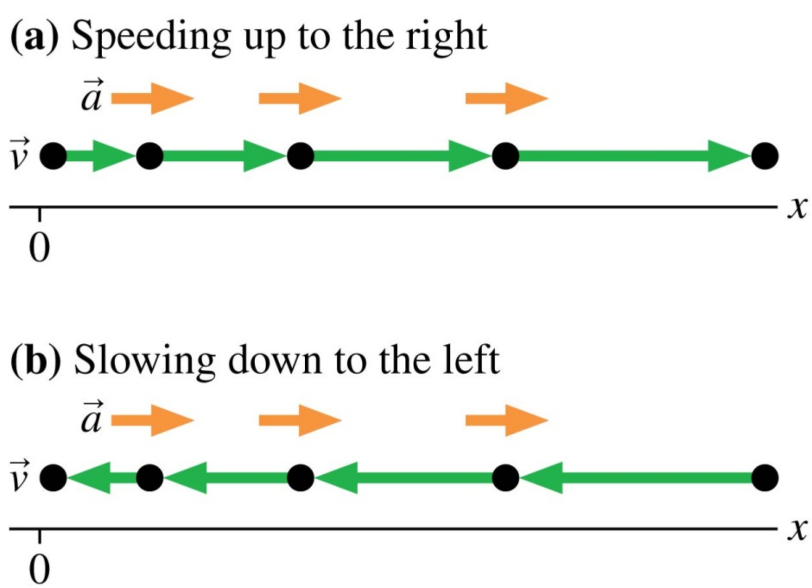
- Sometimes an object's velocity is constant as it moves.
- More often, an object's velocity changes as it moves.
- Acceleration describes a *change* in velocity.
- Consider an object whose velocity changes from $\vec{v}_1$ to $\vec{v}_2$ during the time interval Δt.
- The quantity $\Delta\vec{v} = \vec{v}_2 - \vec{v}_1$ is the change in velocity.
- The *rate of change of velocity* is called the **average acceleration:**

$$a_{\text{avg}} = \frac{\Delta\vec{v}}{\Delta t}$$

The Audi TT accelerates from 0 to 60 mph in 6 s.

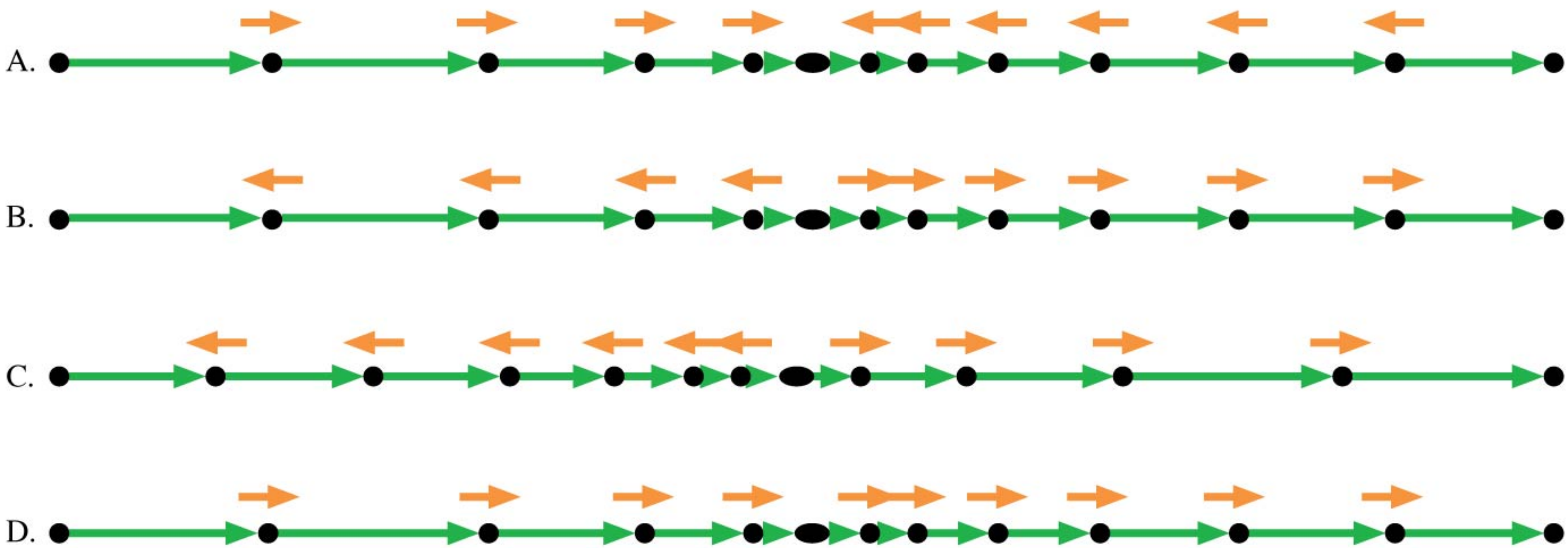
Speeding Up or Slowing Down?

