Lecture 2

Motion along a straight line

(HR&W, Chapter 2)

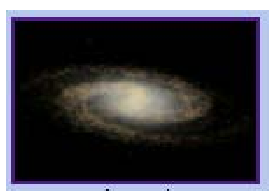
Physics 105; Summer 2007

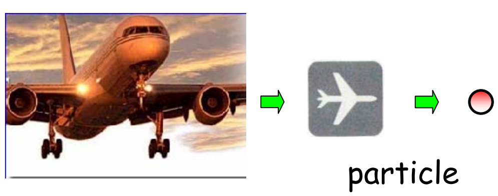
Motion along a straight line

- Motion
- Position and Displacement
- Average velocity and average speed
- Instantaneous velocity and speed
- Acceleration
- Constant acceleration: A special case
- Free fall acceleration

Motion

- Everything moves!
- Classification and comparison of motion ⇨ **kinematics**
- Simplification
  - Motion along straight line
  - Forces cause changes in motion
  - Moving object is a particle or moves like a particle





Motion along a straight line

- this is the simplest type of motion
- it lays the groundwork for more complex motion

Kinematic variables in one dimension

Position	**x(t)**	meters
Velocity	**v(t)**	meters/second
Acceleration	**a(t)**	meters/second ^{2}

All depend on time

All are vectors: have direction and magnitude.

One Dimensional Position: x(t)

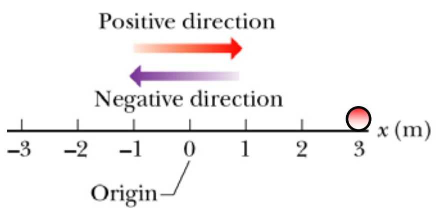
Position is a vector quantity.

Position has both a direction and magnitude.

Position has units of [Length]: *meters.*

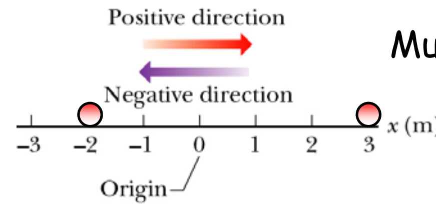
Must define:

- x = 0 some position (Origin)
- positive direction for x



x = 3 m

Displacement Along a Straight Line



Must define: t = 0

Displacement: $\Delta x = x_2 - x_1$

Displacement is a change of position in time.

It is a vector quantity.

It has both a direction and magnitude.

It has units of [Length]: *meters*.

x_1 = 3 m

x_2 = -2 m

Δx = -5 m

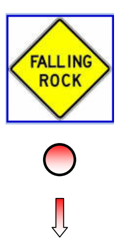
Displacement Along a Straight Line

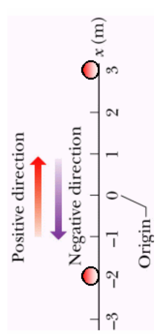
t=0; (start the clock) x = 0; (origin)

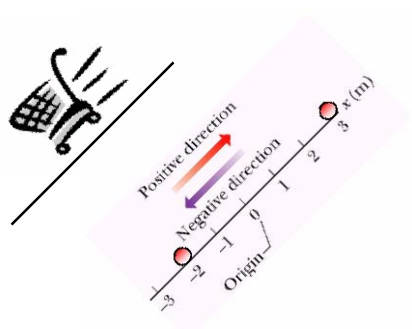
x(t=0) does not have to be 0

Straight line can be oriented

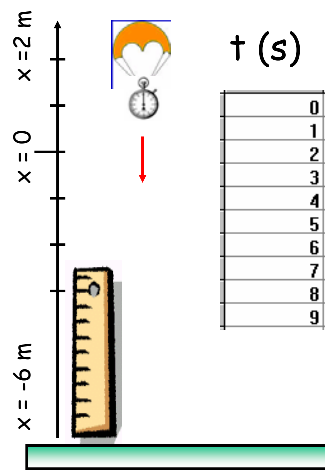
Horizontal, vertical, or at some angle



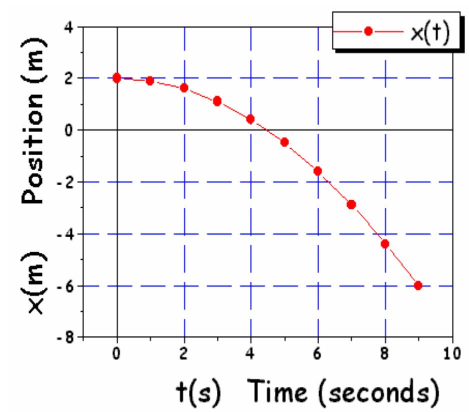




Displacement Along a Straight Line



t (s)	x (m)
0	2
1	1.9
2	1.6
3	1.1
4	0.4
5	-0.5
6	-1.6
7	-2.9
8	-4.4
9	-6



Motion with respect to the origin !

