Thursday Jan 12

- Assign 1 – Friday
- Long Pre-class for Tuesday
- Math Quiz Due Monday
- Lab next week
  - Print lab and do pre-lab
  - NO OPEN-TOED SHOES
  - NO FOOD/GUM/DRINKS
- Help Room Tonight 6-9 - Walter 245
- Office Hours:
  - 10-11am Wed or by appointment
  - 204 Edwards Accelerator Lab
- SI Sessions start next week: Morton 326
  - Mon & Wed 7:15-8:45PM

Today's Material:

1-d Motion/Kinematics

- Displacement
- Velocity
- Acceleration
- Graphing Motion

Goal:

- Kinematics – 'How'
- Dynamics – 'Why' (Forces)

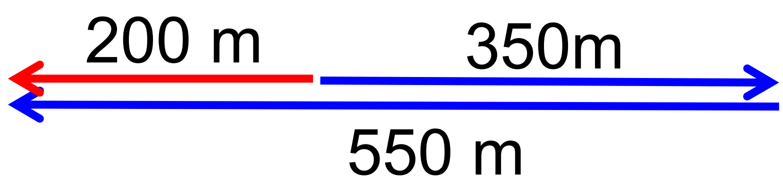
LON-CAPA Notes:

- Units for angles – deg
- Critical messages
- Can print assignments
- Options at top of course contents for different views

Reading “Quiz”: Displacement

A runner runs 350 m due East, then turns around and runs 550 m due West. What is the total displacement of the runner relative to the starting position?

(1) 200 m West
(2) 200 m East
(3) 350 m West
(4) 350 m East
(5) 550 m West
(6) 550 m East
(7) 900 m West
(8) 900 m East



Displacement is a vector – distance between two positions

What would be the total distance traveled? 900 m

Kinematics: Some Definitions

Sect 2.1

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

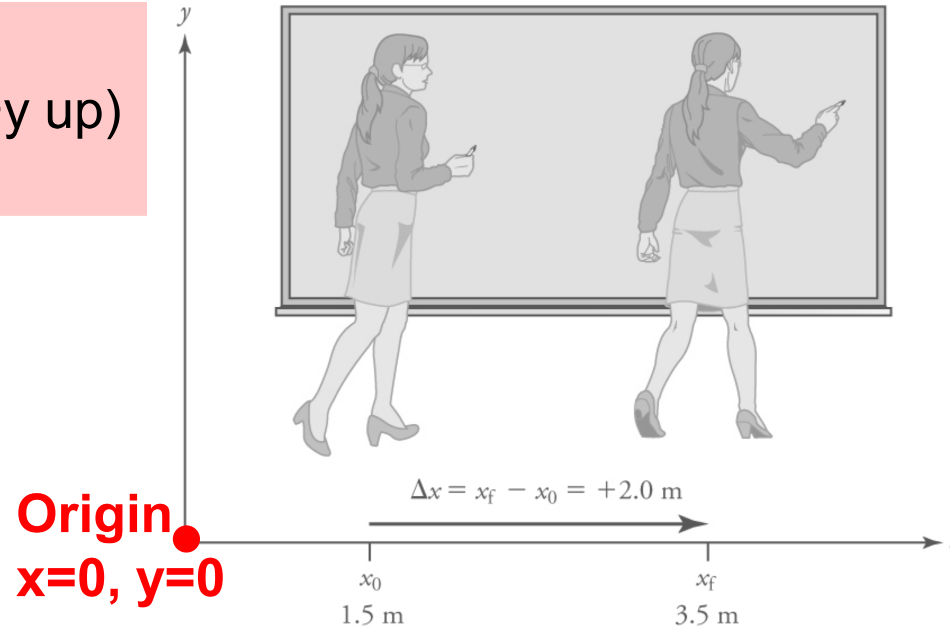
- Key quantities:
  - Position, Displacement, Velocity, Acceleration
    - All vector quantities (i.e. Have an associated direction)
    - 3-dimensional (i.e. have an “x”, “y”, and “z” component)
  - Distance traveled, speed
    - Scalar quantities (i.e. just have a magnitude/“size”)

Position, Displacement, Distance Traveled

Sect 2.1

Need coordinate system:
- Axes (we've chosen +x to right and +y up)
- Origin defined as x,y = 0,0

"Position": Location relative to origin
Initial position: $x_0 = +1.5\text{m}$
Final position: $x_f = +3.5\text{m}$
For both, $y_0 = y_f = 0$



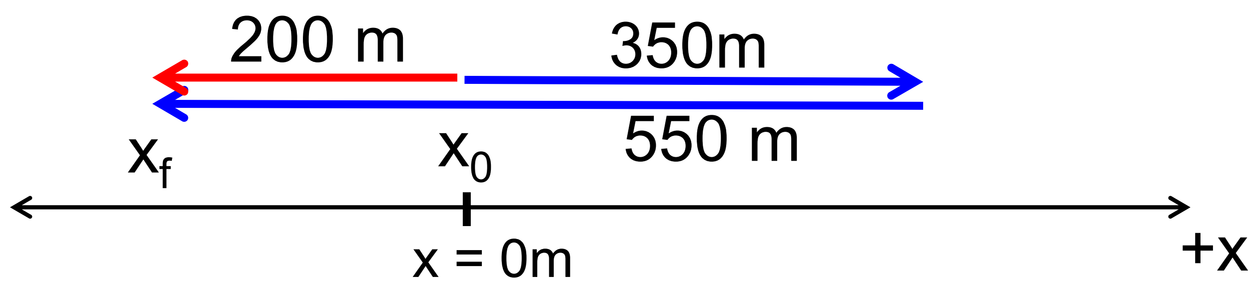
"Displacement": Change in Position
$\Delta x = x_f - x_0$
Displacement would be 2.0m to the right
(Δ = change = final – initial)

capital Greek letter delta

"Distance Traveled":
Ignore direction and add up distance traveled

Displacement and Distance Traveled

A runner runs 350 m due East, then turns around and runs 550 m due West. What is the displacement? The distance traveled?



