Physics 1

Chapter 2 Motion Along A Straight Line

1. Motion
2. Position & Displacement
3. Average Velocity & Speed
4. Instantaneous Velocity & Speed
5. Acceleration
6. Constant Acceleration
7. Another Look at Constant Acceleration
8. Free-Fall Acceleration

Review & Summary

Questions

Exercises & Problems

Motion

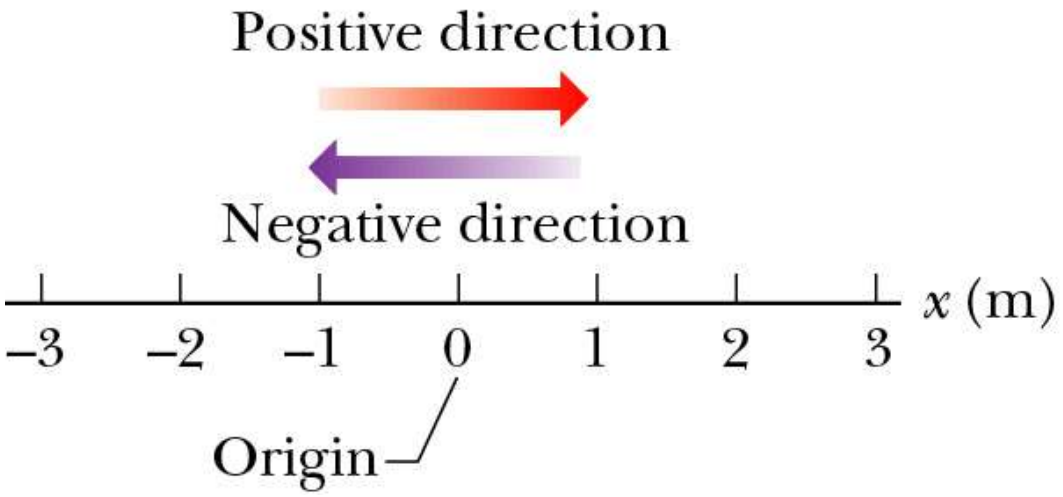
- “Kinematics”

- In this Chapter:
  - Motion in a straight line
  - Forces causing the motion are not discussed
  - Motion of point particles or objects for which every part moves in the same direction at the same rate.

- Chapter 3 - motion in 2 or 3 dimensions

Position and Displacement

- **Origin** - reference point relative to which position is measured.



- **Displacement** - change from one position to another.

$\Delta x = x_2 - x_1$

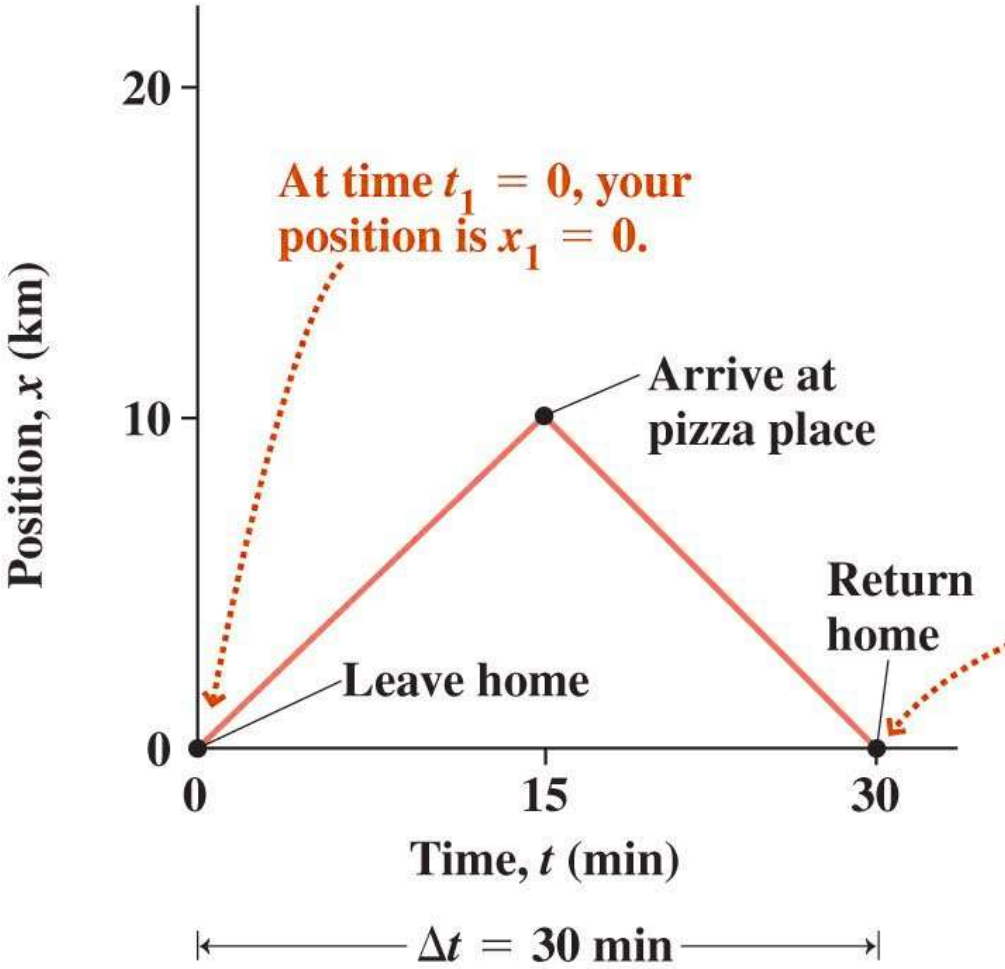
Average Velocity & Average Speed

- Average speed (scalar) = Distance / Elapsed time
- Average velocity (vector) = Displacement / Elapsed time

$$\mathbf{v}_{avg} = (\mathbf{x} - \mathbf{x}_0) / (t - t_0) = \Delta\mathbf{x} / \Delta t$$

- Note that the average velocity points in the same direction as the displacement vector
  - if the displacement points in the + direction, the velocity is +
  - if the displacement points in the - direction, the velocity is -

Velocity Compared to Speed

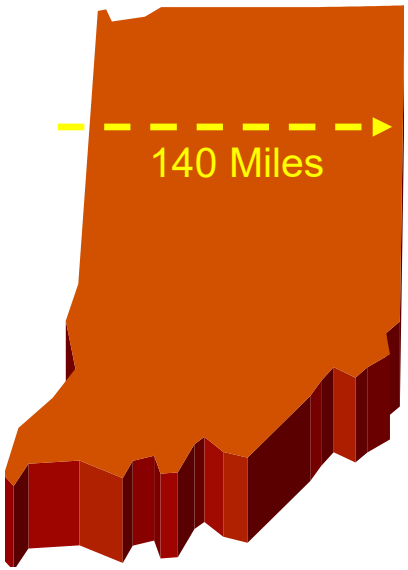


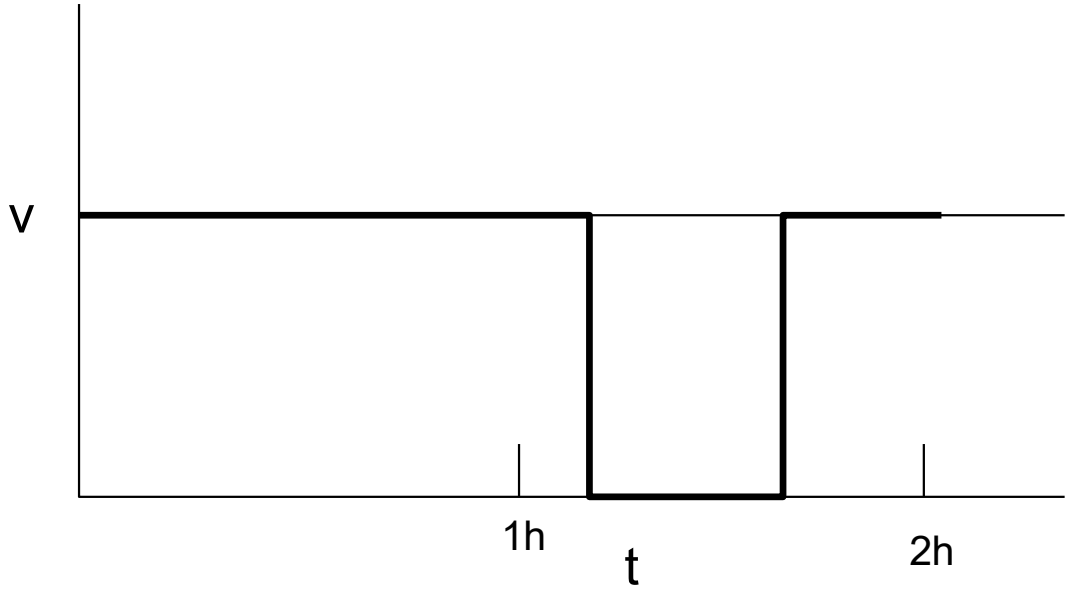
At time $t_2 = 30$ min, your position is $x_2 = 0$. So for the round trip, your displacement $\Delta x = x_2 - x_1 = 0$, and your average velocity $\bar{v} = \frac{\Delta x}{\Delta t} = 0$. However, your average speed was 40 km/h.