- speeding up: acceleration and velocity vectors point in the *same direction*.
- slowing down: acceleration and velocity vectors point in *opposite directions*.
- constant velocity = acceleration is zero.
- Positive accelerations do not always mean speeding up!



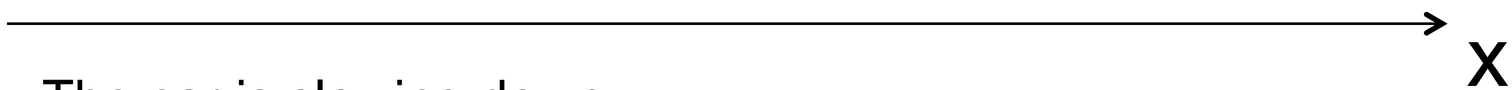
Clicker question 1-2.5

A cyclist riding at 20 mph sees a stop sign and actually comes to a complete stop in 4 s. He then, in 6 s, returns to a speed of 15 mph. Which is his motion diagram?



Clicker question 1-2.6

A toy car on a straight 1D track is measured to have a negative acceleration, if we define the x-axis to point to the right. What else must be true of the acceleration?

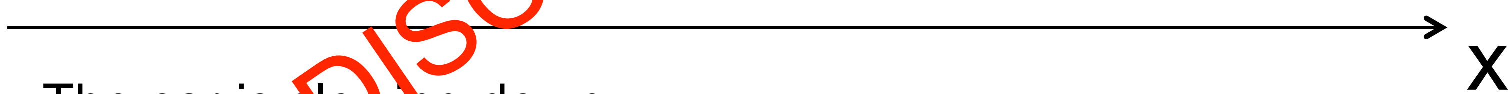


1. The car is slowing down.
2. The car is speeding up.
3. The car is moving to the left.
4. The acceleration vector points to the left.

Clicker question 1-2.6

A toy car on a straight 1D track is measured to have a negative acceleration, if we define the x-axis to point to the right. What else must be true of the acceleration?

DISCUSS!



1. The car is slowing down.
2. The car is speeding up.
3. The car is moving to the left.
4. The acceleration vector points to the left.