Displacement:
$\Delta x = x_f - x_0 = -200\text{m} - 0\text{m} = -200\text{ m}$
(200 m to the left of the origin)

Distance Traveled:
350m + 550m = 900m

Note: Displacement rarely equals Distance Traveled
(only when traveling in the exact same direction the whole time)

Scalars and Vectors

- *Scalars*: Have magnitude (roughly speaking, a "size")
- *Vectors*: Have magnitude ***and*** direction (relative to an origin)

Quick way to check: Does adding a geographical direction make sense?

- A force of 10 N to the East ? fine – vector
- A mass of 10kg to the West? nonsensical - scalar

Examples of *Scalars*:

- Time
- Mass
- Energy

Examples of *Vectors*:

- Force
- Displacement
- Velocity

Scalars and Vectors

Why do we care?

- Scalars add, subtract, multiply the way we're used to.
- For vectors, must be more careful mathematically.
  - For vectors, need to account for direction – may need trig.
  - If parallel or antiparallel, then can treat more simply.
  - If not – need to use trig.

Magnitude of vector is its ‘size’ (ignore direction).
The magnitude of a vector “3m to the left” is 3m.
Magnitude of a scalar is just the absolute value.

The book will represent vectors as bold face (**x**, **v**, **a**).
Vector magnitudes will be italicized (*x*, *v*, *a*).

Velocity and Speed

Sect 2.1

- Velocity: how fast and in what direction (vector)
- Speed: how fast (scalar)

- Average Velocity = (*Displacement*)/(Elapsed time)
  - Vector
  - Only depends on initial and final position
  - Same direction as displacement
  - Bar over **v** represents average

- Average Speed = (*Distance traveled*)/(Elapsed time)
  - No mention of direction
  - **Average Speed is *<u>not</u>* the magnitude of average velocity**

Useful formulas for 1D:

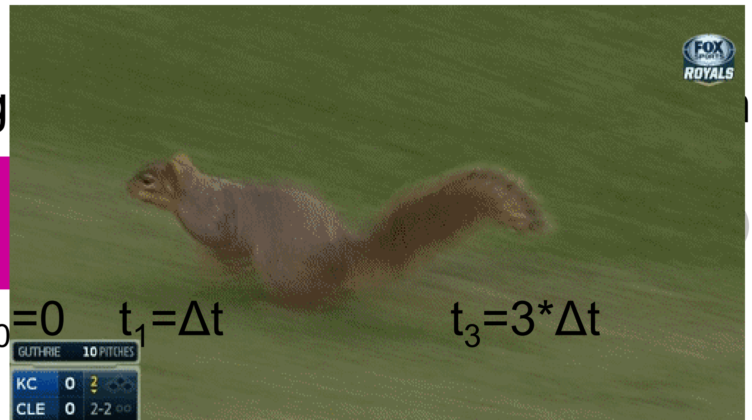
$$\boxed{\begin{gathered}\bar{v} = \frac{\Delta x}{\Delta t} \\ \bar{v} = \frac{x_f - x_0}{t_f - t_0}\end{gathered}}$$

$$\boxed{x_f = x_0 + \underbrace{\bar{v}\Delta t}_{\text{Displacement}}}$$

Motion: Has multiple representations

We can represent a motion in a variety of ways:

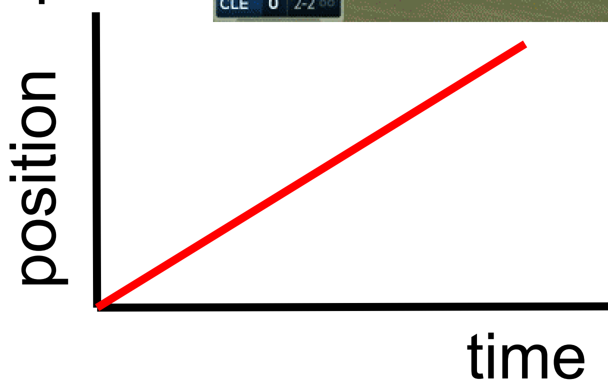
- Text: “A squirrel runs at a constant speed of 2 m/s in a straight line.”
- Equation: $x_f = x_0 + v\Delta t = x_0 + (2\text{m/s})\,\Delta t$
- Animation
- Motion Diag … tervals)