Classroom Exercise – Average Velocity

- Your driving across Indiana on the toll road, a total distance of 140 miles. The speed limit is 70 mph, but you have a heavy foot and always drive at 90 mph! If you take one rest stop, how long must it be so that you don't get a ticket as you exit the tollway!

A) 7 min; B) 18 min; C) 27 min; D) 40 min; E) 47 min.





Average Velocity & Average Speed

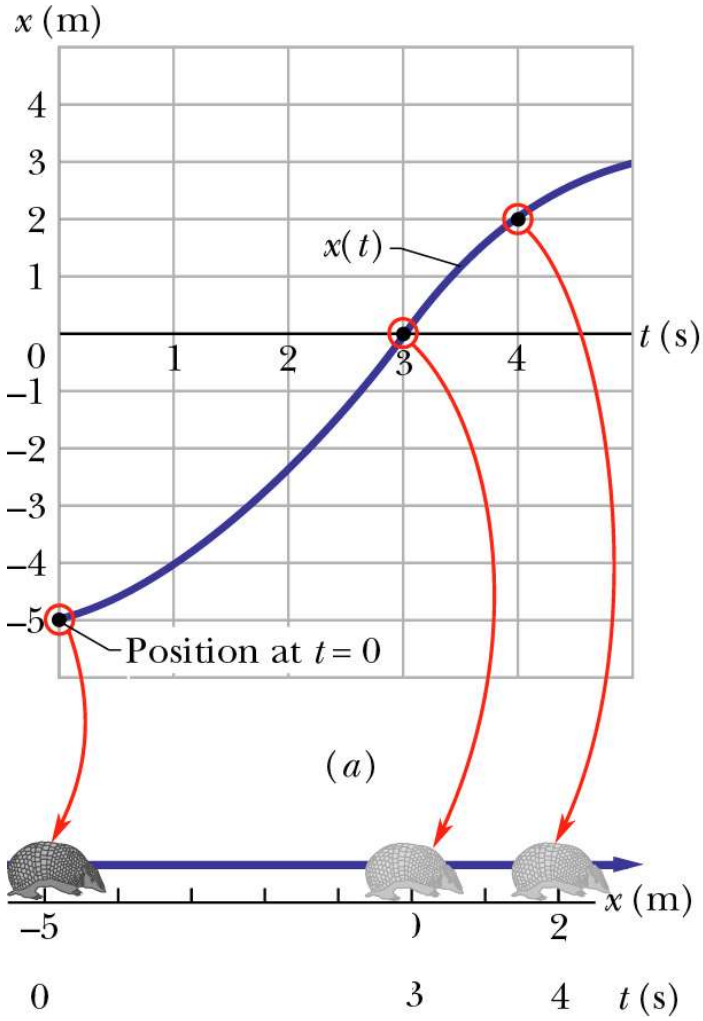
Average Velocity = ratio of the displacement to the time interval:

$$V_{avg} = \frac{\Delta x}{\Delta t}$$

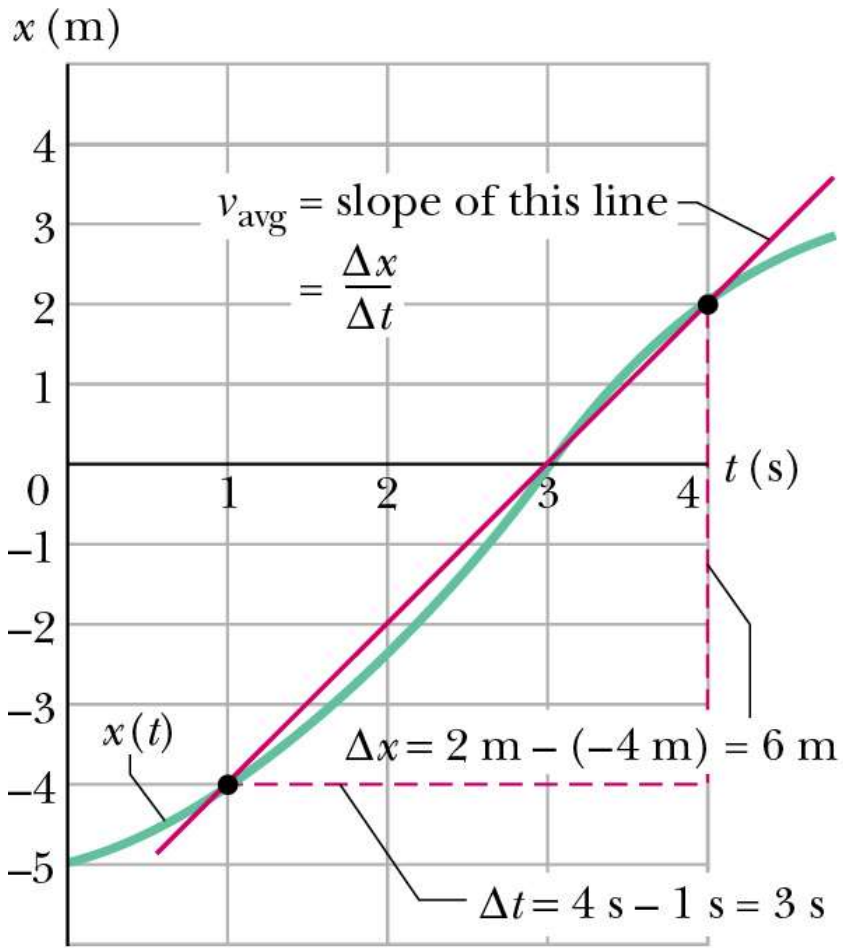
The *slope* of the straight line connecting the starting point to the end point.

Average Speed = ratio of the total distance traveled to the time interval:

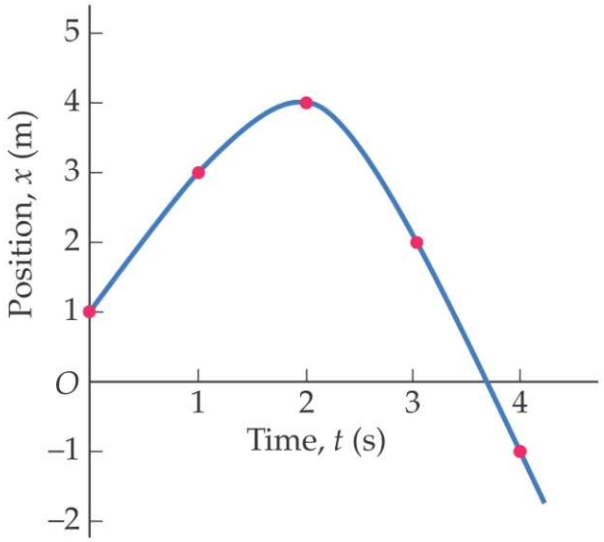
$$s_{avg} = \frac{\text{distance}}{\Delta t}$$

