Welcome Back to Physics 215!

(Honors Physics I)

Thurs. Aug 29th , 2019

- Last time:
  - Syllabus
  - Units and dimensional analysis
- Today:
  - Displacement, velocity, acceleration graphs
- Next time:
  - More acceleration and free fall!

Office hours

- My office hours will be:
  - Wednesdays 9-10am
  - Wednesdays 3:30-4:30pm
  - or by appointment
  - in Physics 229B

Reading for next Tuesday

- More 1D motion and vectors
- Open Stax Ch 3.5, 2.1-2.2

Ask a physicist….

If you email me questions, I'm happy to answer them here….

Good question on dimensional analysis

- Why is e a pure number?
  - What about mathematical functions?
  - e.g. does exp (60 mins) or cos(80 miles) make sense?
- for more info: Open Stax Ch 1. problem 89

Kinematics--
describing motion

1D

Linear motion

Circular motion

Projectile motion

Rotational motion

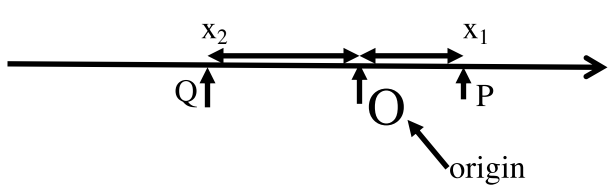
Four basic types of motion

Slide 1-19

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



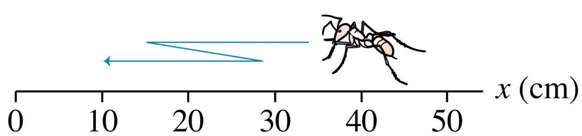
- Displacement (P→Q) = x_2 - x_1 = Δx
- Displacement does NOT depend on origin!

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*

SG 1-2.0

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



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

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

Describing motion

- Average velocity (for a time interval):

  $v_{average}$ =

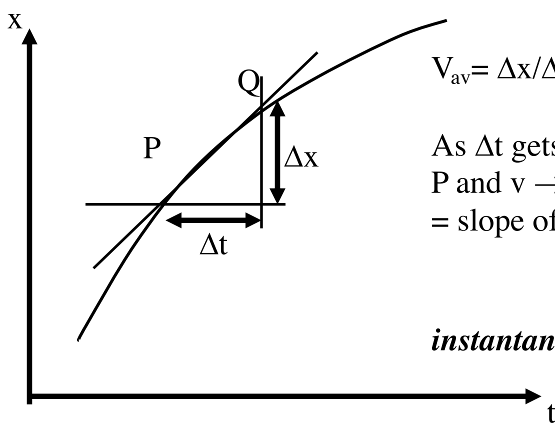
- Instantaneous velocity (at an instant in time)

  $v_{instant} = v$ =

- Instantaneous speed

  $|v|$

Velocity from graph



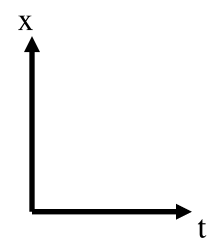
$V_{av} = \Delta x/\Delta t$

As Δt gets small, Q approaches P and $v \to dx/dt$
= slope of tangent at P

instantaneous velocity

Interpretation

- Slope of x(t) curve reveals v_{inst} (= v)
- Steep slope =
- 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 x(t) curve is a **straight line**
  - Tangent to curve is same at all points in time

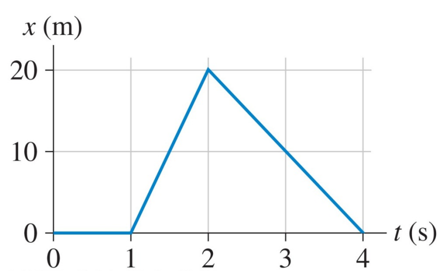
- We say that such a motion is a constant velocity motion
  - we'll see that this occurs when no **forces** act

cart demo

- No fan.
- Provide an initial push, but almost no forces act while cart is moving
- What do the position and velocity plots look like?