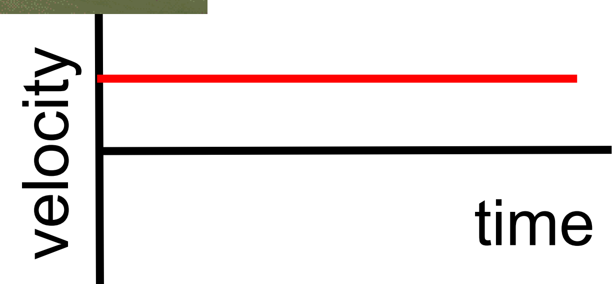


Sped-up after snapshot # 4

$t_0=0$ $t_1=\Delta t$ $t_3=3*\Delta t$ $t_5=5*\Delta t$

- Graph:



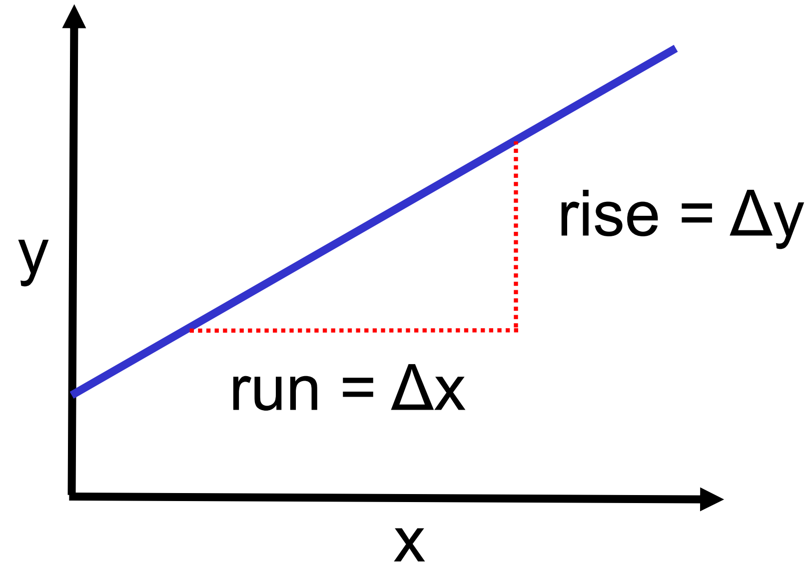


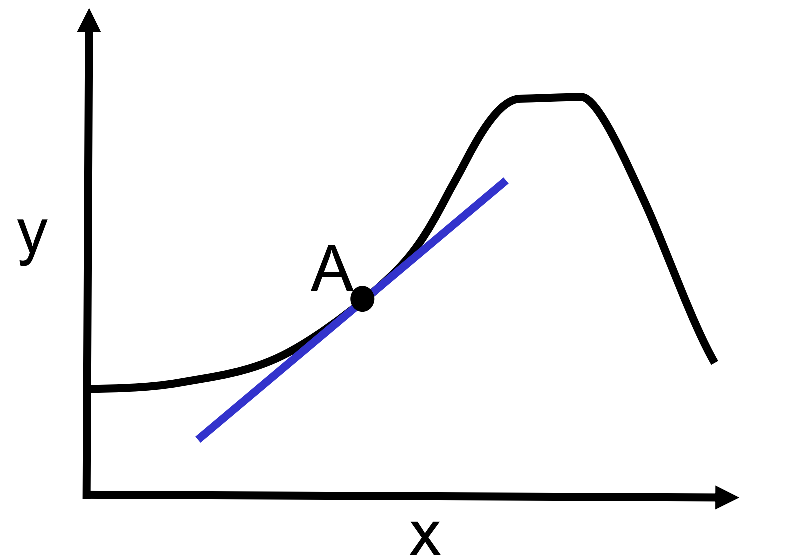
Slope of a Function on a Graph

- Slope = rise/run = $\Delta y/\Delta x$
- Up to the right is a positive slope.
- Down to the right is negative slope.

- Slope of a function at a point is the slope of tangent line.
- Slope of straight line same at any point.

- When finding slope off a graph, use the longest straight section possible in order to minimize your error.

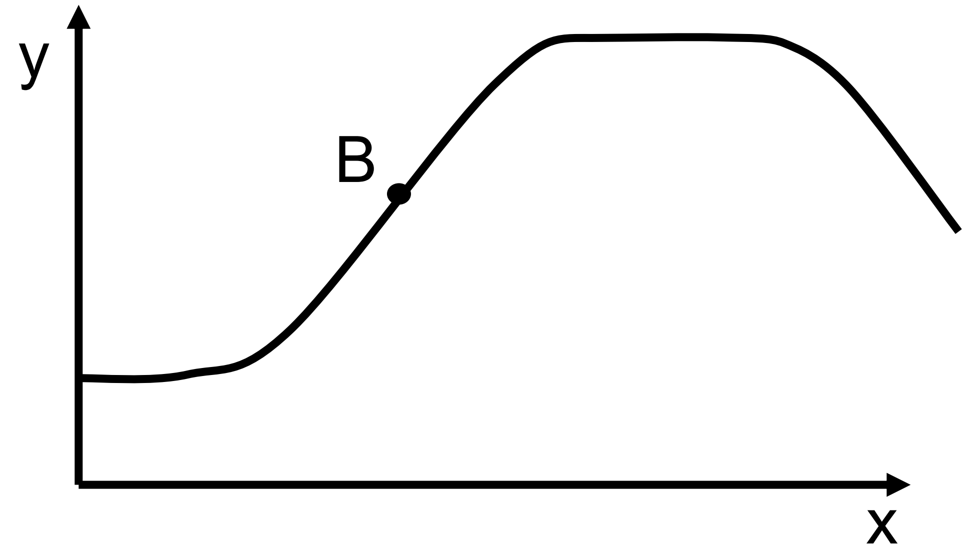




Phet

The slope at point B on this function is _ as you move to the right on the graph.
(Think about slope just a 'smidgen' to the left and right of Point B.)