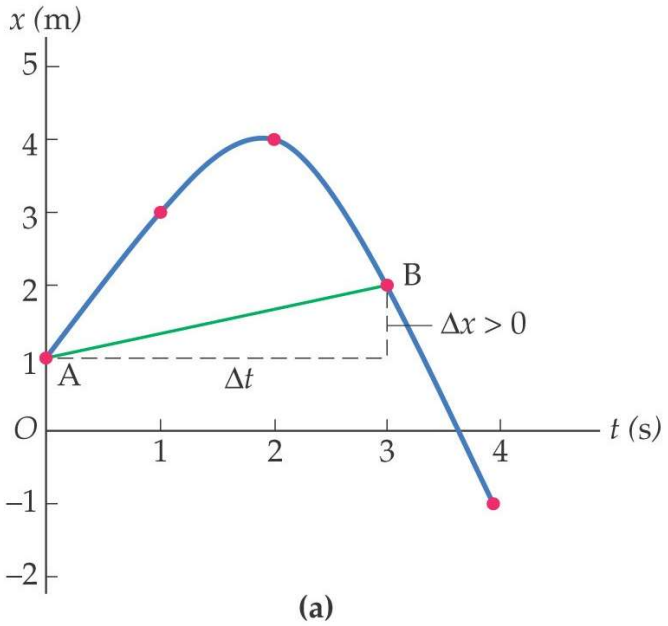


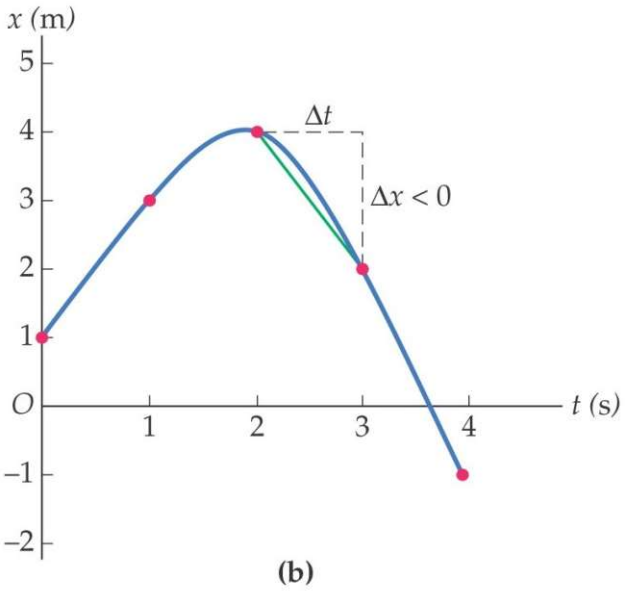
Average Velocity



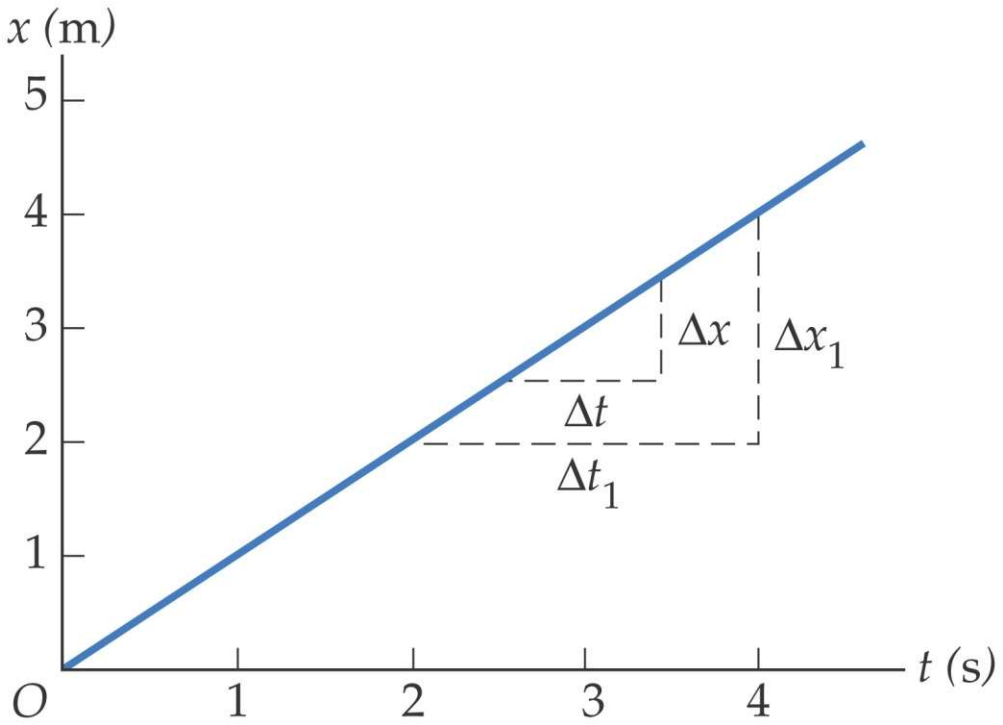
Position vs Time graphs





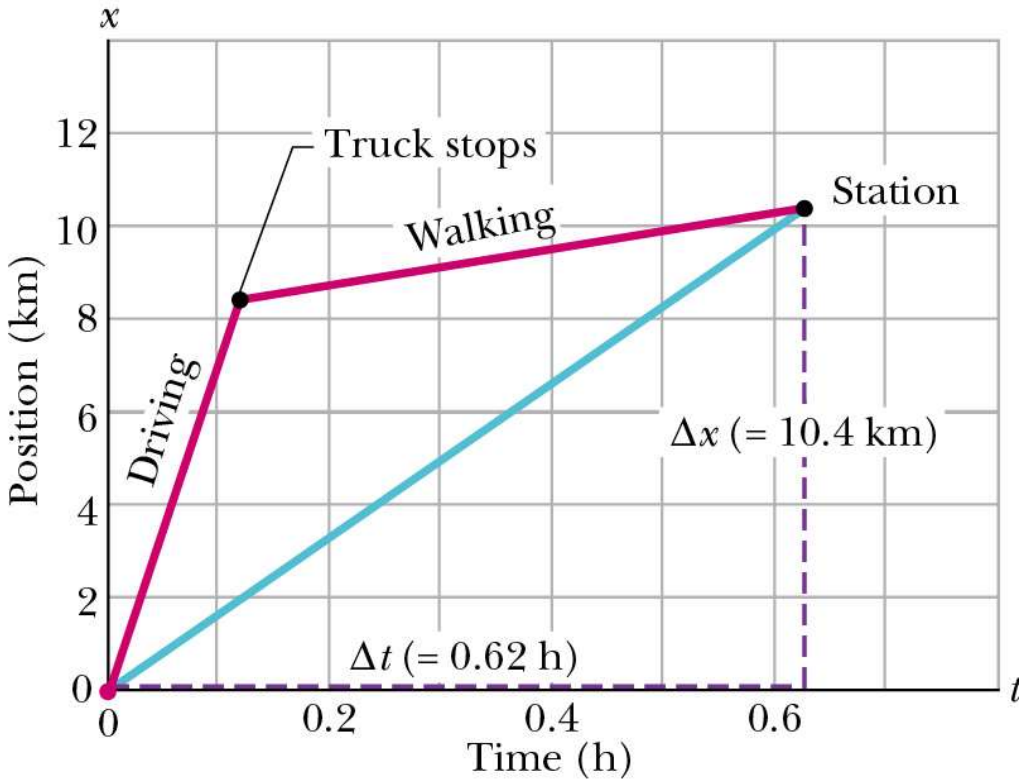


Constant Velocity on an x-Versus-t Graph



Sample Problem

Drive 8.4 km @ 70 km/h
Walk 2 km in 30 min
Get gas & walk back in 45 min.



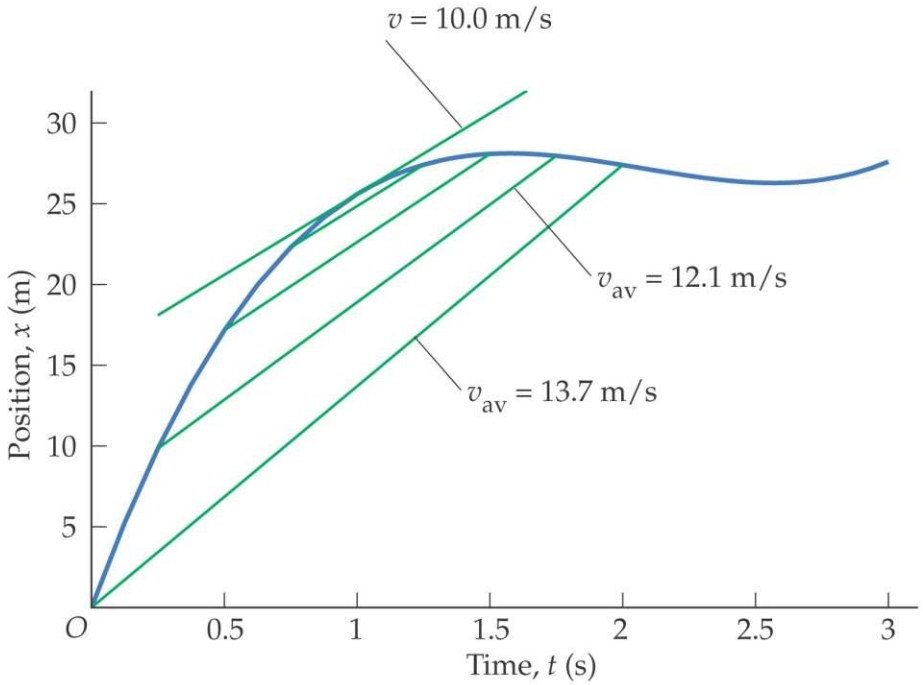
(a) Displacement to station?

(b) Time interval Δt?

(c) $V_{avg.}$ to station?

(d) $s_{avg.}$ Total (start-car)?

Instantaneous Velocity



- Define "instantaneous velocity"
  - –measure of velocity over a very short period of time:
    - $\mathbf{v} \sim \mathbf{v}_{avg} = \Delta\mathbf{v} / \Delta t$ for sufficiently small Δt
    - $\mathbf{v} = \lim (\Delta t \rightarrow 0)\ \Delta\mathbf{x}/\Delta t$

Acceleration

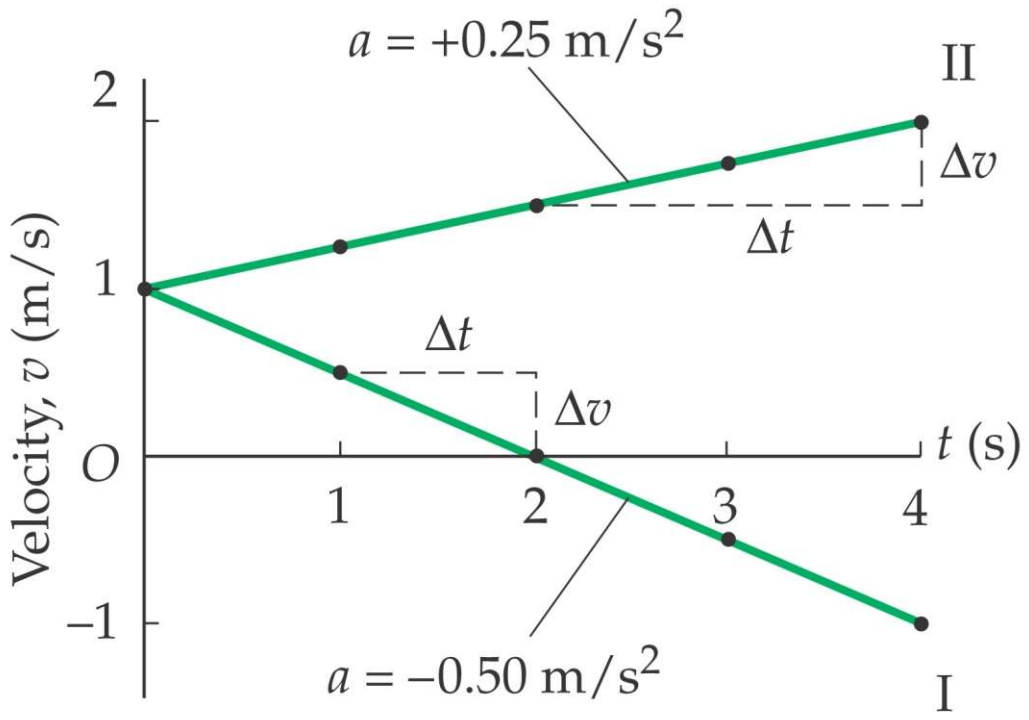
- What if the velocity changes with time:
  - average acceleration = Change in velocity / Elapsed time

