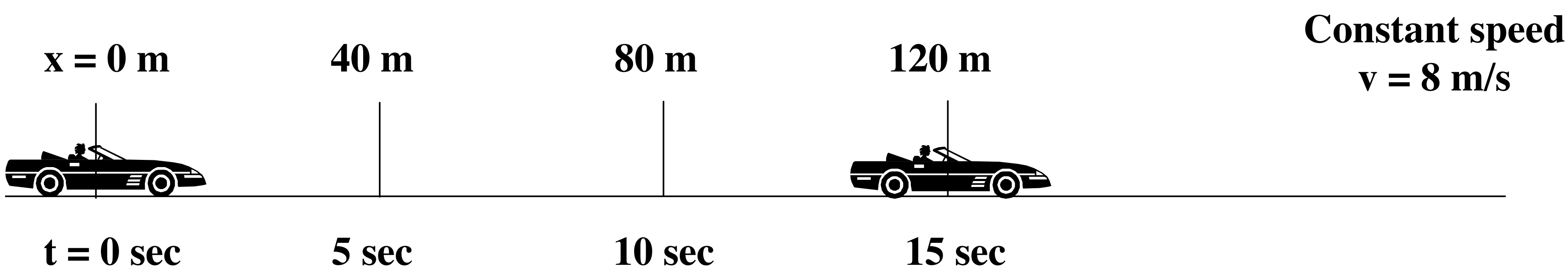
Examples of Linear Motion

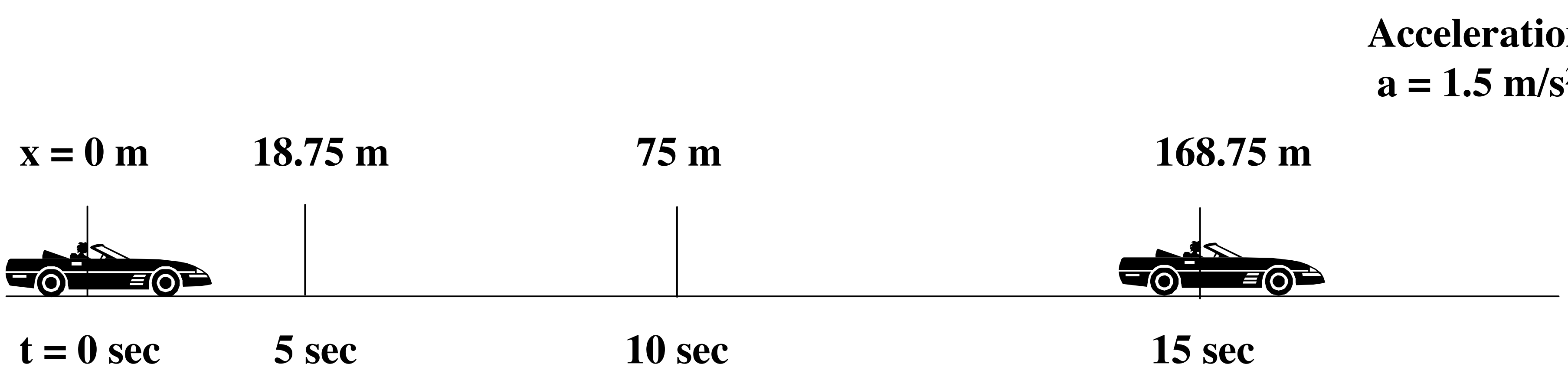
- **Horizontal motion**
  - **Constant Speed**
  - **Acceleration**

- **Vertical Motion (in a gravitational field)**

Linear Motion - Horizontal

Consider the distance traveled by two cars - one traveling at a constant speed and the other accelerating from rest. Graphing techniques allow us the characterize the behavior of each car.





Linear Motion - Constant Speed

Time (sec)	Car 1 (meters)
0	0
1	8
2	16
3	24
4	32
5	40
6	48
7	56
8	64
9	72
10	80
11	88
12	96
13	104
14	112
15	120

For a car moving at a constant speed, the distance covered is the same for each equally spaced time interval.