Acceleration

- Average acceleration -- keep time interval Δt non-zero

$$a_{av} = \Delta v/\Delta t = (v_F - v_I)/\Delta t$$

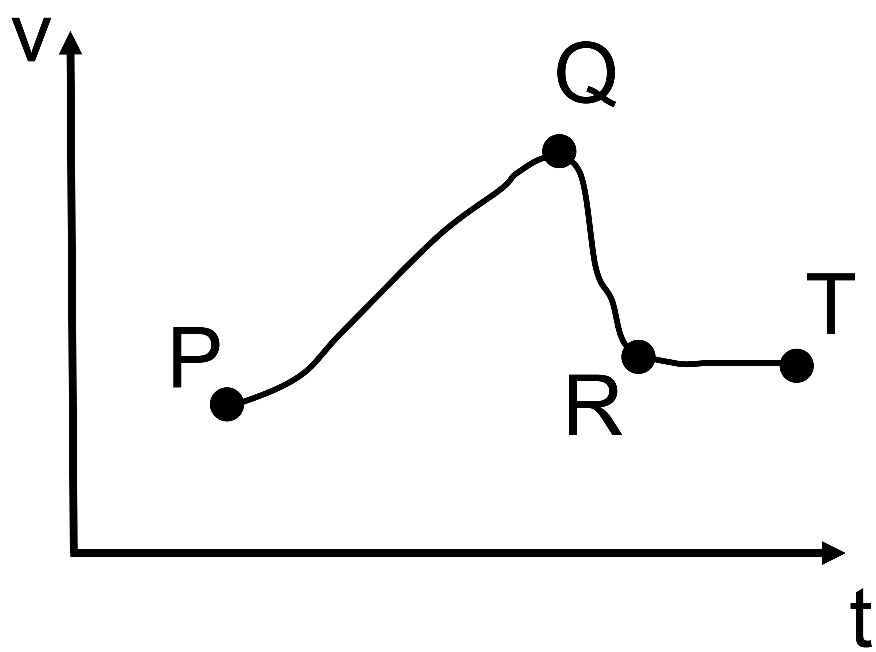
- Instantaneous acceleration

$$a_{inst} = \lim_{\Delta t \to 0} \Delta v/\Delta t = dv/dt$$

Sample problem

- A car's velocity as a function of time is given by
- $$v(t) = (3.00\ \text{m/s}) + (0.100\ \text{m/s}^3)\ t^2.$$
  - Calculate the avg. accel. for the time interval $t = 0$ to $t = 5.00$ s.
  - Calculate the instantaneous acceleration for i) $t = 0$; ii) $t = 5.00$ s.

1-2.6-8: Acceleration from graph of v(t)



What is a_{av} for
6. PQ ?
7. QR ?
8. RT ?

1. $a_{avg} > 0$
2. $a_{avg} < 0$
3. $a_{avg} = 0$

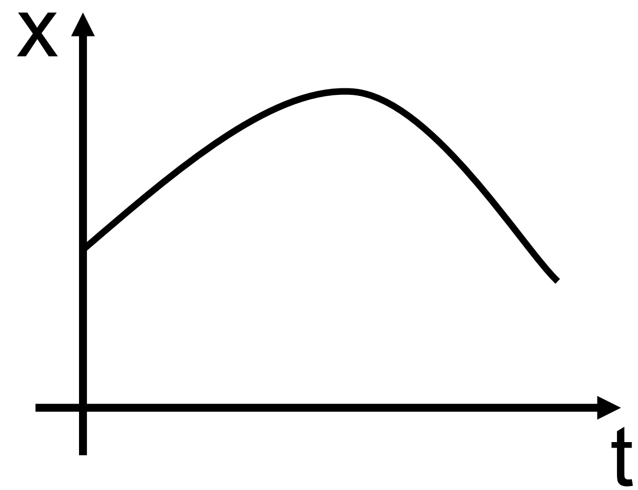
- Slope measures acceleration
  - Positive a means v is increasing
  - Negative a means v decreasing

Cart demo

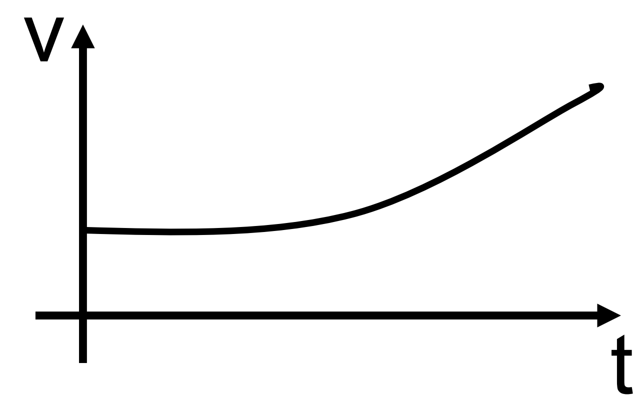
- Sketch graphs of position, velocity, and acceleration for cart

Interpreting x(t) and v(t) graphs

- Slope at any instant in **x(t)** graph gives instantaneous **velocity**



- Slope at any instant in **v(t)** graph gives instantaneous **acceleration**



- What else can we learn from an x(t) graph?