    $\mathbf{a}_{avg} = (\mathbf{v} - \mathbf{v}_0) / (t - t_0) = \Delta\mathbf{v} / \Delta t$

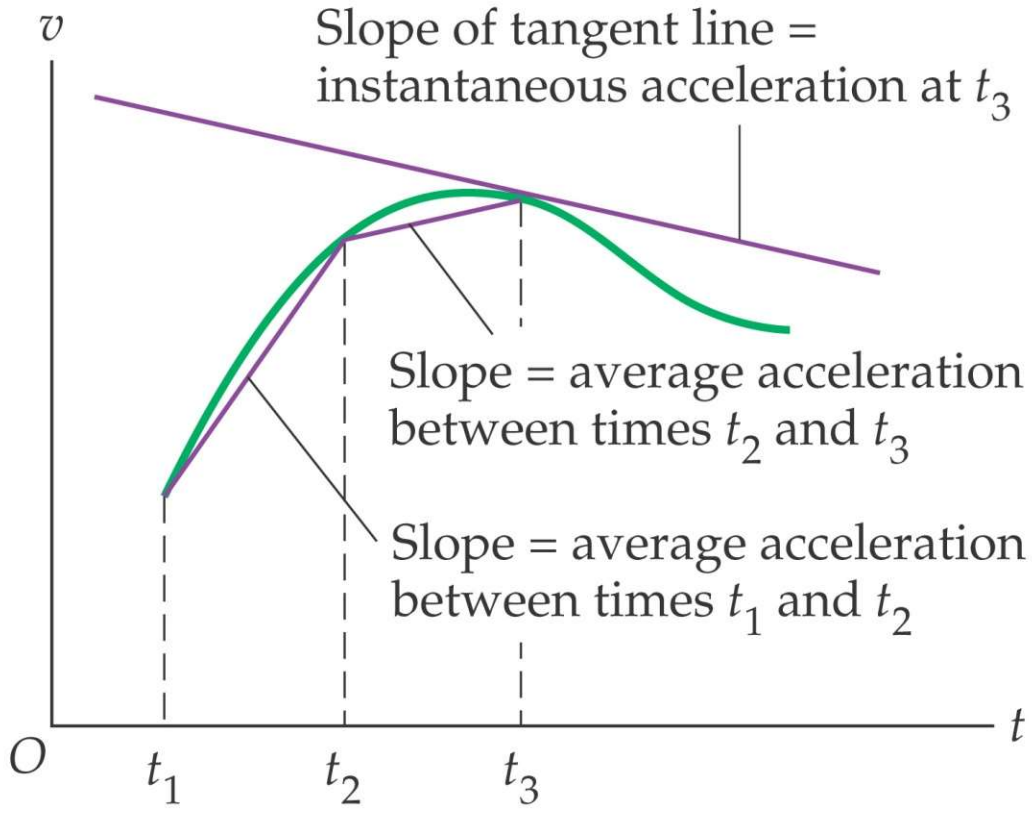
  - Instantaneous acceleration

    $\mathbf{a} = \lim (\Delta t \rightarrow 0)\ \Delta\mathbf{v}/\Delta t$

Motion with Constant Acceleration



Average and Instantaneous Acceleration



Instantaneous Velocity, Speed & Acceleration

- Instantaneous Velocity = derivative of position wrt time

$$v = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t} = \frac{dx}{dt}$$ slope of the x vs t curve

- Instantaneous Speed = magnitude of the velocity

$$speed = \left| \frac{dx}{dt} \right|$$

- Instantaneous Acceleration = derivative of velocity wrt time

$$a = \frac{dv}{dt} = \frac{d}{dt}\left(\frac{dx}{dt}\right) = \frac{d^2x}{dt^2}$$

Another Look at Constant Acceleration

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

$$dv = a\ dt$$

$$v = \int a\ dt$$

$$v = a\ t + C$$

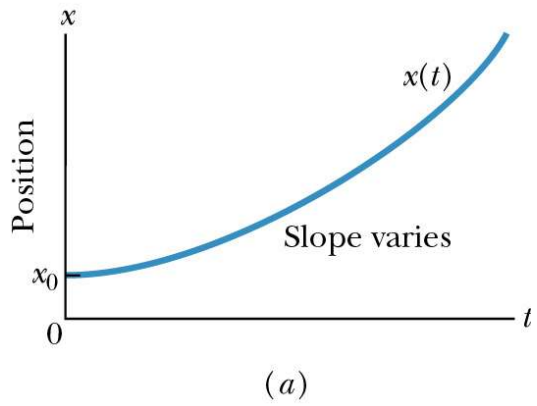
$$When\ t = 0,\ C = v_0$$

$$v = a\ t + v_0$$

Similarly: $$x = \int v\ dt$$

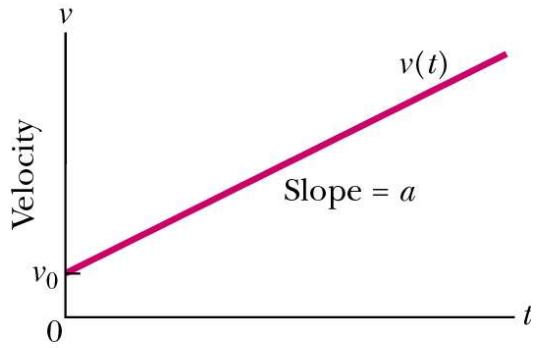
Constant Acceleration

$$x = x_0 + v_0 t + \tfrac{1}{2} a t^2$$



(a)

$$v = v_0 + at$$



(b)

$$a = \text{constant}$$

Constant Acceleration Equations

$$a = \text{constant}$$

$$v = v_0 + at$$

$$x - x_0 = v_0 t + \tfrac{1}{2} a t^2$$

A little algebra:

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

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

Equations or Constant Acceleration

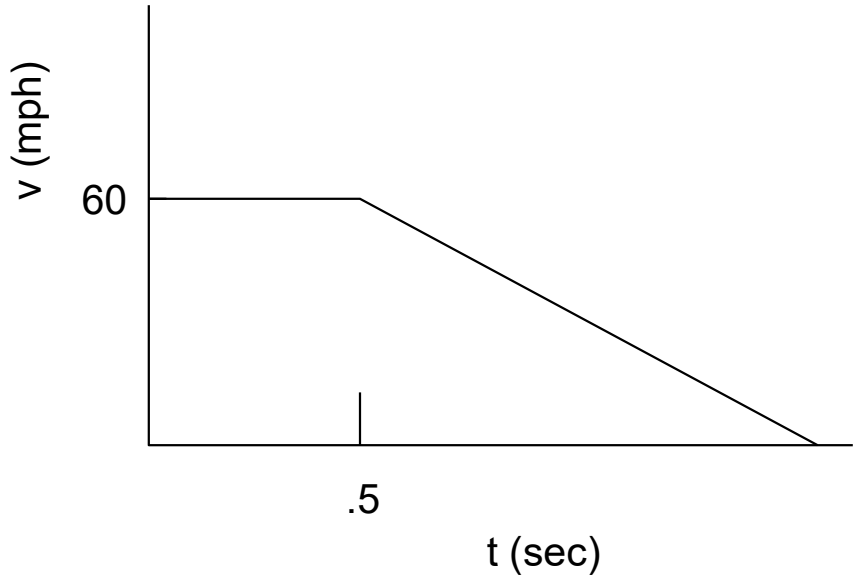
Variables Related	Equation	Number
Velocity, time, acceleration	$v = v_0 + at$	2-7
Initial, final, and average velocity	$v_{av} = \frac{1}{2}(v_0 + v)$	2-8
Position, time, velocity	$x = x_0 + \frac{1}{2}(v_0 + v)t$	2-9
Position, time, acceleration	$x = x_0 + v_0t + \frac{1}{2}at^2$	2-10
Velocity, position, acceleration	$v^2 = v_0^2 + 2a(x - x_0) = v_0^2 + 2a\Delta x$	2-11