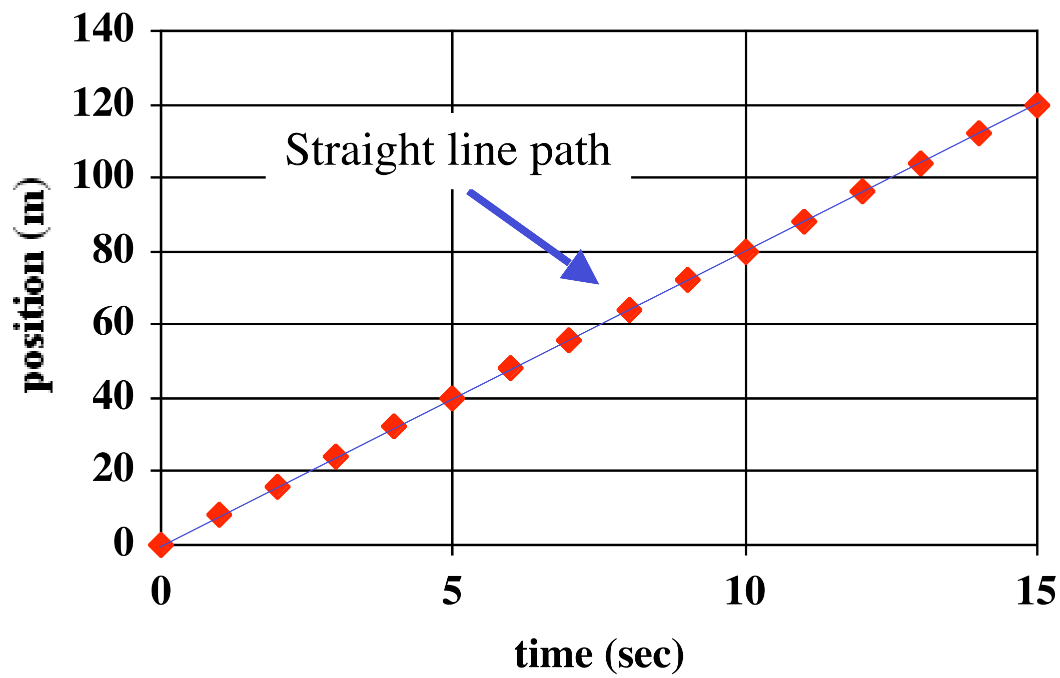
t = 0 sec to t = 1 sec: $\Delta x = 8$ m

t = 9 sec to t = 10 sec: $\Delta x = 8$ m

KEY Equation:

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

0



Linear Motion - Acceleration

For a car that is accelerating, the distance traveled by the car increases during each time interval (say 1 sec).

Time (sec)	Car 1 (meters)
0	0 ←
1	0.75 ←
2	3
3	6.75
4	12 ←
5	18.75 ←
6	27
7	36.75
8	48
9	60.75 ←
10	75 ←
11	90.75
12	108
13	126.75
14	147
15	168.75