Clicker question 1-2.8: You are throwing a ball up in the air. At its highest point, the ball's

1. Velocity v and acceleration a are zero

2. v is non-zero but a is zero

3. Acceleration is non-zero but v is zero

4. v and a are both non-zero

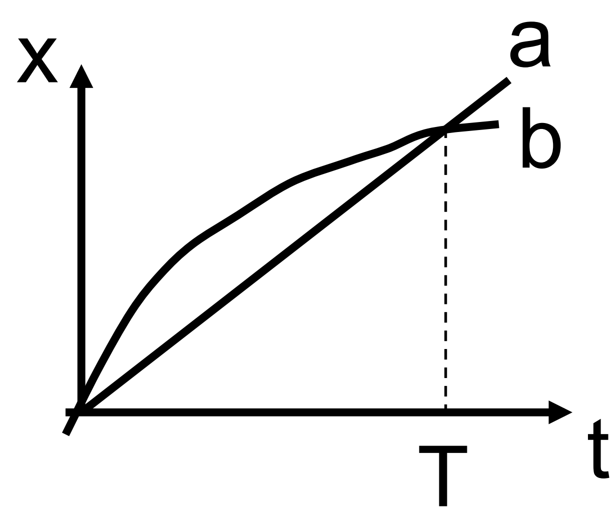
Reading assignment

- Kinematics, constant acceleration
- 2.4 – 2.7 in textbook

Acceleration from x(t) plot ?

- If x(t) plot is linear → zero acceleration
- Is x(t) is curved → acceleration is non-zero
  - If slope is decreasing
    - a is negative
  - If slope is increasing
    - a is positive
  - If slope is constant
    - $a = 0$
- Acceleration is rate of change of slope!

Clicker question 1-2.10



The graph shows 2 trains running on parallel tracks. Which is true:

1. At time T both trains have same v
2. Both trains speed up all time
3. Both trains have same v for some t<T
4. Somewhere, both trains have same a

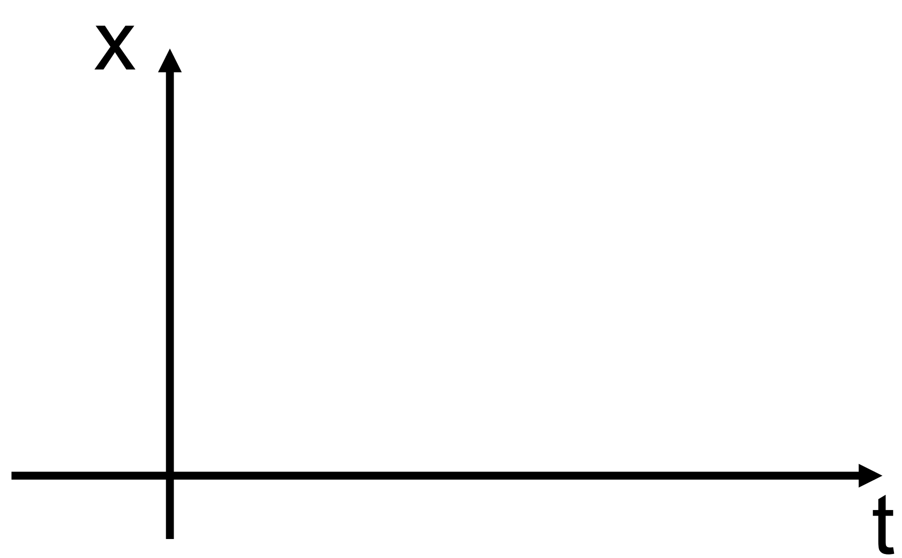
Acceleration from x(t)

- Rate of change of slope in x(t) plot equivalent to *curvature* of x(t) plot

- Mathematically, we can write this as

  a =

  – Negative curvature
    - $a < 0$
  – Positive curvature
    - $a > 0$
  – No curvature
    - $a = 0$

