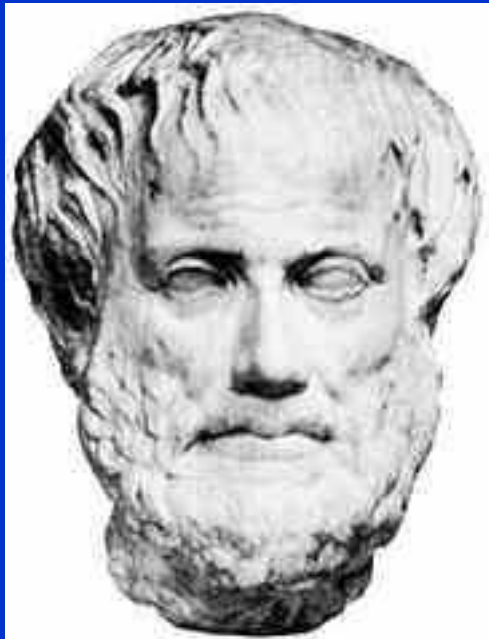
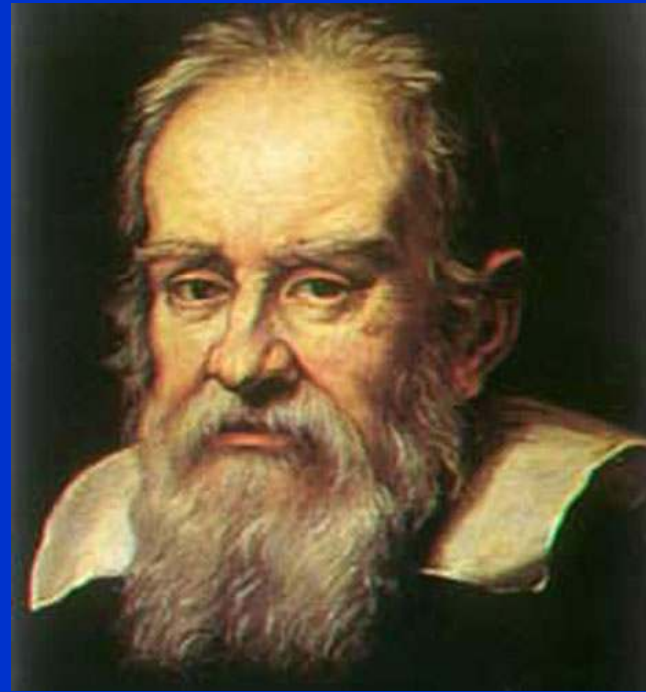


Linear Motion 1



Aristotle

384 B.C. - 322 B.C.



Galileo

1564 - 1642

Scalars and Vectors

- The motion of objects can be described by words such as
 - distance, displacement, speed, velocity, and acceleration.

Scalars

Vectors

Scalars & Vectors

Scalars: fully described by magnitude (or size) alone. That is, direction is not involved.

- o distance, speed, mass, temperature

- o 3m, 5 m/s, 60 kg, 5°C

- **Vectors** are quantities fully described by both magnitude (size) and direction.

- o displacement, velocity

- o 3m, right; 5 blocks south; -2 m (the sign is the direction); 2 m/s, up

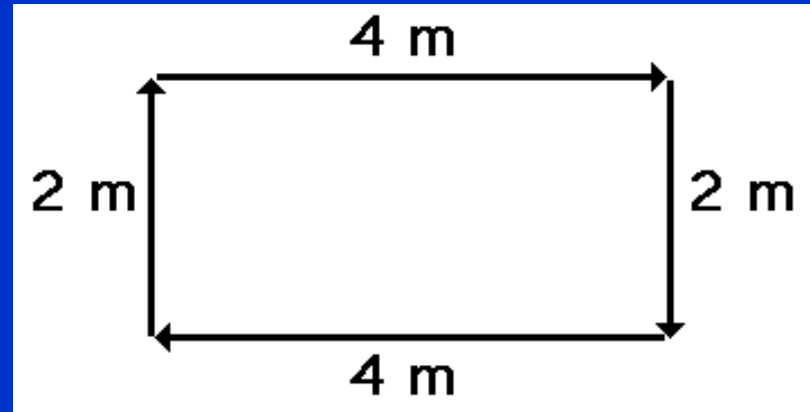
Distance and Displacement

- **Distance** is a scalar quantity referring to how far an object or person has traveled. It is the reading on a pedometer or on an odometer.
- **Displacement** is a vector quantity referring to the object's change in position. Displacement is calculated by subtracting the initial position from the final position: $X_{\text{final}} - X_{\text{initial}}$

