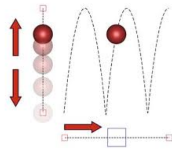
Motion: Acceleration



How do we change velocity? How can we describe changes in velocity?

Day 3:
- Get your clickers ready!
- Motion
  - Position, velocity
  - Acceleration

Reminders:
HW 1 due tonight
Helproom **today**, Ths and Mon
Next up: finish acceleration, move on to force

Reading Quiz (Sections 1.1, 1.2)

1. Which carries more information about motion?
   a. speed
   b. velocity
   c. Neither, they are the same

2. Acceleration:
   a. Is always positive
   b. Depends on position
   c. Is a change in velocity

3. Weight is:
   a. A type of mass due to gravity
   b. A type of force due to gravity
   c. A type of acceleration due to gravity

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Summary

Last time:

- **Scalars:** Distance and Speed
- **Vectors:** Position and velocity

Speed = Distance covered/Time taken

Velocity: $\underline{v} = \Delta\underline{x} / \Delta t$

Graphs: x vs t and v vs t

Today:

- Graphs: relationship between position and velocity graphs
- Acceleration
- Equations of motion
  - Constant velocity
  - Constant acceleration
- Changing units

Speed and velocity question

1. You are driving 60 miles per hour north.
2. You are driving 60 miles per hour.

a. both give your speed, can't tell your velocity.
b. 2. gives speed, 1. gives velocity.
c. both are giving your velocity.
d. 2 gives velocity, 1. gives your speed.

ans. b. 1. gives speed and direction = velocity. 2. gives only your speed, but since direction not specified, do not know velocity.

if speed is constant 60 mph, can velocity be changing?

yes! driving in circle. direction changing = velocity changing = accelerating!

Tricky speed and velocity question

I start in Boulder and drive 20 miles west to Nederland in 40 mins. When I get to Ned I go round the roundabout and head straight back to Boulder. Its downhill so I only take 20 mins for the return trip.

What is my average speed for whole trip?
a. 0 mph
b. 30 mph
c. 40 mph
d. 60 mph
e. Something else

Hint: Average Speed = Total distance covered/Total time taken

Tricky speed and velocity question

I start in Boulder and drive 20 miles west to Nederland in 40 mins. When I get to Ned I go round the roundabout and head straight back to Boulder. Its downhill so I only take 20 mins for the return trip.

What is my average speed for whole trip?

a. 0 mph
b. 30 mph
c. 40 mph
d. 60 mph
e. Something else

Hint: Average Speed = Total distance covered/Total time taken

Average speed = 40 miles/60 minutes
= 0.67 miles/minute × 60 minutes/hour
= 40 mph

Tricky speed and velocity question

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d. 60 mph
e. Something else

Hint: Average $\underline{v} = \underline{\Delta x} / \Delta t$

Tricky speed and velocity question

I start in Boulder and drive 20 miles west to Nederland in 30 mins. When I get to Ned I go round the roundabout and head straight back to Boulder. Its downhill so I only take 20 mins for the return trip.

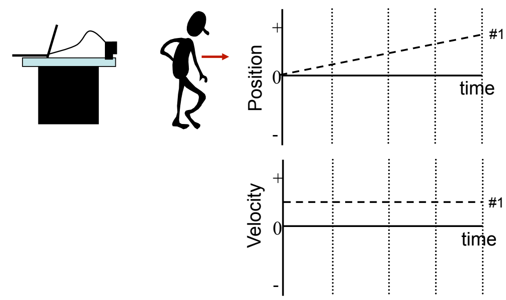
What is my average velocity for whole trip?

a. 0 mph
b. 30 mph
c. 40 mph
d. 60 mph
e. Something else

Hint: Average $\underline{v} = \underline{\Delta x} / \Delta t$
$= (\underline{x}_f - \underline{x}_i) / \Delta t$
$= 0$

Position and velocity graphs

Person #1 moves away from the origin as shown
Sketch **position vs. time** and **velocity vs. time** graphs for person #2 moving **away** from origin (motion detector) at **twice** the velocity of person #1



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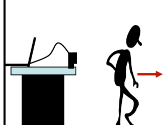