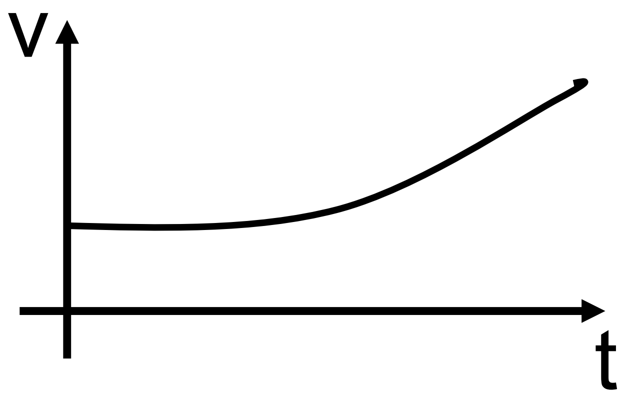


Sample problem

- An object's position as a function of time is given by $x(t) = (3.00\ \text{m}) - (2.00\ \text{m/s})\ t + (3.00\ \text{m/s}^2)\ t^2$.
  - Calculate the avg. accel. between t = 2.00s and t = 3.00 s.
  - Calculate the instantaneous accel. at i) t = 2.00 s; ii) t = 3.00 s.

Displacement from velocity curve?

- Suppose we know v(t) (say as graph), can we learn anything about x(t) ?