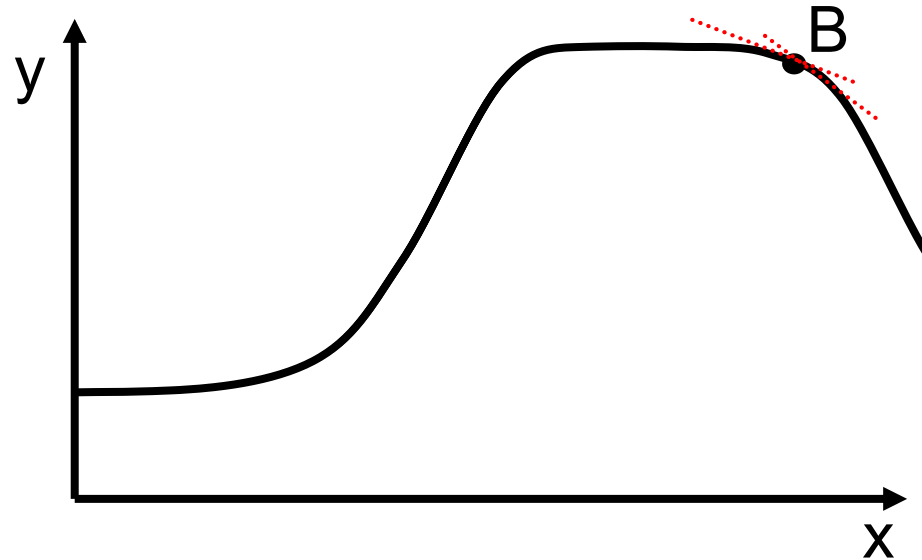
A. increasing
B. decreasing
C. staying the same



Slope of a straight line is the same anywhere along that line.
Along the straight portion of the curve, the slope is not changing.

The slope at point B on this function is _ as you move to the right on the graph.

A. increasing
B. decreasing
C. staying the same



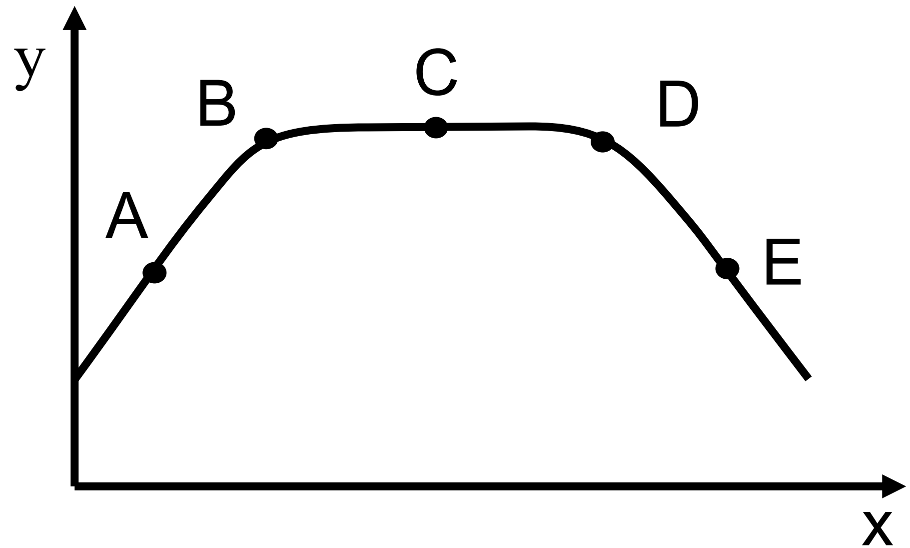
Think about slope just a 'smidgen' to the left and right of the point.

As slope gets more negative, it is decreasing.

If we asked about the magnitude of the slope (absolute value in this case), the magnitude of the slope is increasing.

At what point or points is the slope of the function decreasing as you move to the right on the graph?

(A) A
(B) B
(C) C
(D) D
(E) E
(F) D, E
(G) B, D, E
(H) B, D
(I) B, C, D
(J) A, B



Think about slope just a 'smidgen' to the left and right of the point.

On the straight line segments the slope is constant, the same, not changing.

At B the slope is less steep as you move to the right.

At D the slope is becoming more negative (so it is decreasing).

This position versus time graph represents the position of a person as a function of time. At what point or points is the person standing still?