Displacement

Displacement in time:

$\Delta t = t_2 - t_1$

Displacement in Space:

$\Delta x = x(t_2) - x(t_1)$

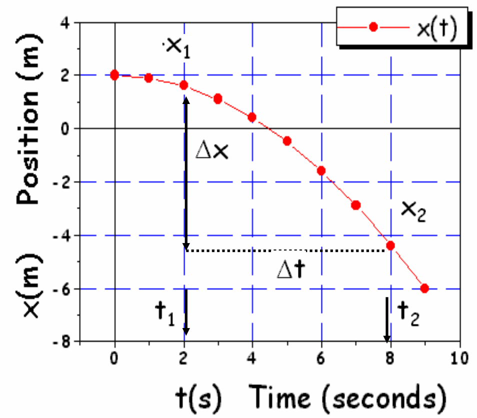
or

$\Delta x = x_2 - x_1$

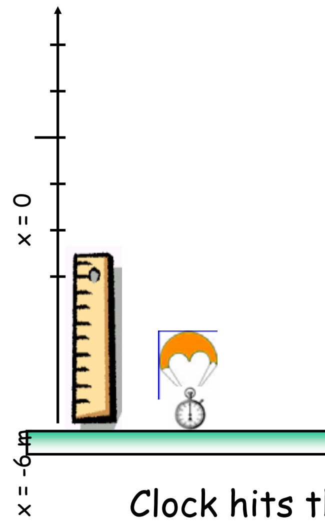
Avg:

$x(t_2) - x(t_1)$

is negative



Displacement Along a Straight Line



t (s)	x (m)
0	2
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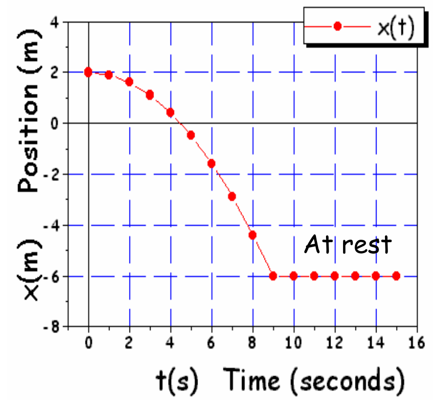
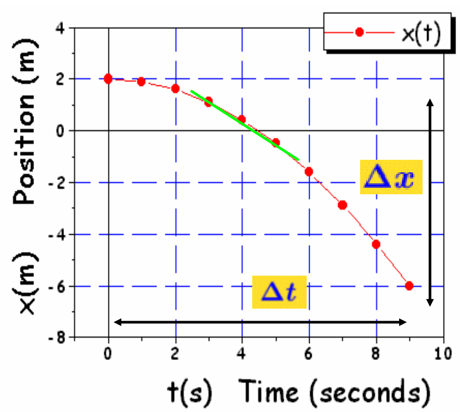
5	-0.5
6	-1.6
7	-2.9
8	-4.4
9	-6
10	-6
11	-6
12	-6
13	-6
14	-6
15	-6
16	-6



Clock hits the ground at t = 9 s

Velocity



Average velocity

$$v_{avg} = \frac{\Delta x}{\Delta t} = \frac{x_2 - x_1}{t_2 - t_1}$$

=-8/9 m/s

≈ -0.9 m/s

Average speed

$$s_{avg} = \frac{\text{total distance}}{\Delta t}$$

=8/9 m/s

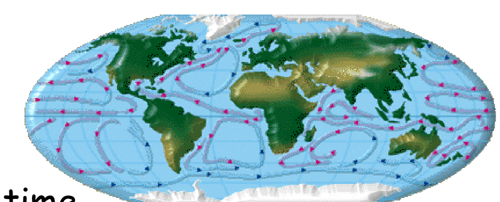
≈ 0.9 m/s

Instantaneous velocity

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

Velocity is the rate of change of position

Velocity is a vector !