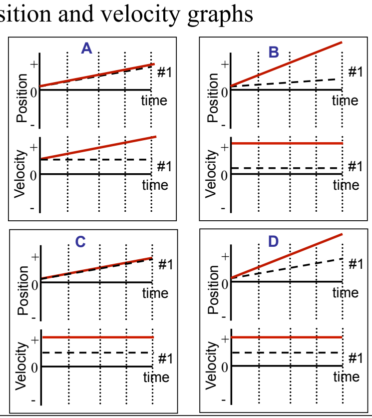

Pasco demo

Position and velocity graphs

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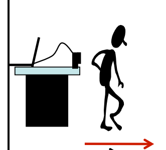
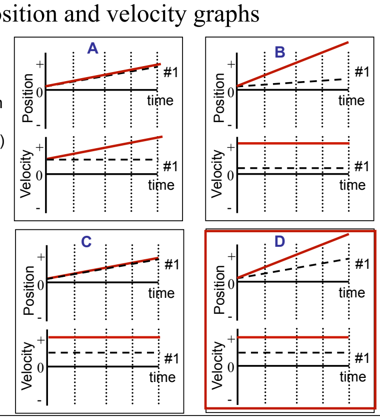
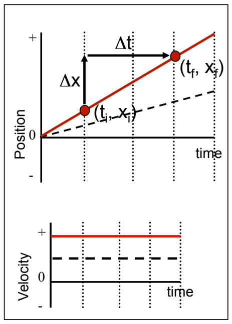


Velocity vectors



Relationship between position vs time graph and velocity vs time graph



Velocity = $\frac{\text{Change in position } (\Delta x)}{\text{Time taken } (\Delta t)}$

= slope of the position/time graph

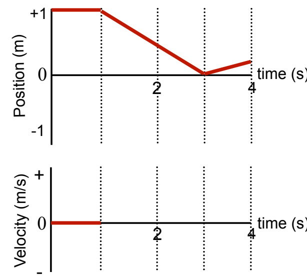
man walking, web demo.

Relationship between position vs time graph and velocity vs time graph

Velocity is the slope of position-time graph

What does velocity graph look like?

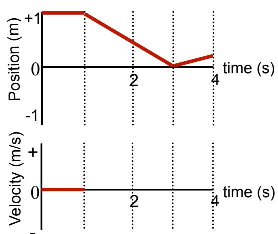
What does it look like between 0 and 1s?



Relationship between position vs time graph and velocity vs time graph

Velocity is the slope of position-time graph

What about velocity between 1s and 3s?
a)Negative, decreasing magnitude
b)Negative , Increasing magnitude
c)Negative, constant magnitude
d)Positive , constant magnitude
e)Can't tell from info given



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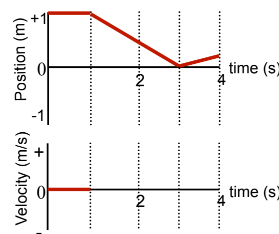
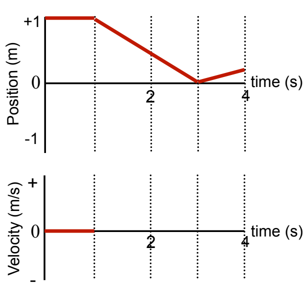


Relationship between position vs time graph and velocity vs time graph

Velocity is the slope of position-time graph

Velocity at 2 s is:
a) 1 m/s
b) -1 m/s
c) 0.5 m/s
d) -0.5 m/s
e) - 1/6 m/s



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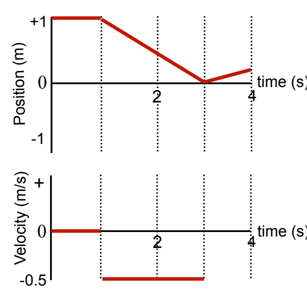