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(A) A

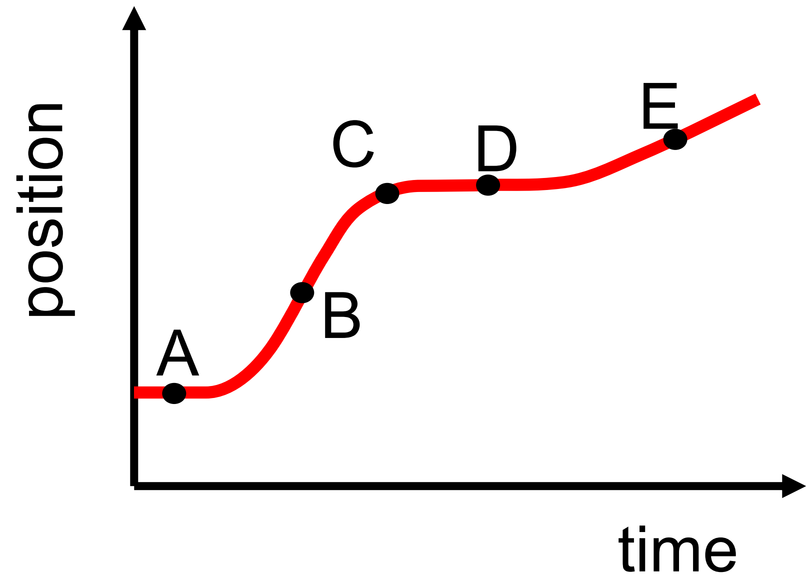
(B) D

(C) C

(D) A and D

(E) B and E

(F) A, B, D and E



At A and D the position is not changing

Moving Man PhET

Average and Instantaneous

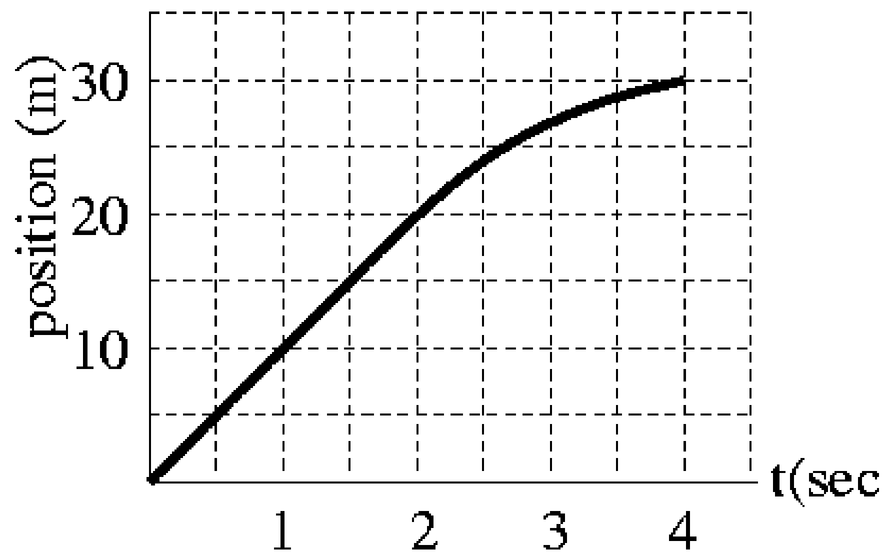
- Average – need beginning and end 'events' (times)
  - 'event' – time, place, velocity, acceleration

- Instantaneous – that instant
  - shrink Δt to very small
    (think zooming-in on the graph)

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

- Slope on position vs. time graph is change in position divided by change in time.

PhET



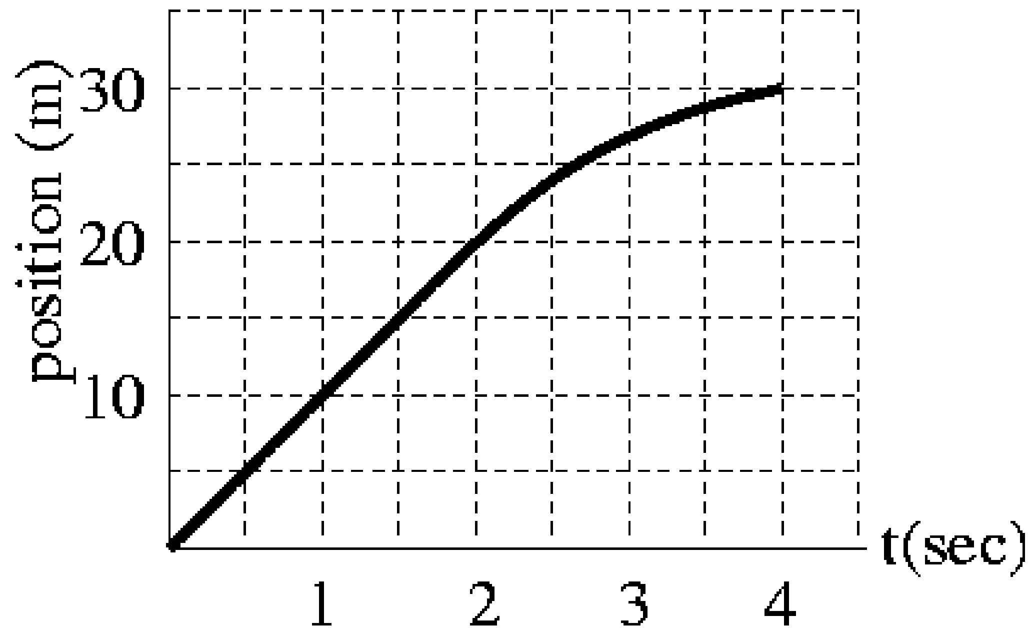
The graph represents the position of a runner as a function of time. What is the average velocity of the runner during the time interval from 1 to 4 s?