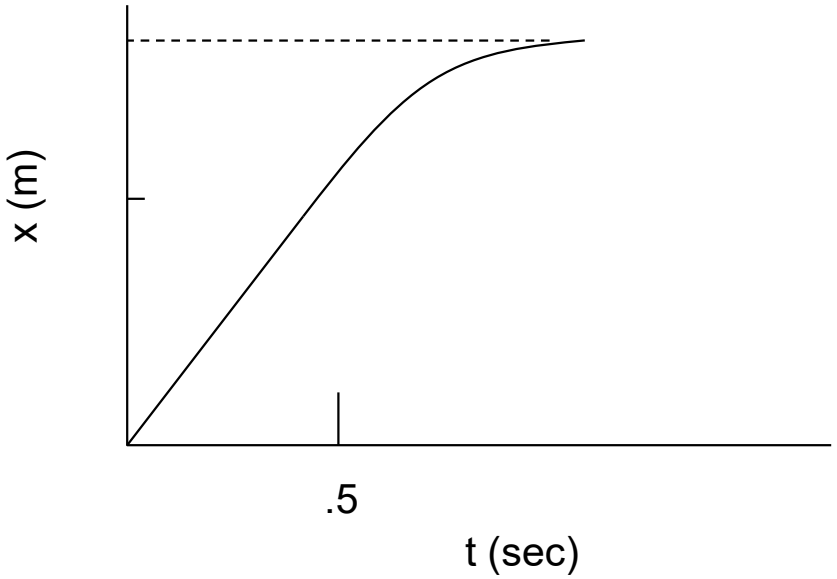
Reasoning Strategy

- Make a drawing
- Choose a coordinate system relative to a conveniently chosen coordinate origin
- Write down the values, *with the correct sign,* for any of the kinematic variables that you have been given
- Check that you have information for at least three of the variables and then select the appropriate kinematics equation. Remember that motion of two objects may be interrelated so that only two variables may be given for one part of the problem.
- When the motion is divided into segments, remember the the final velocity of segment 1 is the intial velocity of segment 2
- Remember that there can be two possible answers to a kinematics problem. understand the different physical situations to which the answers apply

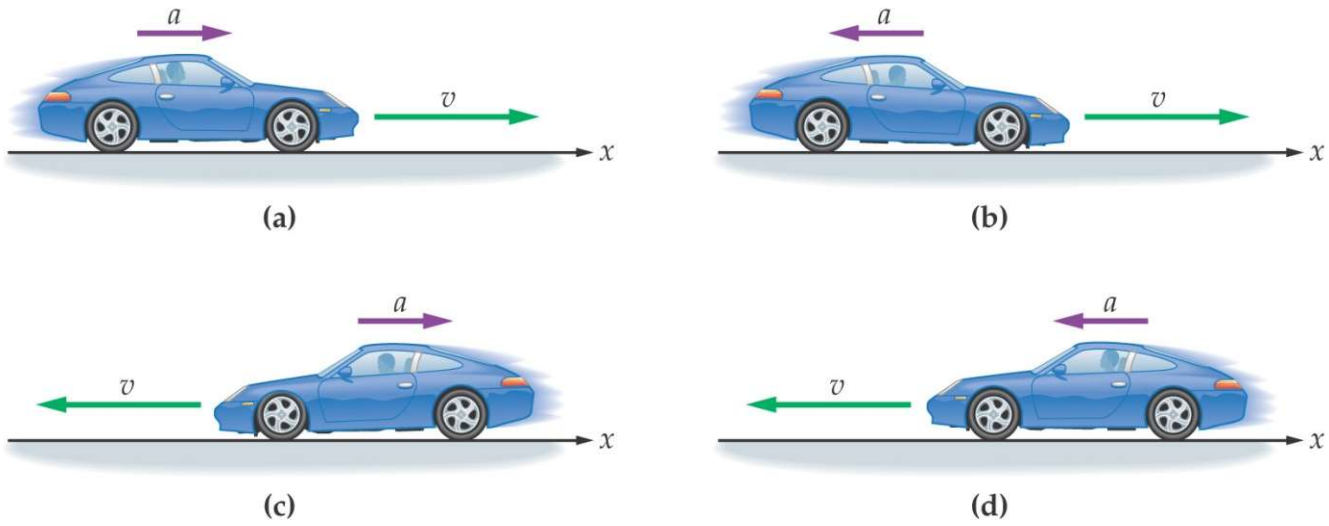
Example

- You are driving at 60 mph and see an accident ahead. It takes you 0.5 seconds to apply your breaks and the car the decelerates at – 10m/s^2. How far, in meters, will the car travel between when you see the accident and when you stop.

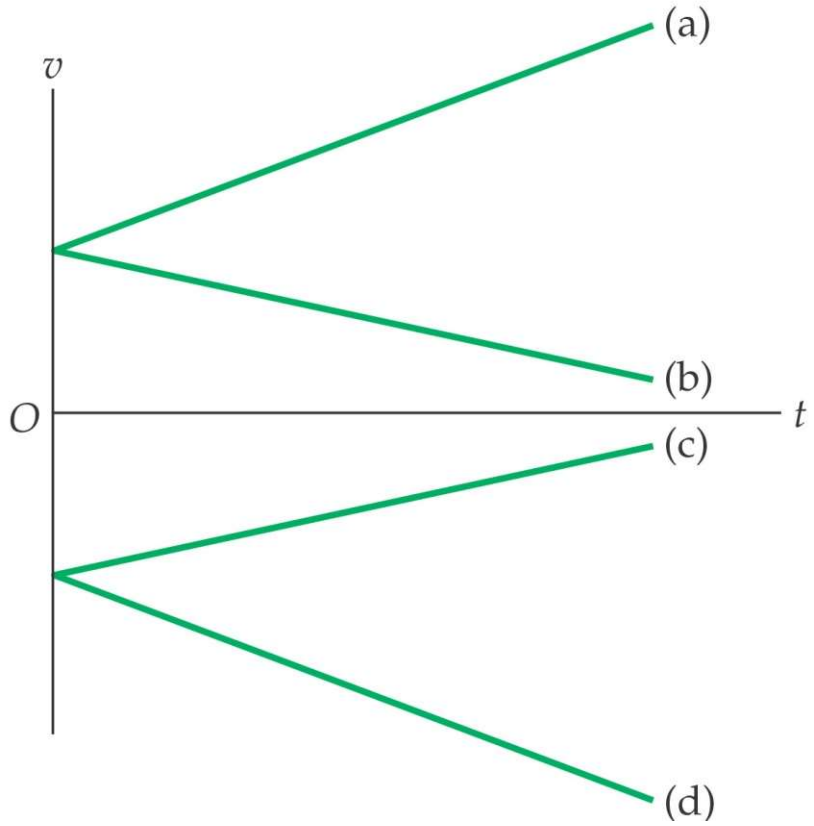




Cars Accelerating or Decelerating

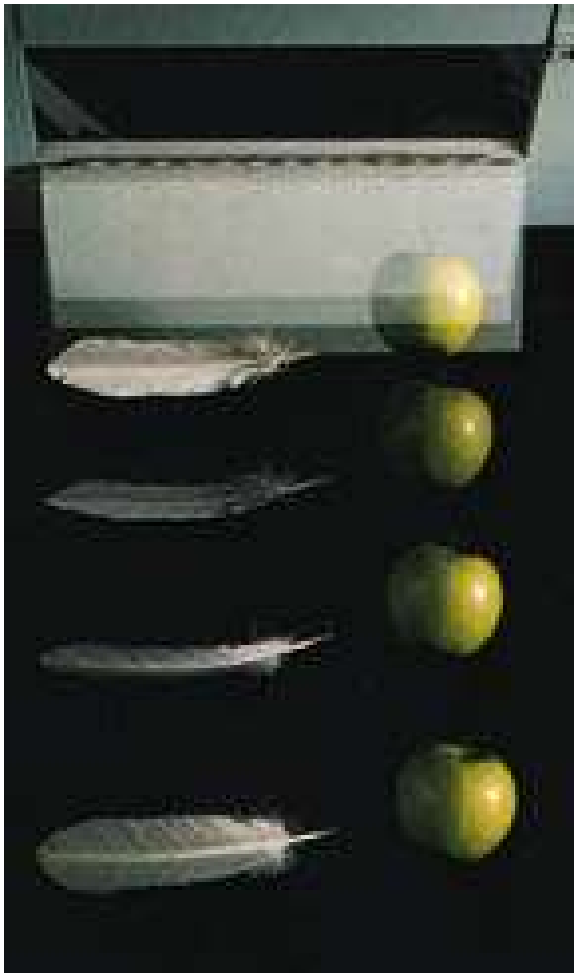


v-Versus-*t* Plots with Constant Acceleration



Free Fall

Accelerating
feathers and apples
in a vacuum!