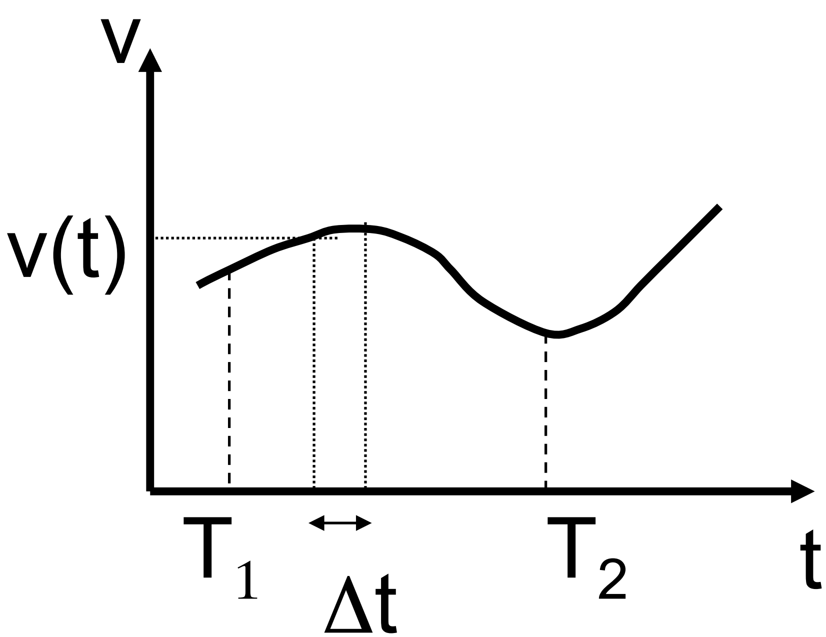
- Consider a small time interval Δt

$$v = \Delta x/\Delta t \rightarrow \Delta x = v\Delta t$$

- So, total displacement is the sum of all these small displacements Δx

$$x = \Sigma \Delta x = \lim_{\Delta t \rightarrow 0} \Sigma v(t)\Delta t =$$

Graphical interpretation



Displacement between T_1 and T_2 is area under v(t) curve

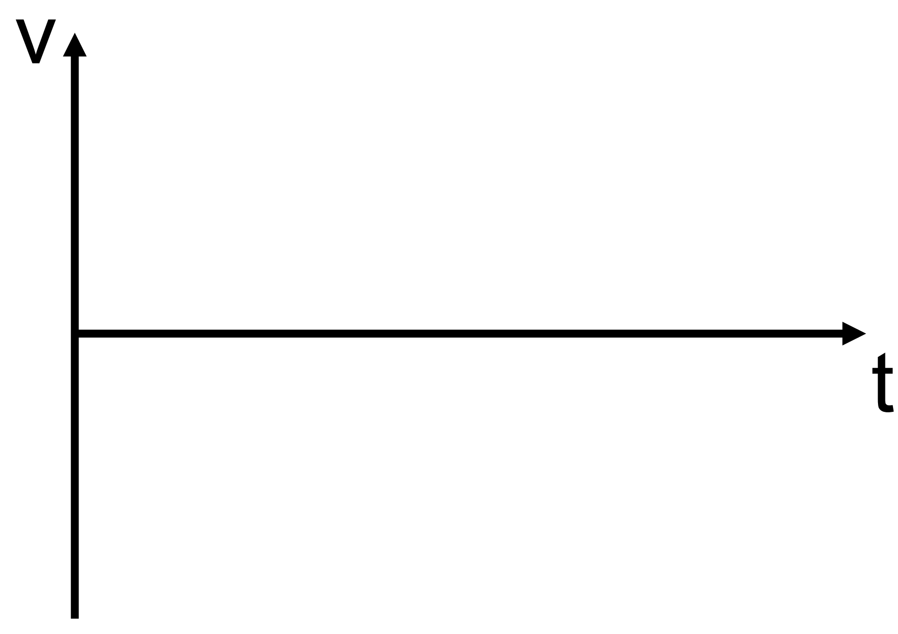
Displacement – integral of velocity

$\lim_{\Delta t \to 0} \Sigma\, \Delta t\, v(t)$ = area under v(t) curve

note: `area' can be positive or negative

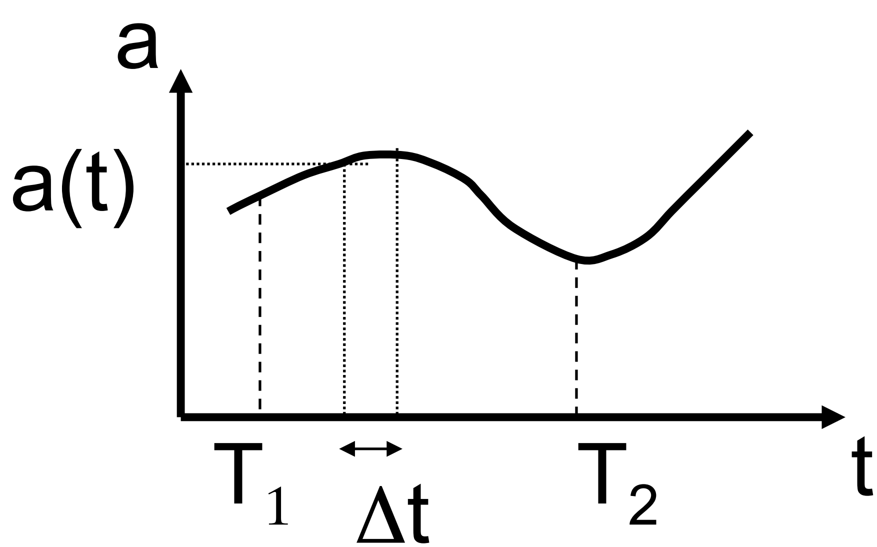
*Consider v(t) curve for cart in different situations…

*Net displacement?



Velocity from acceleration curve

- Similarly, change in *velocity* in some time interval is just area enclosed between curve a(t) and t-axis in that interval.



Summary

- **velocity** $v = dx/dt$

  = *slope* of x(t) curve

  – NOT x/t !!

- **displacement** Δx is

  $$\int v(t)dt$$

  = *area* under v(t) curve

  – NOT v t !!

- **accel.** $a = dv/dt$

  = *slope* of v(t) curve

  – NOT v/t !!

- **change in vel.** Δv is

  $$\int a(t)dt$$

  = *area* under a(t) curve

  – NOT a t !!

Discussion

- Average velocity is that quantity which when multiplied by a time interval yields the net displacement
- For example, driving from Syracuse → Ithaca

Cart on incline demo

- Raise one end of track so that gravity provides constant acceleration down incline (we'll study this in much more detail soon)

- Give cart initial velocity directed up the incline

- Sketch graphs of position, velocity, and acceleration for cart