PHY 107
1D motion

Mohammad Murshed
Department of Math and Physics

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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

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

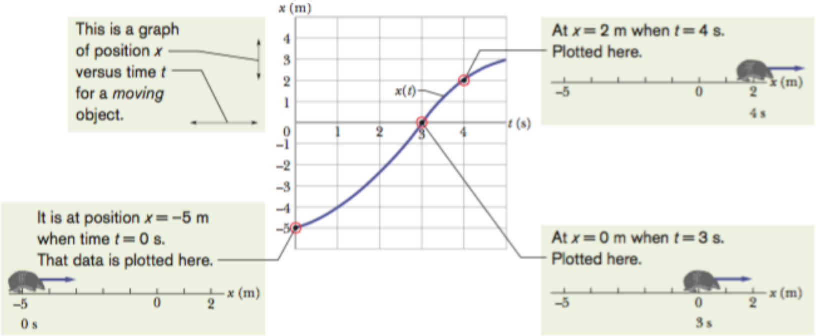
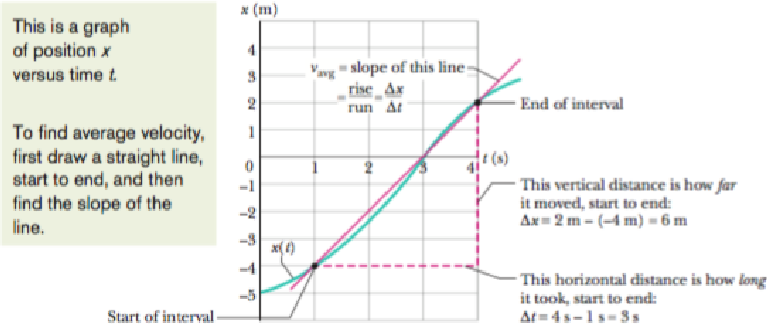


Fig. 2-3 The graph of $x(t)$ for a moving armadillo. The path associated with the graph is also shown, at three times.

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!

Acceleration

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 $t \geq 0$

Constant acceleration

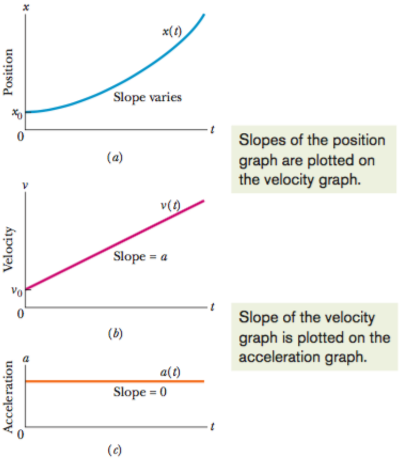


Table 2-1

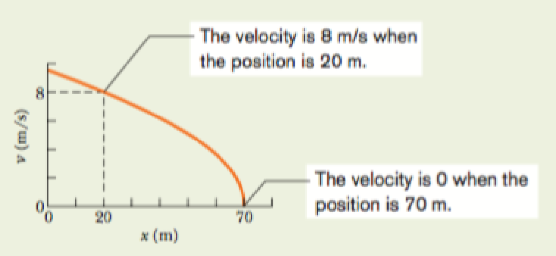
Equations for Motion with Constant Acceleration[a]

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

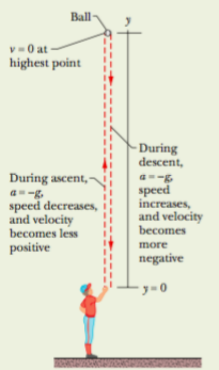
Toss an object up or down
Eliminate effects of air on the flight
Free fall acceleration: constant downward acceleration of the object
Mass, density or shape have no impact on this acceleration.

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)*

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?



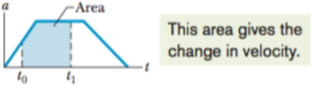
Free fall acceleration

(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

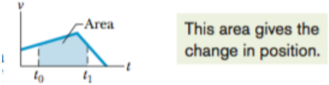
Graphical Integration in Motion Analysis

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



(b)

Reference

[1] Fundamentals of Physics by Halliday and Resnik