Free Fall

$a = g = -9.81\ m/s^2$

$$v = v_0 + gt$$

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

A little algebra:

$$v^2 = v_0^2 + 2g(x - x_0)$$

$$x = x_0 + \tfrac{1}{2}(v + v_0)t$$

$$x = x_0 + vt - \tfrac{1}{2} g t^2$$

Free-Fall Acceleration

$$a = \text{constant} = g$$

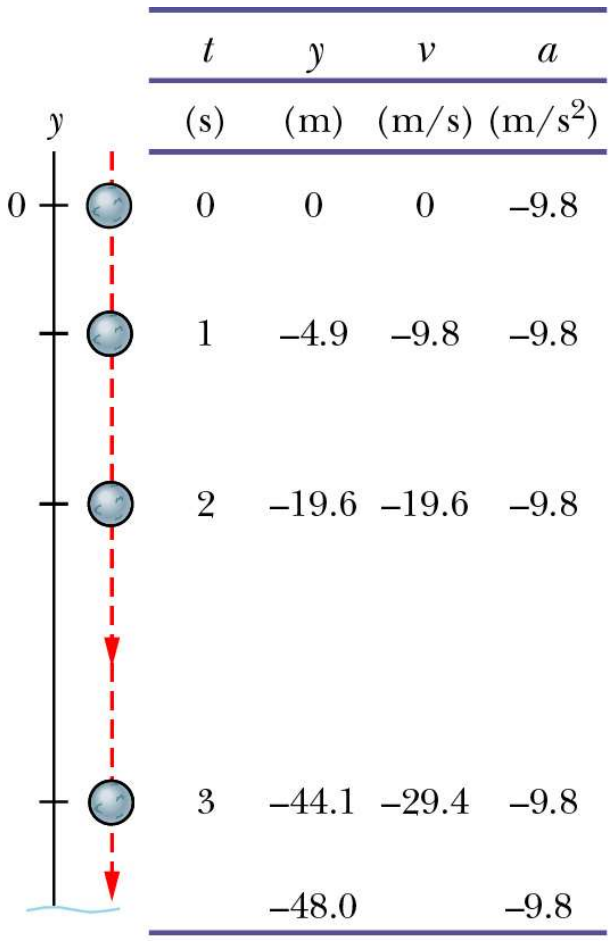
g is the acceleration due to gravity near the earths surface:

$$g = -9.8\ {}^{m}/_{s^2}$$

$$y_0 = v_0 = 0$$

$$v = gt$$

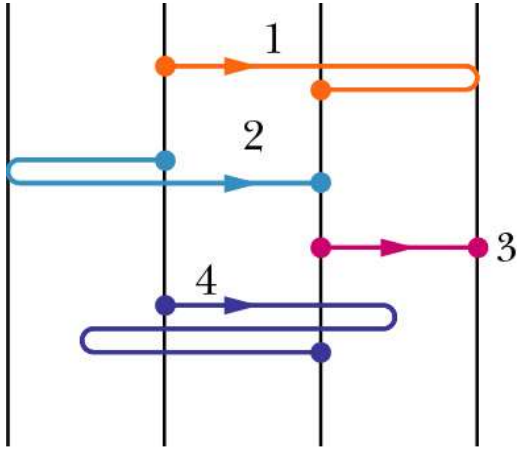
$$y = \tfrac{1}{2} g t^2$$



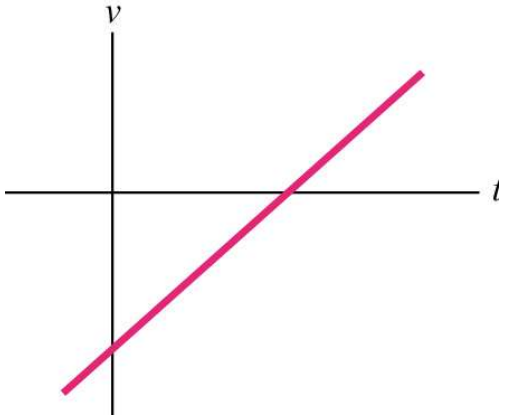
t (s)	y (m)	v (m/s)	a (m/s^2)
0	0	0	–9.8
1	–4.9	–9.8	–9.8
2	–19.6	–19.6	–9.8
3	–44.1	–29.4	–9.8
	–48.0		–9.8

Questions

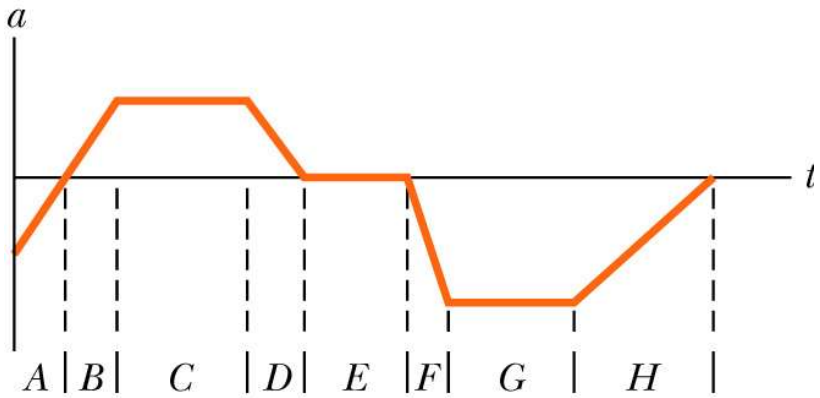
All paths take same time.
Rank according average velocity,
Average speed with greatest first



What are a) initial and b) final direction of travel? Does particle stop? Acceleration + or -, constant or varying?

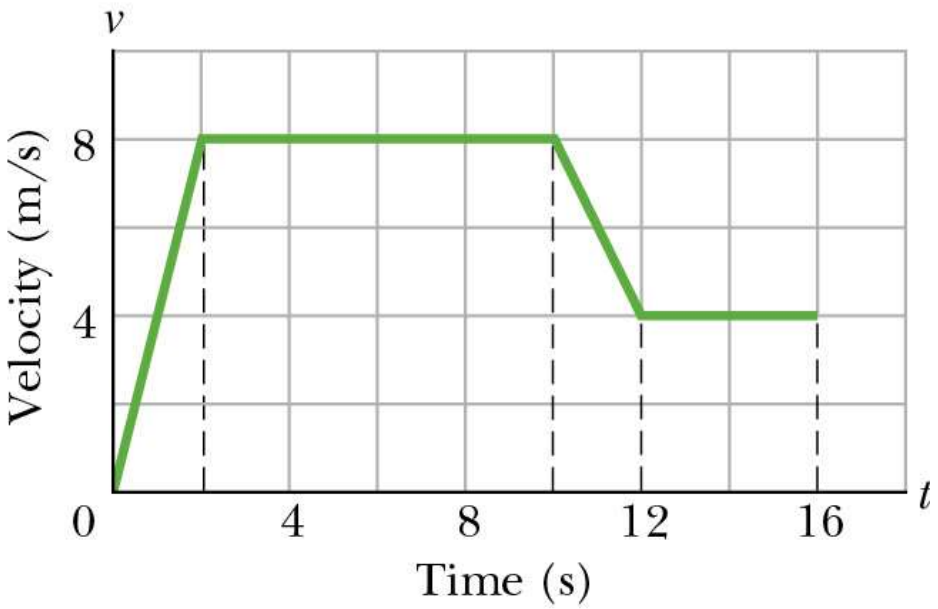


Which time periods are for a constant speed

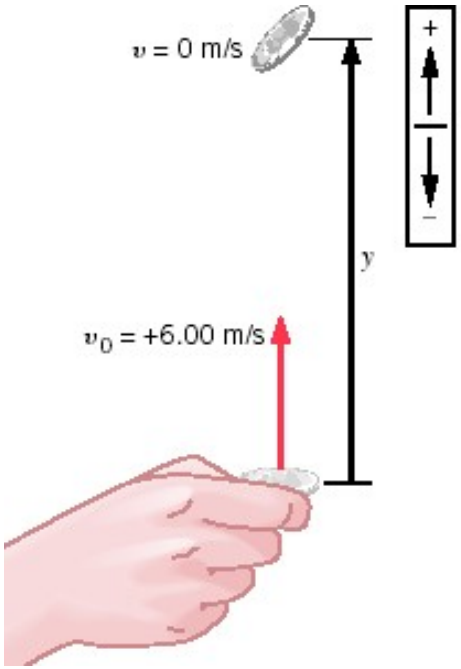


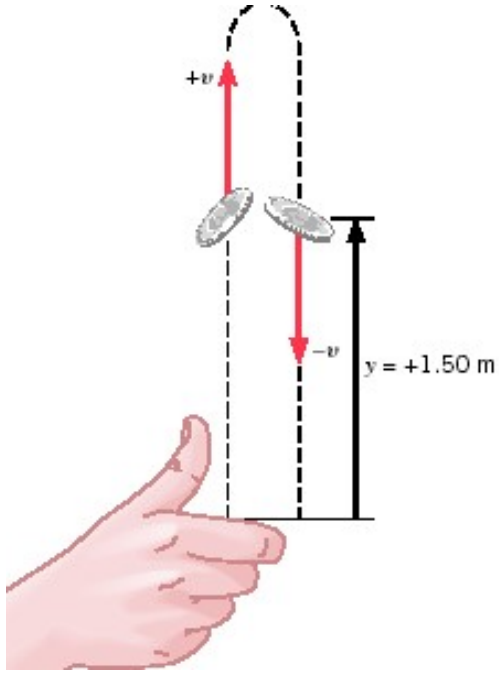
Class Problem

How far does the runner travel in 16s?