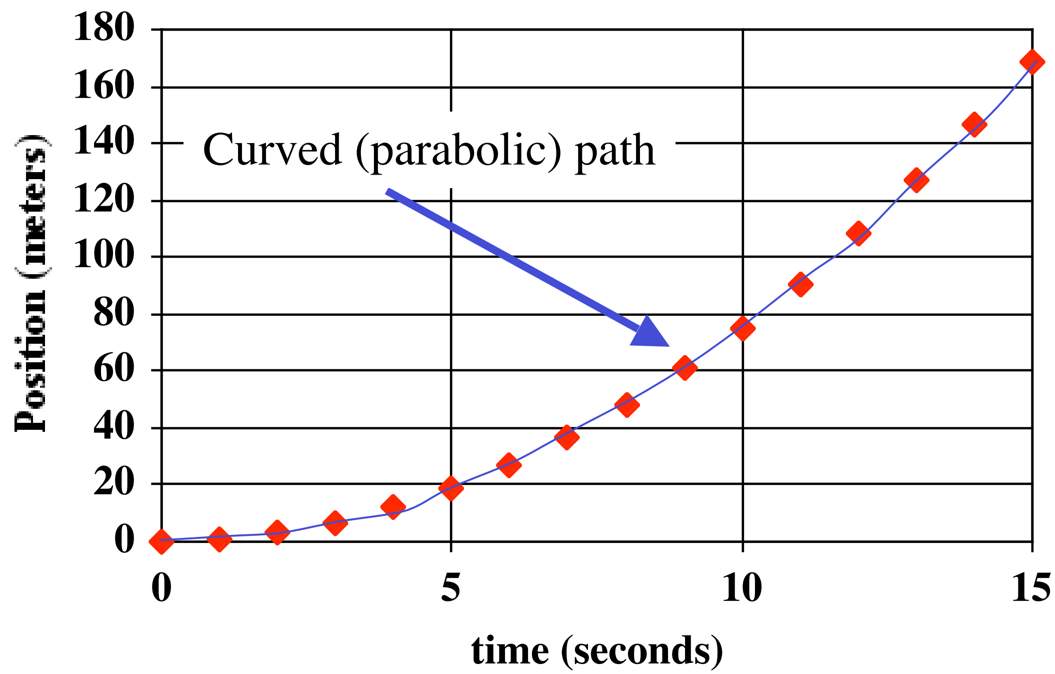
t = 0 sec to t = 1 sec: $\Delta x = 0.75$ m

t = 4 sec to t = 5 sec: $\Delta x = 6.75$ m

t = 9 sec to t = 10 sec: $\Delta x = 14.75$ m

KEY Equation:

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



Key Results:
Horizontal Motion

Constant Speed:

- Object does not increase or decrease speed
- For equal time intervals, the distance traveled is the same
- Position changes linearly with time

Acceleration:

- Speed of object is changing (increasing OR decreasing)
- For equal time intervals, the distance traveled is NOT the same
- Position changes NON-LINEARLY with time

Examples

1. A person driving a car is initially traveling at 20 m/s when they see a cat crossing the road about 55 m in the distance. After an initial delay of 1 second, the person hits the brakes and the car stops just before hitting the cat.

   Find the total time needed to stop the car, the distance traveled by the car, and the acceleration of the car.

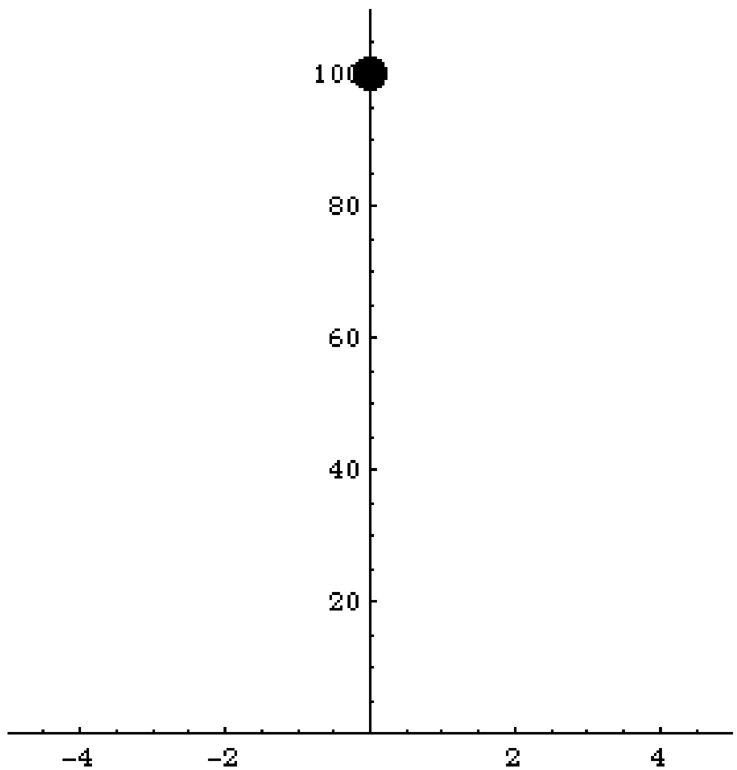
2. A speeding car traveling at a constant 30 m/s when it passes a police car. Five seconds later, the police car begins giving chase to the speeder with a constant acceleration of 1.2 m/s^2.