SG 1-2.1

Here is a position graph of an object:

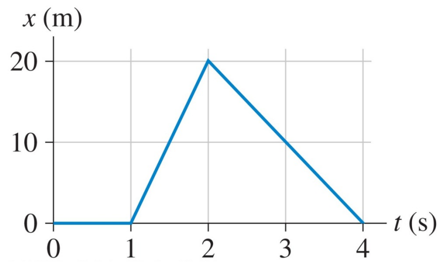


At t = 1.5 s, the object's velocity is

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

SG1-2.2

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

Acceleration

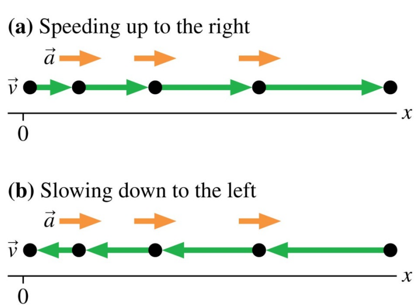
- Sometimes an object's velocity is constant as it moves.
- More often, an object's velocity changes as it moves.
- Acceleration describes a *change* in velocity.
- Consider an object whose velocity changes from $\vec{v}_1$ to $\vec{v}_2$ during the time interval Δt.
- The quantity $\Delta\vec{v} = \vec{v}_2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

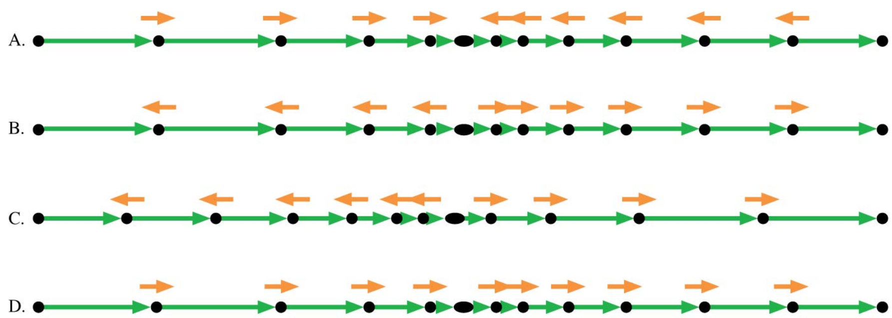
Speeding Up or Slowing Down?

- 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!



Do this by yourself: 1-2.3

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?



SG 1-2.4

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?

A. The car is slowing down.
B. The car is speeding up.
C. The car is moving to the left.
D. The acceleration vector points to the left.

Acceleration

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

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

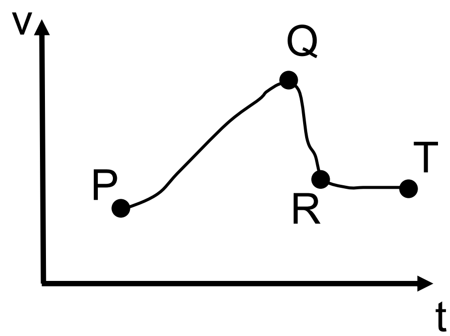
- Instantaneous acceleration

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

Sample problem

- A car's velocity as a function of time is given by
- $v(t) = (3.00\ m/s) + (0.100\ m/s^3)\ t^2$.
  - 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 SG 5-7: Acceleration from graph of v(t)



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

A. $a_{avg} > 0$
B. $a_{avg} < 0$
C. $a_{avg} = 0$

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

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

A. Velocity v and acceleration a are zero

B. v is non-zero but a is zero

C. Acceleration is non-zero but v is zero

D. v and a are both non-zero

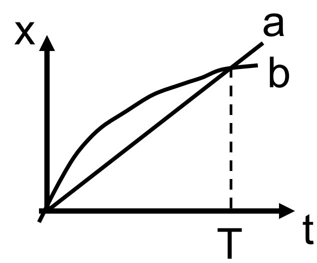
Fan cart demo

- Attach fan to cart - provides a constant force (we'll see later that this implies constant acceleration)
- Depending on orientation, force acts to speed up or slow down initial motion
- Sketch graphs of position, velocity, and acceleration for cart that speeds up