Coin Toss

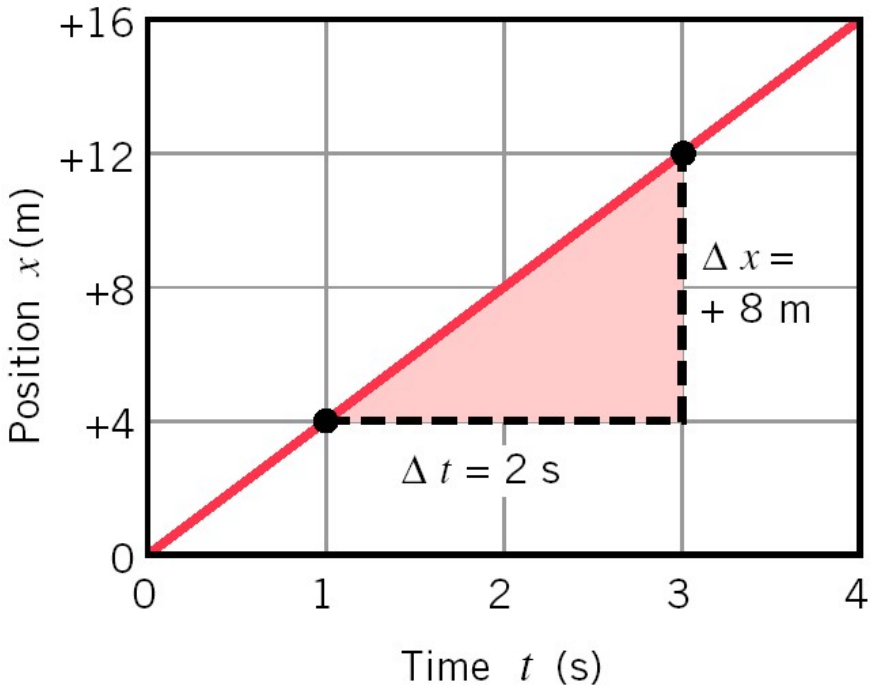




How high does it go
How long is it in the air

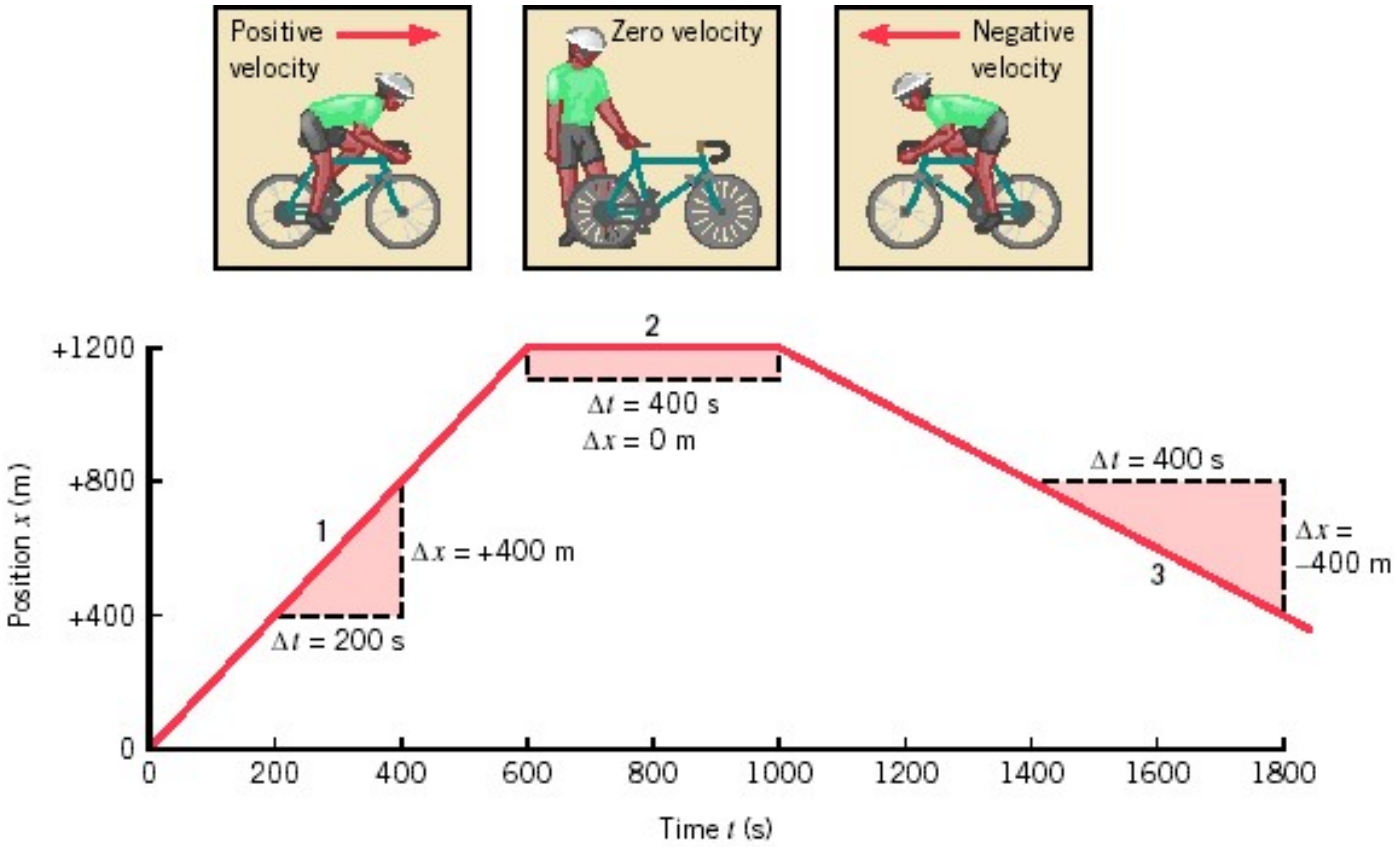
How does its velocity change over its trip
How does its acceleration change
Symmetry in these kinds of problems
- time up = time down
- velocity (y) up = - velocity (y) down

Graphical Analysis (Lab 1)



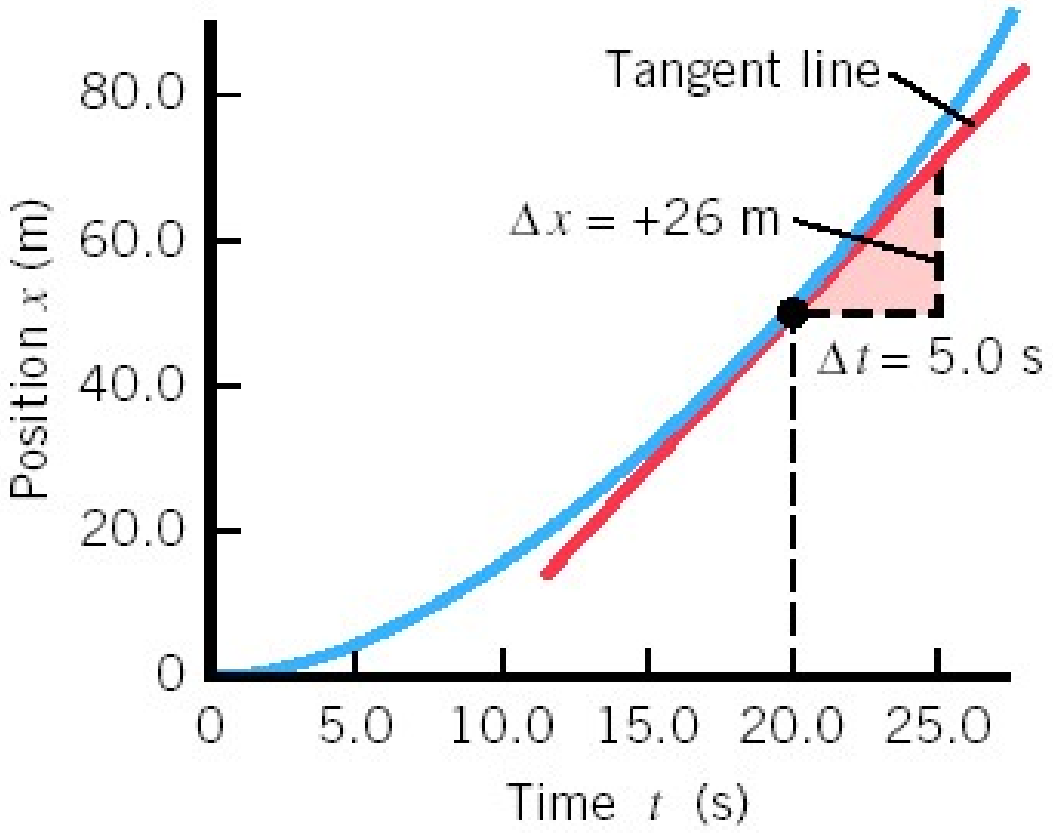
Slope = Dx / Dt = +8m/2s = +4 m/s
Slope = tangent of curve