Displacement

Example

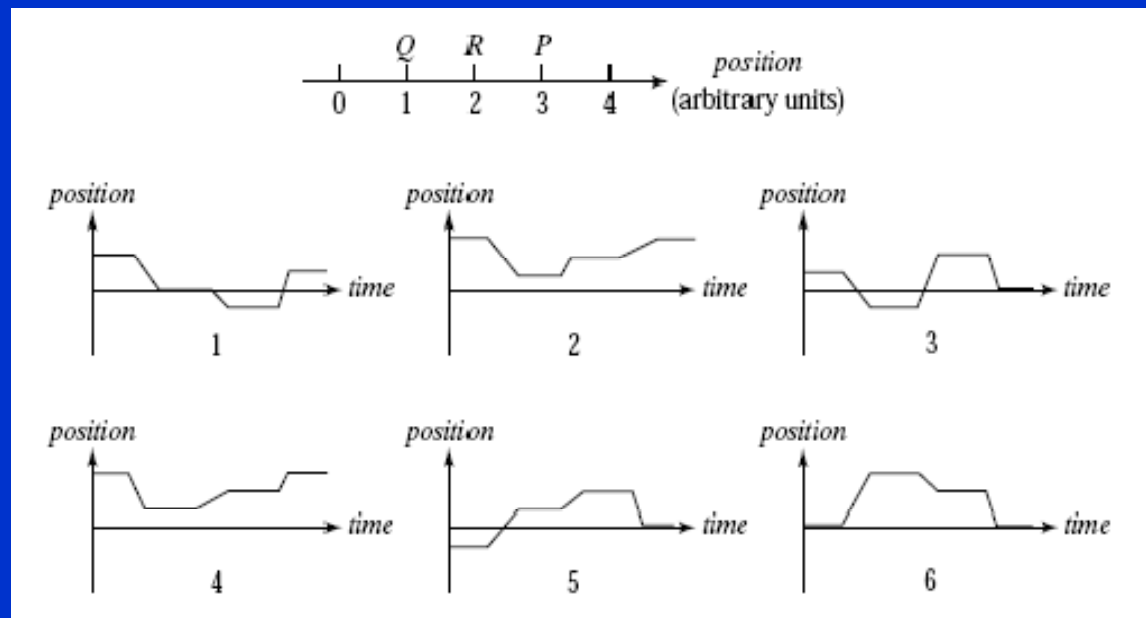
A physics teacher walks 4 meters East, 2 meters South, 4 meters West, and finally 2 meters North.



- The physics teacher has walked a total distance of
- The physics teacher's displacement is

Concept Test #1

A person initially at point P in the illustration stays there a moment and then moves along the axis to Q and stays there a moment. She then runs quickly to R , stays there a moment, and then strolls slowly back to P . Which of the position vs. time graphs below correctly represents this motion?



Concept Test #2

An object goes from one point in space to another. After it arrives at its destination, its displacement is:

1. either greater than or equal to
2. always greater than
3. always equal to
4. either smaller than or equal to
5. always smaller than
6. either smaller or larger than the distance it traveled.

Speed and Velocity

- **Speed** is a scalar quantity referring to how fast an object is moving. A fast-moving object has a high speed while a slow-moving object has a low speed. An object with no movement at all has a zero speed.
- **Velocity** is a vector quantity referring to how fast an object changes its position. Imagine a person moving rapidly - one step forward and one step back - always returning to the original starting position. This motion results in zero velocity.

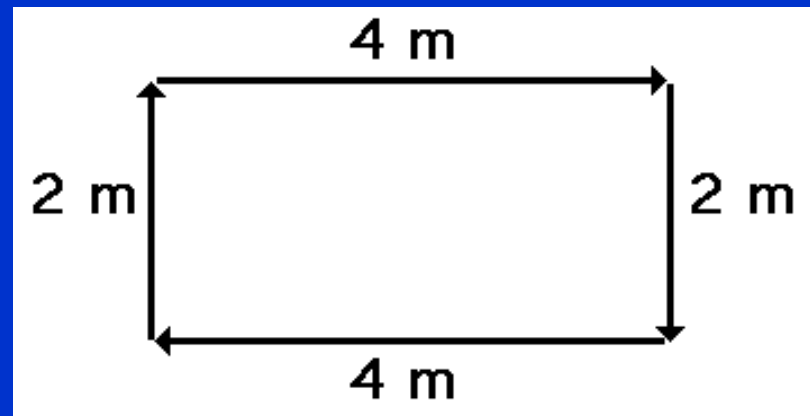
Speed & Velocity

$$\text{Average Speed} = \frac{\text{Distance Traveled}}{\text{Time of Travel}}$$

$$\text{Average Velocity} = \frac{\Delta \text{ position}}{\text{time}} = \frac{\text{displacement}}{\text{time}}$$

Velocity & Speed

- The physics teacher walks 4 meters East, 2 meters South, 4 meters West, and finally 2 meters North. The entire motion lasts 24 seconds. Determine her average speed and average velocity.



The physics teacher walked a distance of 12 meters in 24 seconds; thus, her average speed was 0.50 m/s. However, since her displacement is 0 meters, her average velocity is 0 m/s.