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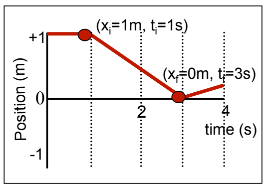


$$\text{Velocity} = \frac{\text{Change in position } (\Delta x)}{\text{Time taken } (\Delta t)}$$

$$= \frac{x_f - x_i}{t_f - t_i}$$

$$= \frac{0m - 1m}{3s - 1s}$$

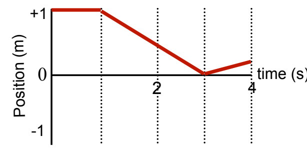
$$= \frac{-1m}{2s} = -0.5 \text{ m/s}$$

Direction Magnitude

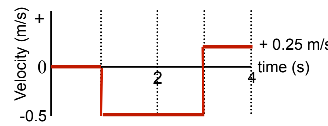
Relationship between position vs time graph and velocity vs time graph

Velocity is the slope of position-time graph

What does velocity graph look like?



What about velocity between 3s and 4s?



Equations of motion

Several ways to describe motion so far:

1. Words
2. Arrows (vectors) and numbers (scalars)
3. Graphs
4. Equations

$$\text{Velocity (v)} = \frac{\Delta x}{\Delta t} = \frac{x_f - x_i}{t_f - t_i}$$

Rearrange:

$$x_f - x_i = v(t_f - t_i)$$
$$x_f = x_i + v(t_f - t_i)$$

Now let $t_i = 0s$ and so $x_i = x_0$.

$$x_f = x_o + v\, t_f$$

The subscript f is now unnecessary so we can write:

$$x = x_o + v\, t$$

Motion at constant velocity

$$x(t) = x_0 + vt$$

your position at time t depends on:

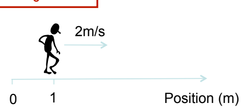
Where you started,

How fast and in what direction you're going,

How long you've been going

Practice question

$$x(t) = x_0 + vt$$

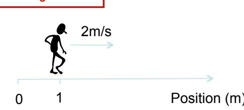


I start 1m to the right of the origin at t=0. I walk to the right for 3s at 2m/s. What is my position at 3s?
(Define positions to the right of the origin as positive)

a. 1m
b. 4m
c. -5m
d. 3m
e. 7m

Practice question

$$x(t) = x_0 + vt$$



I start 1m to the right of the origin at t=0. I walk to the right for 3s at 2m/s. What is my position at 3s?
(Define positions to the right of the origin as positive)

a. 1m
b. 4m
c. -5m
d. 3m
e. 7m

$$x = x_o + v\, t$$
$$= 1m + (2m/s)(3s)$$
$$= 7m$$

Break to discuss units

If you drive 60 miles/hour, that's a speed.
It's also 1 mile/minute
It's also 1/60 mile/s

"Physics" units: meters/second (m/s)

There are 1600 meters in a mile. If you drive 60 miles/hour, how fast is this in m/s?

a) 60 m/s
b) 160 m/s
c) 27 m/s
d) 270 m/s
e) 1600 m/s

There are 1600 meters in a mile. If you drive 60 miles/hour, how fast is this in m/s?

a) 60 m/s
b) 160 m/s
c) 27 m/s
d) 270 m/s
e) 1600 m/s

How did you get that?

- We want to change the units but keep the answer (speed) the same
- Remember 2 things:
  - Multiply any answer by 1 and it doesn't change
  - 1600m = 1mile $\Rightarrow \frac{1600\text{m}}{1\text{ mile}} = 1$
- We have speed in mi/hr, we want m/s so:

Speed = $\left(\frac{60mi}{hr}\right)$

First change miles to meters

Then change hours to seconds

How did you get that?

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Speed = $\left(\frac{60mi}{hr}\right) \times 1$

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Speed = $\left(\frac{60mi}{hr}\right) \times \left(\frac{1600m}{1mi}\right)$

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$$= \left(\frac{60\times1600m}{60\times60s}\right) = 27m/s$$

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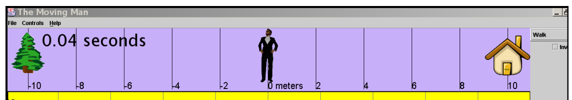
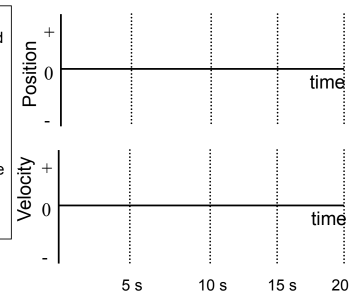
$$= \left(\frac{60\times1600m}{60\times60s}\right) = 27m/s$$