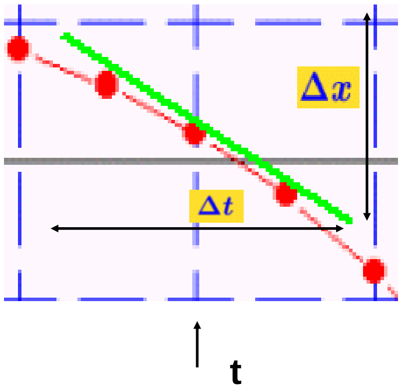


Velocity has direction !

Velocity can change with time

Instantaneous Velocity

Consider smaller time intervals:

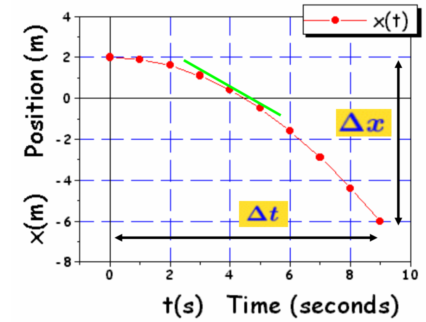


Instantaneous velocity v(t) is the slope of the tangent line to x(t)

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

changes with time !

v(t) is a function of time !

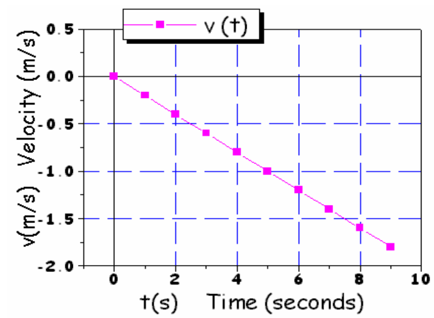


Velocity

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

Example of negative **v**

Velocity is positive in the same direction as x is positive

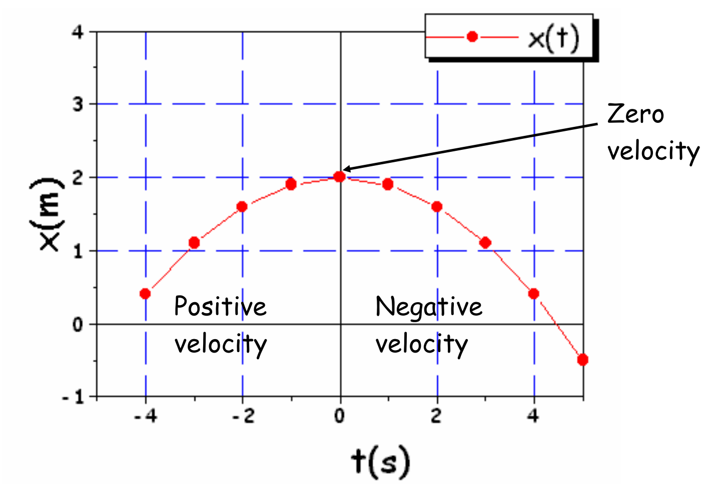


Example of a constant acceleration:

v(t) = at

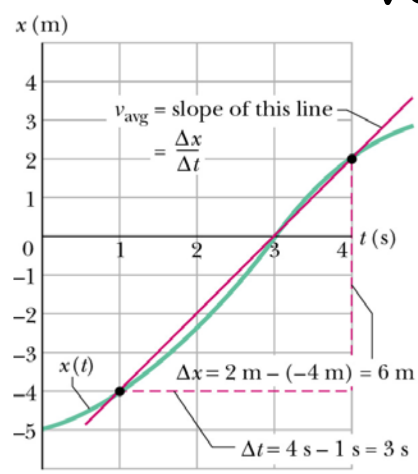
v(t) is a straight line

Sign of velocity



v(t) is a function of time !

Velocity



HR&W

"moving armadillo"