Position, Time, and Velocity



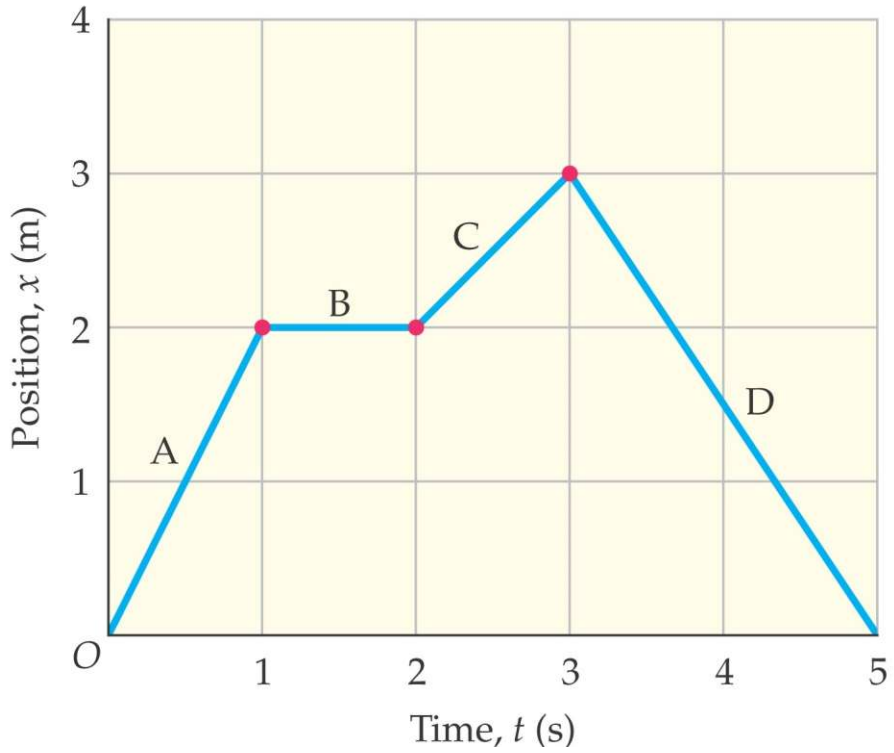
What are the velocities for each stage of this trip?

Velocity with Acceleration

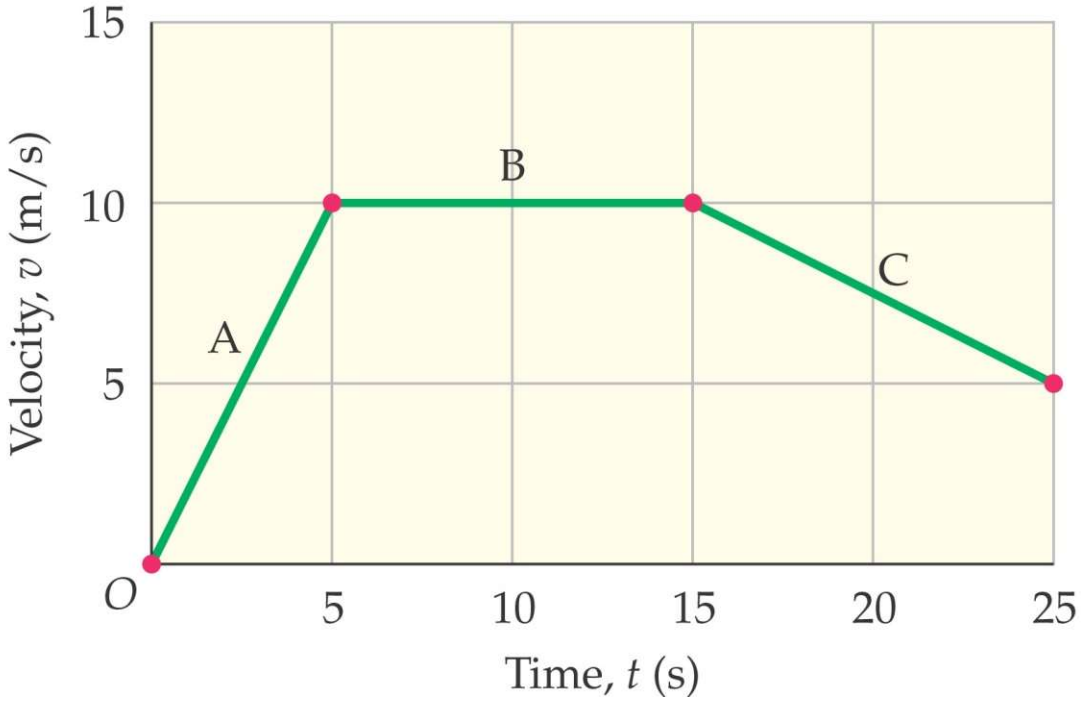


instantaneous velocity = slope of curve at any point

What is velocity in intervals A, B, C, D

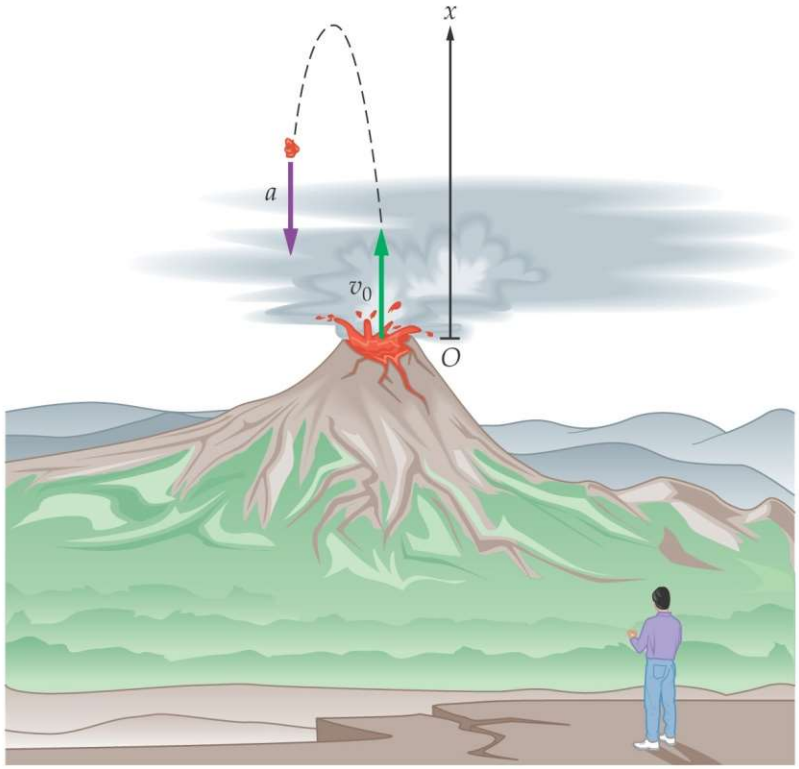


What is Acceleration in Intervals A, B, C

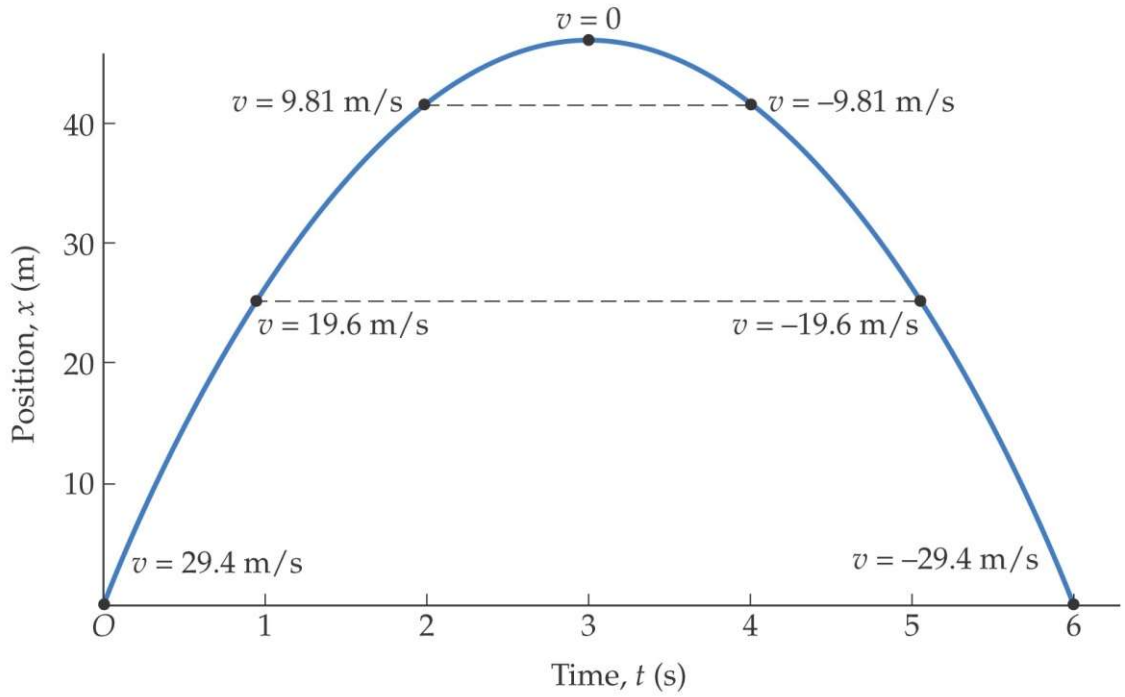


Bombs Away: Calculating the Speed of a Lava Bomb

v_0 = 29 m/s



Position and Velocity of a Lava Bomb



Velocity and Acceleration of a Lava Bomb as Functions of Time