(A) 5 m/s

(B) 6.7 m/s

(C) 7.5 m/s

(D) 10 m/s



$$\bar{v} = \frac{\Delta x}{\Delta t} = \frac{x_f - x_0}{t_f - t_0} = \frac{30m - 10m}{4s - 1s} = 6.7m/s$$

This graph represents the position of a person as a function of time.
At what point or points is the velocity constant (not changing)?

8

(A) A

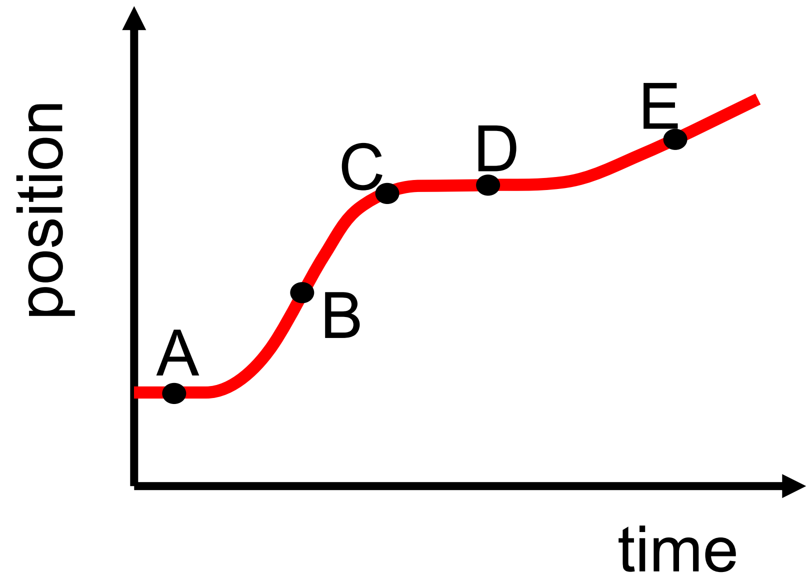
(B) D

(C) C

(D) A and D

(E) B and E

(F) A, B, D and E



Slope represents the velocity.
Anywhere slope is not changing, velocity is not changing!

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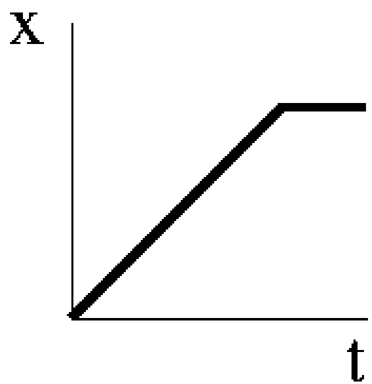
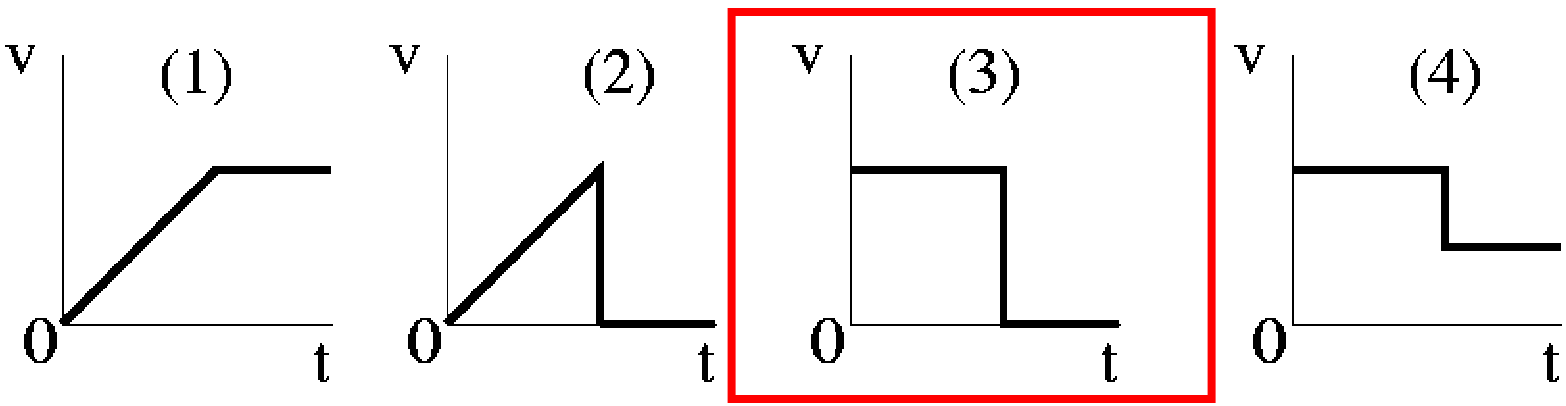
At what point is the person moving fastest?