- Average velocity

$$v_{avg} = \frac{\Delta x}{\Delta t} = \frac{x_2 - x_1}{t_2 - t_1}$$ = 6/3 m/s

- Average speed

$$s_{avg} = \frac{\text{total distance}}{\Delta t}$$ = 6/3 m/s

- Instantaneous velocity

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

Acceleration

- Average acceleration

$$a_{avg} = \frac{v_2 - v_1}{t_2 - t_1} = \frac{\Delta v}{\Delta t}$$

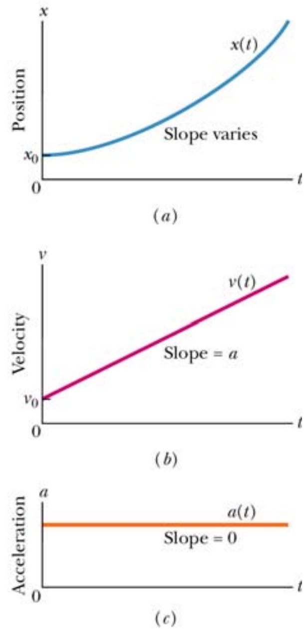
- Instantaneous acceleration

$$a = \frac{dv}{dt}$$

- Constant acceleration

$$v = v_0 + at$$

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



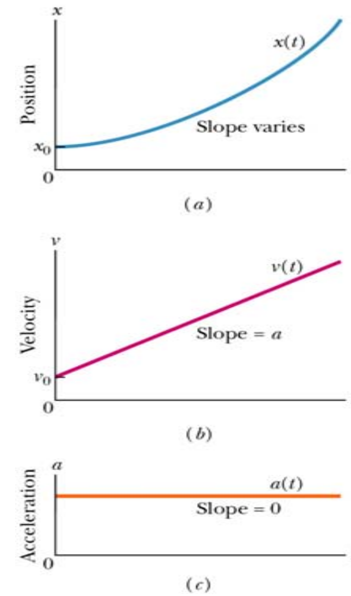
Constant Acceleration

(a > 0)

$v(t) = v_0 + at;$

$x(t) - x_0 = v_0\, t + at^2/2$

$x(t) - x_0 = (v(t)^2 - v_0^2)/2a$



Kinematic Variables

Position is a function of time: $x = x(t)$

Velocity is the rate of change of the position

Acceleration is the rate of change of the velocity

$$v(t) = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t} = \frac{dx}{dt}$$

$$a(t) = \lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t} = \frac{dv}{dt}$$

Position $\xrightarrow{\frac{d}{dt}}$ Velocity $\xrightarrow{\frac{d}{dt}}$ Acceleration

What does zero mean ?

- $t = 0$ beginning of the process
- $x = 0$ is arbitrary; can set where you want it
- $x_0 = x(t=0)$; position at $t=0$; do not mix with the origin

- $v(t) = 0$ x does not change $x(t) - x_0 = 0$
- $v_0 = 0$ $v(t) = at;$ $x(t) - x_0 = at^2/2$
- $a = 0$ $v(t) = v_0;$ $x(t) - x_0 = v_0\, t$

- $a \neq 0$ $v(t) = v_0 + at;$ $x(t) - x_0 = v_0\, t + at^2/2$

help: $t = (v - v_0)/a$ $x - x_0 = \frac{1}{2}(v^2 - v_0^2)/a$

$a = (v - v_0)/t$ $x - x_0 = \frac{1}{2}(v + v_0)t$

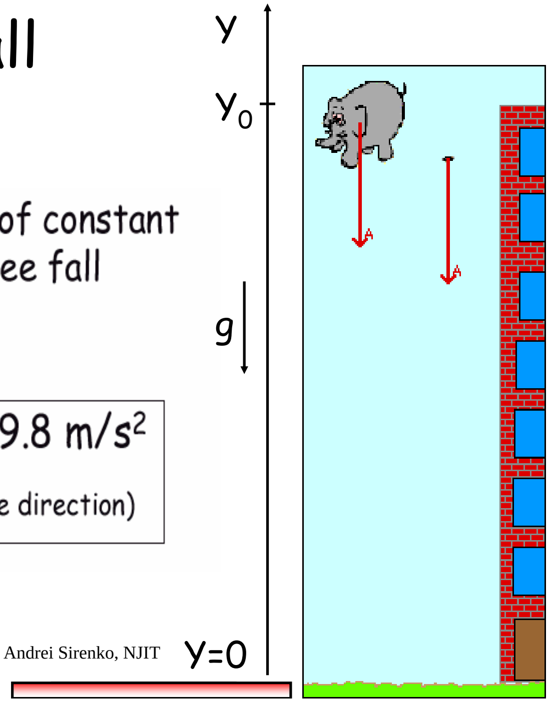
- Acceleration and velocity are positive in the same direction as displacement is positive

Free Fall

Most important case of constant acceleration: Free fall

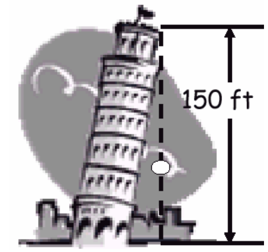
a = -g   where g = 9.8 m/s^2

(defining "up" as the positive direction)



Gravitation is universal

Gravitational acceleration does not depend on the nature of the material or the mass of the object.