   Find the total time and total distance needed for the police car to catch up to the speeder.

Vertical Motion
(in a gravitational field)

Problem One - **FREE FALL**:

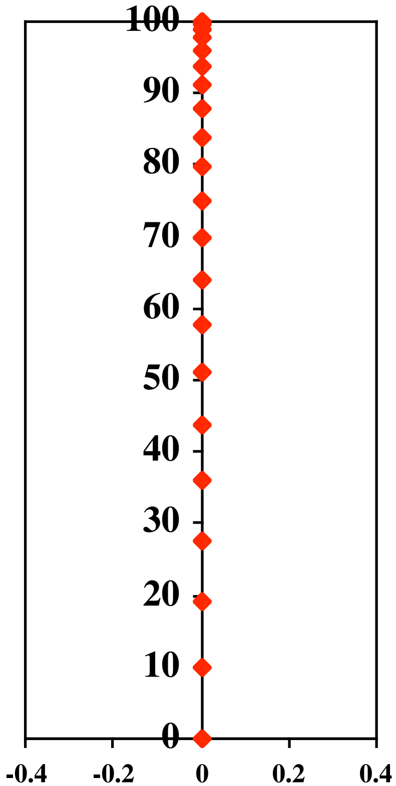
What is the motion of a dropped object (from rest) that falls to the ground?



Dropped ball

As the ball starts to fall, the change in its position is small.

As it accelerates, due to gravity **($a = -g = -9.8\ m/s^2$)** its speed begins to increase and it vertical position begins to change even more rapidly.



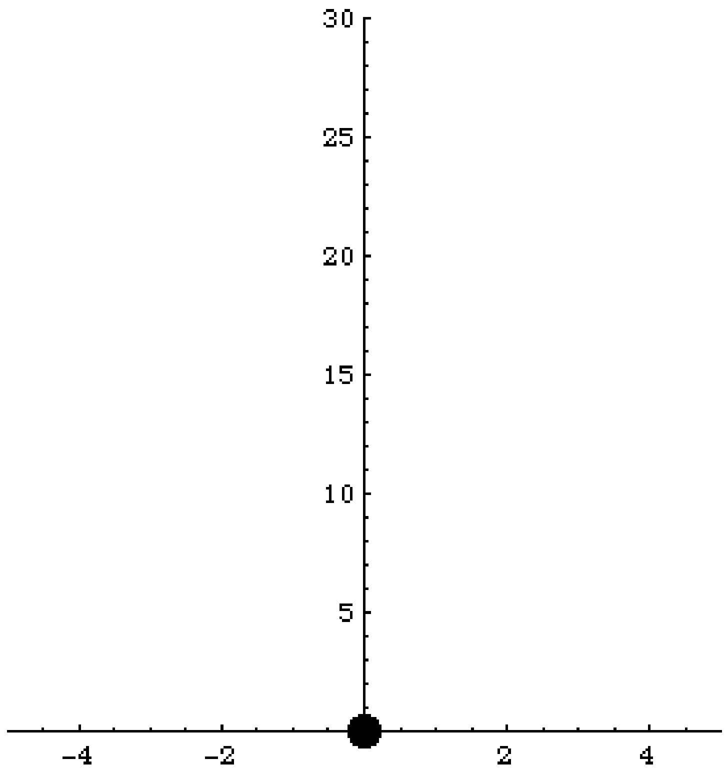
Vertical position of the ball as it falls - the greater the spacing between the points, the faster the ball is moving.

