PHY 107
1D motion

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OUTLINE

- Motion
- Position and Displacement
- Velocity
- Acceleration
- Concept of instantaneous and average quantities
- Constant Acceleration Equations
- Free Fall
- Graphical Integration

Motion

Kinematics: Classification and comparison of motions

Assumptions:

1. Motion is along a straight line (horizontal, vertical, slanted)
2. No interest in force
3. The object is treated as a particle

Displacement

It means change in position.
Displacement is a vector quantity (magnitude and direction)
1. A particle moves from x=5m to x=7m $\rightarrow$ Displacement = 2m
2. A particle is at position x=2m. It then moves to x=100m and finally comes to position x=2m

Displacement= $x_2 - x_1$= 0 m
What about distance?

Average Velocity

It is the ratio of the displacement Δx that occurs in a time interval Δt to the time interval Δt

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

t=0: x=2m;

t=1: x=6m

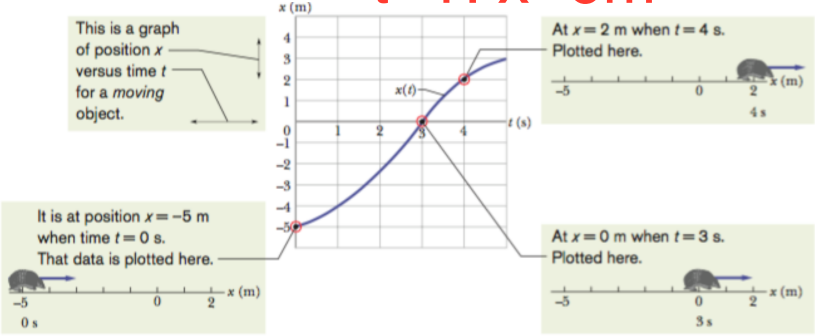
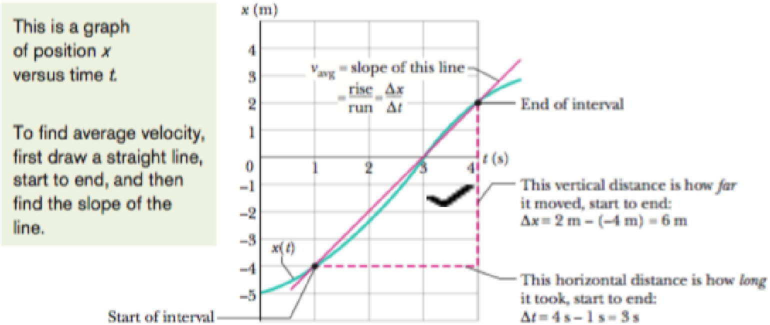


Fig. 2-3 The graph of $x(t)$ for a moving armadillo. The path associated with the graph is also shown, at three times.

Average Velocity



$$v_{avg} = \frac{\Delta x}{\Delta t} = \frac{6m}{3s} = 2m/s$$

Instantaneous Velocity

The velocity at any instant is obtained from average velocity by shrinking the time interval Δt closer to zero (but NOT equal to zero)

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

Calculus comes into play!

x = t^(3) - 2t^(2)

Find v at t=1

v=dx/dt=3t^(2)-4t

Acceleration

v=dx/dt=-27+3t^(2)

a=dv/dt=6t

Acceleration is the change in velocity in a given amount of time

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

Instantaneous acceleration: $a = \frac{dv}{dt} = \frac{d}{dt}\frac{dx}{dt} = \frac{d^2x}{dt^2}$

Example A particle's position on the x-axis is given by $x = 4 - 27t + t^3$ with x in meters and t in seconds

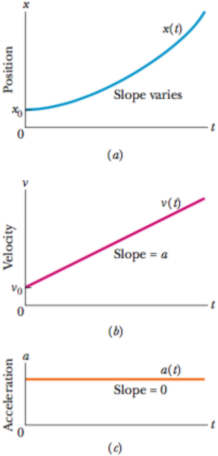
1. Find v(t) and a(t)
2. Is there ever a time when v=0?
3. Describe the particle's motion for $t \geq 0$

-27+3t^(2)=0

t^(2)=9

Constant acceleration

$a = 6$ m/s^(2)



Slopes of the position graph are plotted on the velocity graph.

Slope of the velocity graph is plotted on the acceleration graph.

Table 2-1

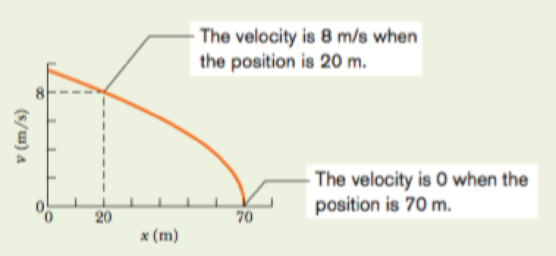
Equations for Motion with Constant Acceleration[a]

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.

Constant acceleration

EXAMPLE The plot below shows a particle's velocity versus its position as it moves along an x axis with constant acceleration. Find its velocity at position x=0.



1. $v^2 = v_0^2 + 2a(x - x_0)$
2. Use two points on the curve to find acceleration.
3. Use the computed a to find $v(x = 0)$

Free Fall Acceleration

Toss an object up or down
Eliminate effects of air on the flight
Free fall acceleration: constant downward acceleration of the object
Mass, density or shape have no impact on this acceleration.

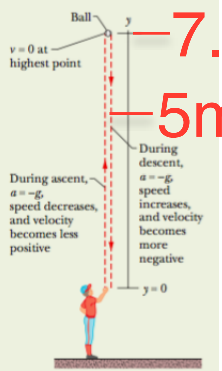
Fig. 2-10 A feather and an apple free fall in vacuum at the same magnitude of acceleration g. The acceleration increases the distance between successive images. In the absence of air, the feather and apple fall together. *(Jim Sugar/Corbis Images)*

g=9.8 m/s^(2)

The directions of motion are along the y axis with the positive direction of y upward.
The free-fall acceleration near Earth's surface:
$a = -g = -9.8 m/s^2$

Free fall acceleration

EXAMPLE A pitcher tosses a baseball up along a y axis, with an initial speed of 12 m/s.
a)How long does the ball take to reach its maximum height?
b)What is the ball's max height above its release point?
c)How long does the ball take to reach a point 5.0 m above its release point?



u=12 m/s

speed(h_max)=0

a=-9.8 m/s^(2)

S=ut+0.5at^(2)

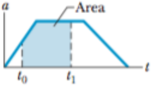
5=12t+0.5(-9.8)t^(2)

Free fall acceleration

(a) $t = \frac{v - v_0}{a}$ Ans:1.2 s
(b) $y = \frac{v^2 - v_0^2}{2a}$ Ans:7.3m
(c) $y = v_0 t - 0.5gt^2$
$5 = 12t - 0.5(9.8)t^2$
$4.9t^2 - 12t + 5 = 0$
t = 0.53 s and t = 1.9 s

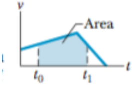
Graphical Integration in Motion Analysis

$a = \frac{dv}{dt}$: Fundamental theorem of Calculus: $v_1 - v_0 = \int_{t_0}^{t_1} a \; dt$
$v = \frac{dx}{dt}$: Fundamental theorem of Calculus: $x_1 - x_0 = \int_{t_0}^{t_1} v \; dt$



(a)

This area gives the change in velocity.



(b)

This area gives the change in position.

a=dv/dt

dv= a dt

x to v to a

a to v to x

a=5t

Reference

[1] Fundamentals of Physics by Halliday and Resnik