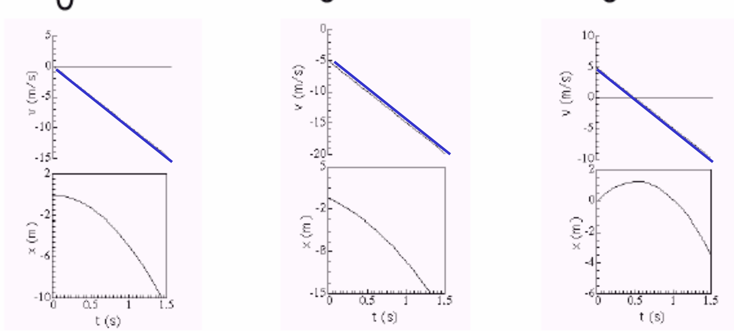
Three cases of free fall

$$x(t) = x_0 + v_0 t + \tfrac{1}{2}(-g)t^2$$

$$v(t) = v_0 + (-g)t$$

+

$v_0 = 0$ $v_0 < 0$ $v_0 > 0$



Sample Problem II-2

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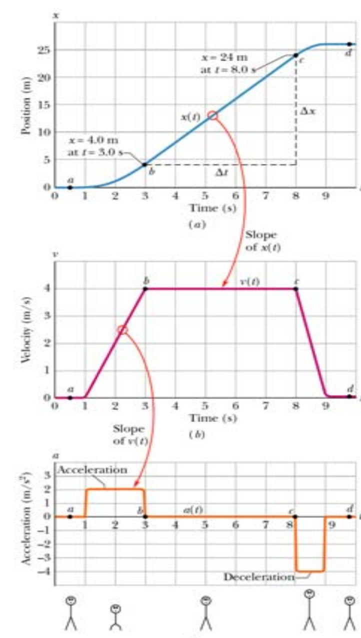
An elevator is initially stationary, then moves upward (which we take the positive direction of *x*), and then stops. Plot *V* as a function of time.

(a) x(t) curve for an upward moving elevator cab

(b) v(t) curve for the cab. Note $v = dx/dt$!

(c) a(t) curve for the cab. Note $a = dv/dt$!



http://webphysics.ph.msstate.edu/

Conclusions:
Motion along a straight line

- the simplest type of motion
- the groundwork for more complex motion

<u>Kinematical variables in one dimension</u>

Position:	$x(t)$	meters
Velocity:	$v(t)$	meters/second
Acceleration:	$a(t)$	meters/second ^{2}

All depend on time

All are vectors: have direction and magnitude.

TABLE 2-1 Equations for Motion with Constant Acceleration[a]

Equation Number	Equation	Missing Quantity
2-11	$v = v_0 + at$	$x - x_0$
2-15	$x - x_0 = v_0 t + \frac{1}{2}at^2$	v
2-16	$v^2 = v_0^2 + 2a(x - x_0)$	t
2-17	$x - x_0 = \frac{1}{2}(v_0 + v)t$	a
2-18	$x - x_0 = vt - \frac{1}{2}at^2$	v_0

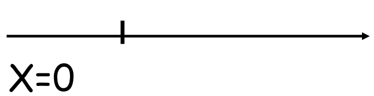
[a] Make sure that the acceleration is indeed constant before using the equations in this table.

Next Lecture:
Motion in 2D and 3D + Vectors

<u>One dimension (1D)</u>

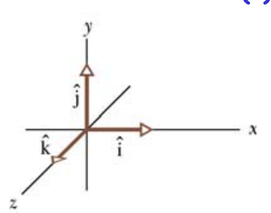
Position:	$x(t)$	m
Velocity:	$v(t)$	m/s
Acceleration:	$a(t)$	m/s ^{2}

All are vectors: have direction and magnitude.



<u>Three dimension (2D)</u>

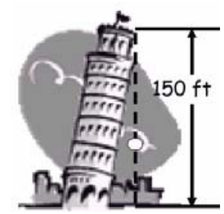
Position:	$\vec{r}(t)$	m
Velocity:	$\vec{v}(t)$	m/s
Acceleration:	$\vec{a}(t)$	m/s ^{2}



Lecture QZ2

A rock is dropped from the height of 150 ft with no initial velocity. What is the rock's speed after the first 2 seconds. (Neglect the air resistance).

Hint: The free fall acceleration $g = 9.8$ m/s ^{2}
(150 ft → ? meters)



Homework:

- Utexas