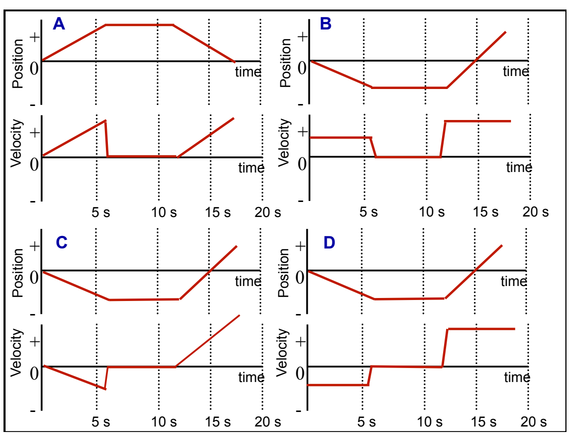
You will convert between different units of distance, time, mass, energy etc etc throughout the course. This method always works!

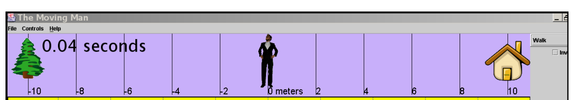


Demo 4:
Sketch **position vs time** and **velocity vs time** graphs for when Moving Man:
walks steadily towards the tree for 6 seconds,
then stands still for 6 seconds, and
then towards the house twice as fast as before for 6 seconds.



(start at v = -0.8 m/s)





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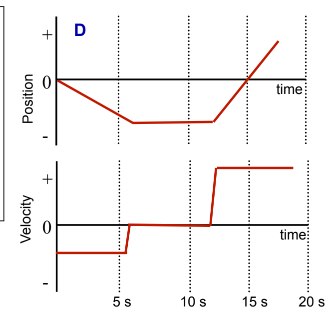
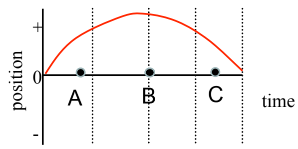


Walking man moves according to the position-time graph, below. At which time is Walking Man slowing down (**speed** getting smaller)?

a) A only
b) B only
c) C only
d) A and C
e) A, B, and C



Answer a: slope is getting smaller with time.

Equations when velocity is changing

What if velocity is changing? … Accelerating

Acceleration (a) is a VECTOR

a = slope of a velocity vs time graph

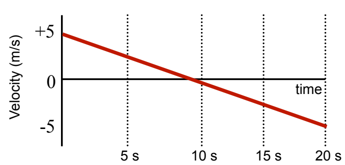
$$= \frac{\text{Change in velocity } (\Delta v)}{\text{Time taken } (\Delta t)}$$

$$= \frac{v_f - v_i}{t_f - t_i}$$

Units = $\frac{m/s}{s}$ = m/s^2

Graph shows the velocity of a car as a function of time. What is its acceleration?

a. - 0.25m/s^2
b. +0.25m/s^2
c. - 0.5m/s^2
d. + 0.5 m/s^2
e. 0 m/s^2



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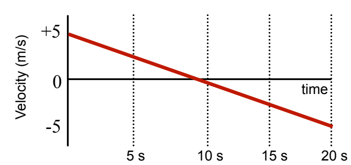
$$a = \frac{v_f - v_i}{t_f - t_i}$$

$$= \frac{-5m/s - 5m/s}{20s - 0s}$$

$$= \frac{-10m/s}{20s} = -0.5m/s^2$$



Equations when velocity is changing

What if velocity is changing? … Accelerating

Acceleration (a) = $\frac{v_f - v_i}{t_f - t_i}$

Rearrange:

$v_f - v_i = a(t_f - t_i)$

$v_f = v_i + a(t_f - t_i)$

Now let t_i = 0s and so $v_i = v_0$ and drop the f subscript

$v = v_0 + a\,t$

Motion at constant acceleration

$v(t) = v_0 + at$

your velocity at time t depends on

Your velocity when you started,

How fast and in what direction you are accelerating,

How long you' ve been going