Fan cart demo

- Sketch graphs of position, velocity, and acceleration for cart that speeds up

SG 1-2.9



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

A. At time T both trains have same v
B. Both trains speed up all time
C. Both trains have same v for some t<T
D. Somewhere, both trains have same a

Reading for next Tuesday

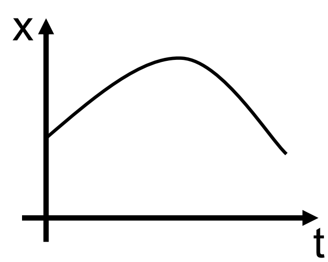
- More 1D motion and vectors
- Open Stax Ch 3.5, 2.1-2.2
- HW due at the beginning of recitation tomorrow (Friday)
  – hint: I did not explicitly give you all the information you need for problem 2 (on purpose).

Assignments due this week

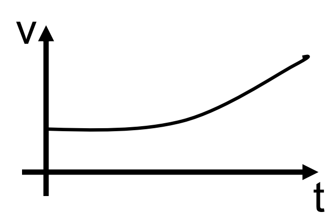
- Due this Friday
  - Pre-assessment (on blackboard)
  - SAGE assignment (should take <5 mins)

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?

Acceleration from x(t)

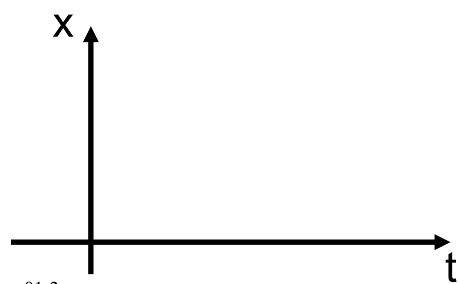
- Rate of change of slope in x(t) plot equivalent to *curvature* of x(t) plot
- Mathematically, we can write this as

  a =

  – Negative curvature
    - a < 0

  – Positive curvature
    - a > 0

  – No curvature
    - a = 0



Lecture 01-2

40

Reading assignment

- Kinematics, constant acceleration
- 2.4 – 2.7 in textbook

Lecture 01-2

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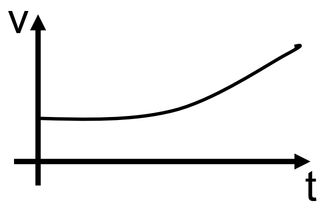
Displacement from velocity curve?

- 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

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

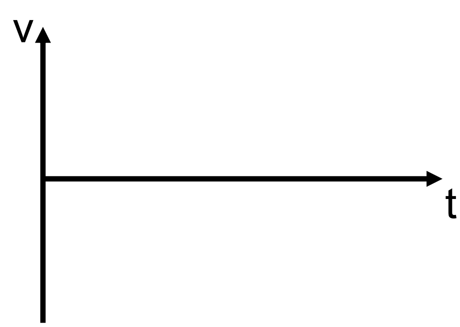
Displacement – integral of velocity

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

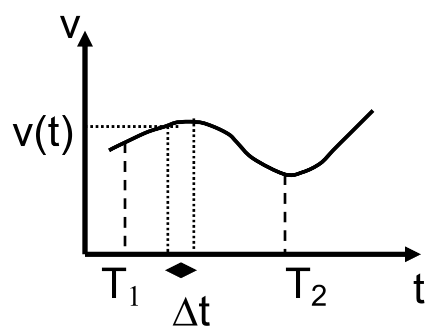
note: `area' can be positive or negative

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

*Net displacement?



Graphical interpretation



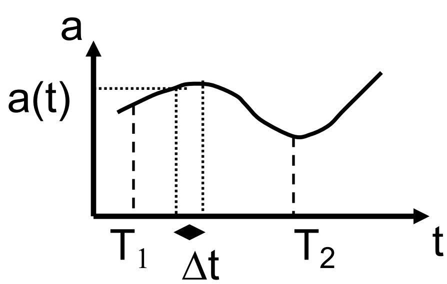
Displacement between T_1 and T_2 is area under v(t) curve

Sample problem

- An object's position as a function of time is given by $x(t) = (3.00\ m) - (2.00\ m/s)\ t + (3.00\ m/s^2)\ t^2$.
  - 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.

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