B – greatest slope

Sect 2.7

Which velocity plot corresponds to this position plot?





x vs t graph: Constant positive slope, then zero slope (zero v)

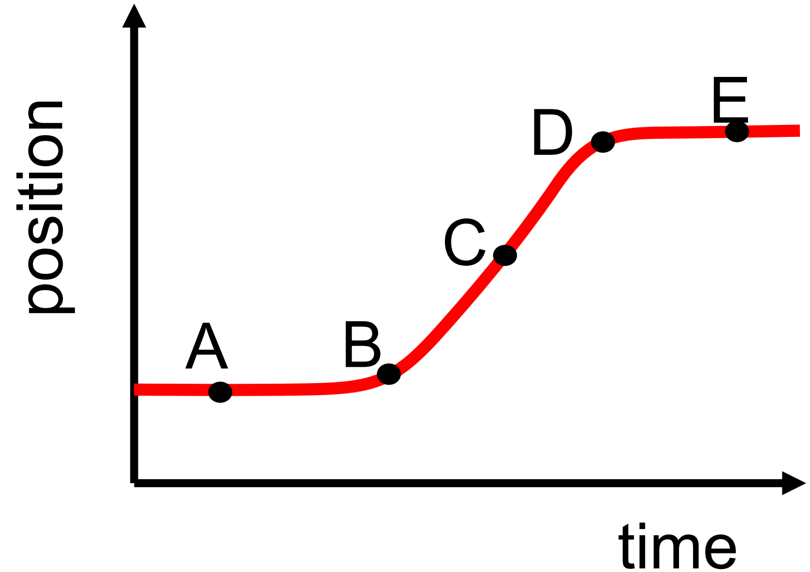
At Point B the velocity is:

A. zero

B. constant

C. increasing

D. decreasing



Slope represents the velocity.

At Point B the slope is increasing as time increases.

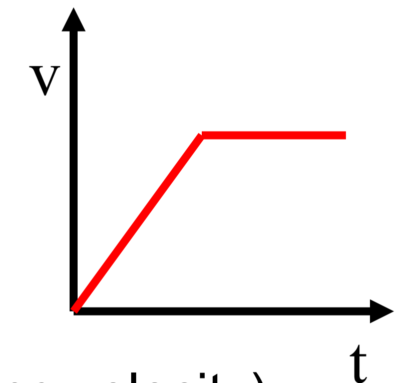
Acceleration

- Change in velocity over change in time
- Vector

$$\boxed{\bar{a} = \frac{\Delta v}{\Delta t}}$$

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

$$\boxed{v_f = v_0 + \bar{a}\Delta t}$$



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

Note: acceleration would be ***slope*** on v vs. t graph (changing velocity)

Would be ***change in*** slope on x vs. t graph

Think about how velocity is changing

2 objects are accelerating over a time period of 6 seconds.
A toy rocket changes its velocity from 140 m/s to 150 m/s.
A bicyclist changes their velocity from 5 m/s to 15 m/s.
Which has the greatest acceleration?

A. The bicyclist has the greater acceleration.
B. The rocket has the greater acceleration.
C. They both have the same acceleration.

Same Δv, same Δt

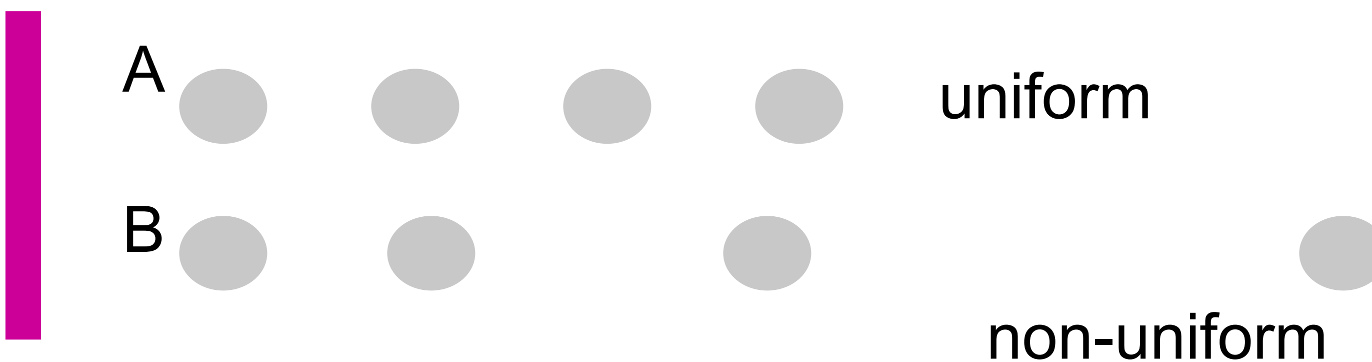
$$\bar{a} = \frac{\Delta v}{\Delta t} = \frac{150\,\text{m/s} - 140\,\text{m/s}}{6\text{s}} = 1.67\,\text{m/s}^2$$

Units on LON-CAPA: m/s^2

Uniform Motion

- Corresponds to constant velocity
- Therefore, a constant speed in constant direction

- Motion diagram of two balls (both are moving to the right):



Which ball is undergoing non-uniform motion?

1-D Kinematics

- Goal:
  - Understand direction (and in 1-d, the sign) of acceleration
  - Try to represent the motion graphically

Moving Man PhET

If acceleration and velocity in same direction: speeding up.

If acceleration and velocity in opposite directions: slowing down.

Speed is magnitude ("size") of velocity (Speed has no direction).