Problem: A ball is dropped from rest a height of 100 m. How long will it take the ball to hit the ground? What is the speed of the ball when it reaches the ground?

Vertical Motion

Problem Two:

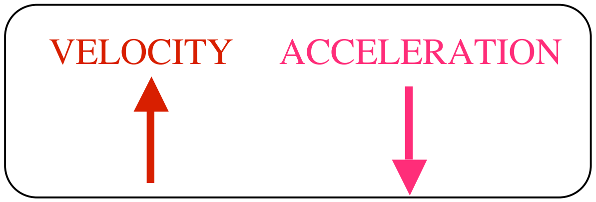
What is the motion of an upwardly thrown object?



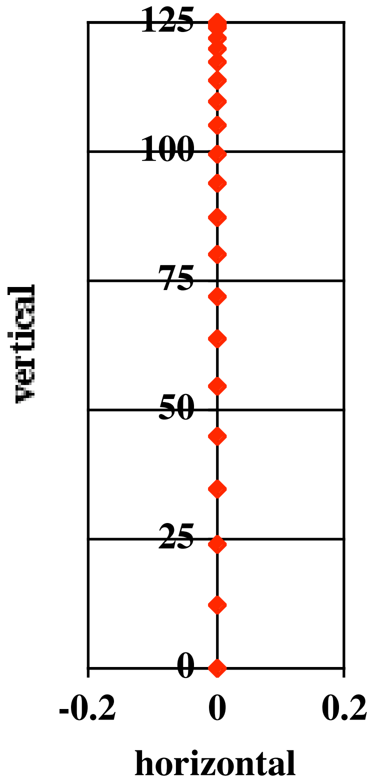
Break problem into two pieces:

Upward Motion

Downward Motion



Upward Motion

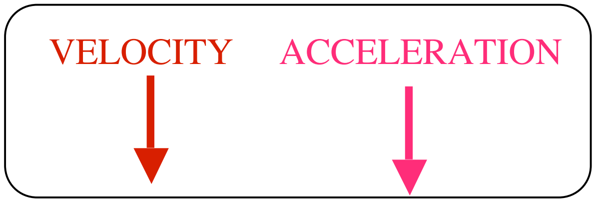


During the upward part of the motion, the velocity is UPWARD, but the acceleration is DOWNWARD (due to gravity).

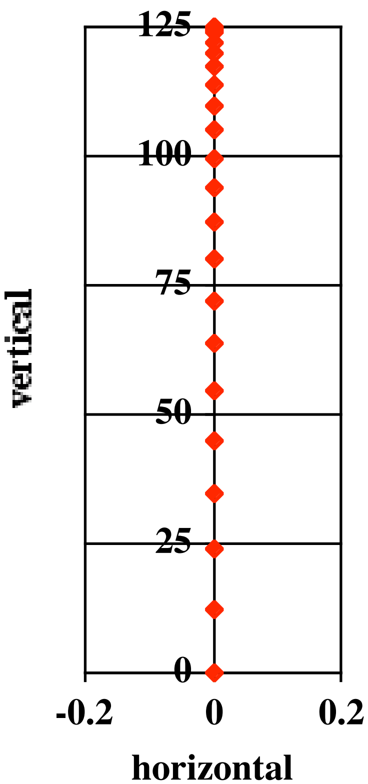
As a result of the downward acceleration, the particle SLOWS as it moves upward

IMPORTANT:

Vertical velocity at the maximum height is **ZERO!!**



Downward Motion



During the downward part of the motion, the velocity is DOWNWARD, **and** the acceleration is DOWNWARD (due to gravity).

As a result of the downward acceleration, the particle MOVES FASTER as it falls.

Problem: A ball is thrown upward at an initial speed of 15 m/s. Find: (a) maximum height, (b) total time in the air, (c) final velocity just before hitting the ground.