Motion with Constant Acceleration

If constant net force → *Then* constant acceleration

$$\Delta x = \bar{v}\Delta t$$ Displacement

$$\Delta v = \bar{a}\Delta t$$ *if a=constant, then $\bar{a} = a$

$$\boxed{x = x_0 + \bar{v}t}$$

$$\boxed{\bar{v} = \frac{1}{2}(v_0 + v)}$$

$$\boxed{v = v_0 + at}$$

$$\boxed{x = x_0 + v_0 t + \frac{1}{2}at^2}$$

$$\boxed{v^2 = v_0^2 + 2a(x - x_0)}$$

ONLY IF ACCEL. IS CONST.

Problem Solving Approach

Sect 2.5

1. Read, take your time
2. Draw/Imagine, lay out coordinate system
3. What do we know? Don't know? Want to know?
4. Physical Processes? Laws? Conditions?
5. Valid Relationships/Formulas
6. Solve Work out each step. You don't get extra points for mental math.
7. Is your answer reasonable?

$$\boxed{x = x_0 + \overline{v}t}$$

$$\boxed{\overline{v} = \frac{1}{2}\left(v_0 + v\right)}$$

$$\boxed{v = v_0 + at}$$

$$\boxed{x = x_0 + v_0 t + \frac{1}{2}at^2}$$

$$\boxed{v^2 = v_0^2 + 2a\left(x - x_0\right)}$$

***ONLY IF ACCELERATION IS CONSTANT**

Problem Solving Example: Plane Landing

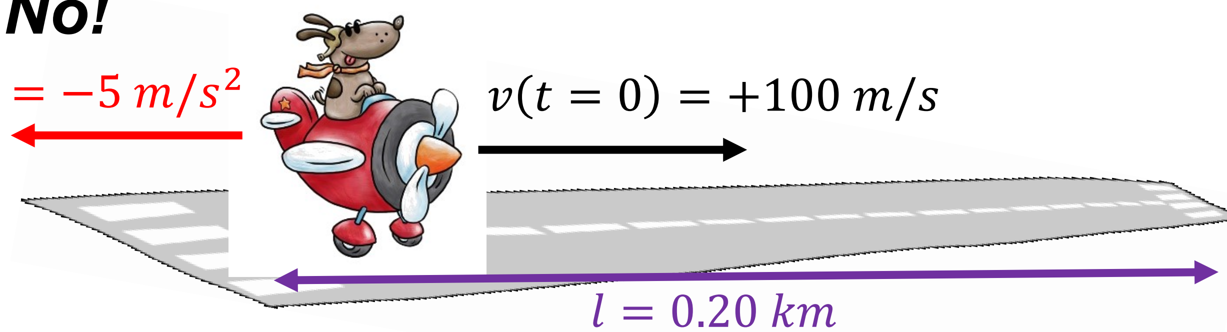
Sect 2.5

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.

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

b) Can this plane land on a small island airport where the runway is 0.2km long? ***No!***

1. Read
2. Draw
3. Know?
4. Processes
5. Formulas
6. Solve
7. Reasonable?



- 1D-kinematics, constant acceleration
- (a) $v = v_0 + at$
- (b) $v^2 = v_0^2 + 2a(x - x_0)$

a) $v = v_0 + at = \left(+100\,\frac{m}{s}\right) + \left(-5.0\,\frac{m}{s^2}\right)t = 0 \;\rightarrow\; t = \left({}^{-100m/s}/_{-5m/s^2}\right) = 20\ s$

b) $v^2 = v_0^2 + 2a(x - x_0) \;\rightarrow\; (0\ m/s)^2 = (100\ m/s)^2 + 2\left(-5\,\frac{m}{s^2}\right)(x - 0\ m)$

$\rightarrow\; 0\,\frac{m^2}{s^2} = 10000\,\frac{m^2}{s^2} - \left(10\,\frac{m}{s^2}\right)x \;\rightarrow\; \mathrm{x} = \left(-10^4\,\frac{m^2}{s^2}\right) / \left(-10\,\frac{m}{s^2}\right) = 1000m = 1km$

Problem Solving Example: Accelerating Car

Sect 2.5

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

Find the distance the car travels in this time and the constant acceleration of the car. Define the +x direction to be in the direction of motion of the car.

<u>What do we know?</u>

- "Accelerates uniformly": a = constant
- "from rest": $v_i = v(t=0) = 0$ m/s
- "to a speed of 25 m/s in 8 s": $v_f = v(t=8\text{s}) = 25$ m/s

<u>What do we want to know?</u>

- "Find the distance": $x_f - x_i = ?$ (say $x_i=0$, so $x_f = ?$)
- Find "the acceleration": $a = ?$

<u>Which equations are useful?:</u>

- Eqn. 1 gives distance …but need to combine with 2 to get average velocity
- Eqn. 3 gives the acceleration if you know the initial and final velocities

<u>Solutions:</u>

1. $x - x_0 = \bar{v}t = 0.5\left(0\,\frac{m}{s} + 25\,\frac{m}{s}\right)(8\ s) = 100\ m$
2. $a = \frac{(v-v_0)}{t} = \left(25\,\frac{m}{s} - 0\,\frac{m}{s}\right)\frac{1}{(8\ s)} = 3.1\ m/s^2$

<u>1D, a=constant Eqns:</u>

1. $x = x_o + \bar{v}t$
2. $\bar{v} = \frac{v_0+v}{2}$
3. $v = v_0 + at$
4. $x = x_0 + v_o t + (½)at^2$
5. $v^2 = v_0^2 + 2a(x - x_0)$