Instantaneous and Average

- **Instantaneous Speed** - speed at any given instant in time
 - speedometer reading
- **Average Speed** - total distance divided by total time of travel
 - rate you would have to travel constantly to cover the same distance in the same time

Constant and Changing Speed

**An object moving with
a constant speed of 6 m/s**

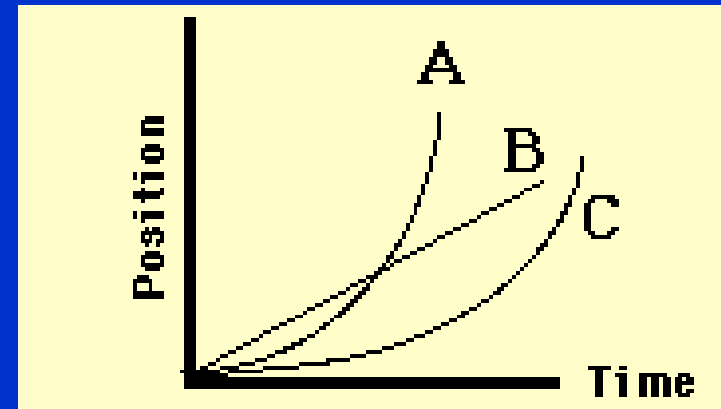
Time (s)	Position (m)
0	0
1	6
2	12
3	18
4	24

**An object moving with
a changing speed**

Time (s)	Position (m)
0	0
1	1
2	4
3	9
4	16

Acceleration

- **Acceleration** is a vector quantity defined as the rate at which an object changes its velocity. An object is accelerating if it is changing its velocity.



Accelerating Objects

Accelerating Objects are Changing Their Velocity ...

**... by a constant amount
each second ...**

Time (s)	Velocity (m/s)
0	0
1	4
2	8
3	12
4	16

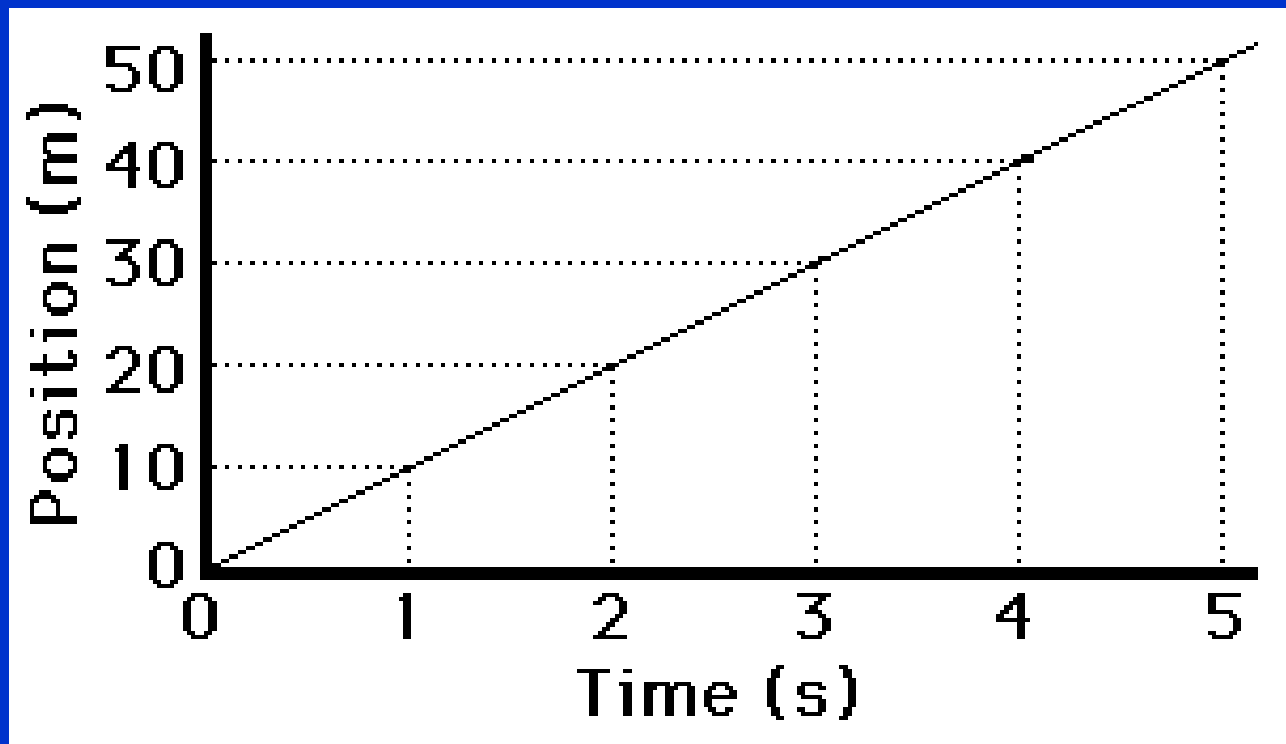
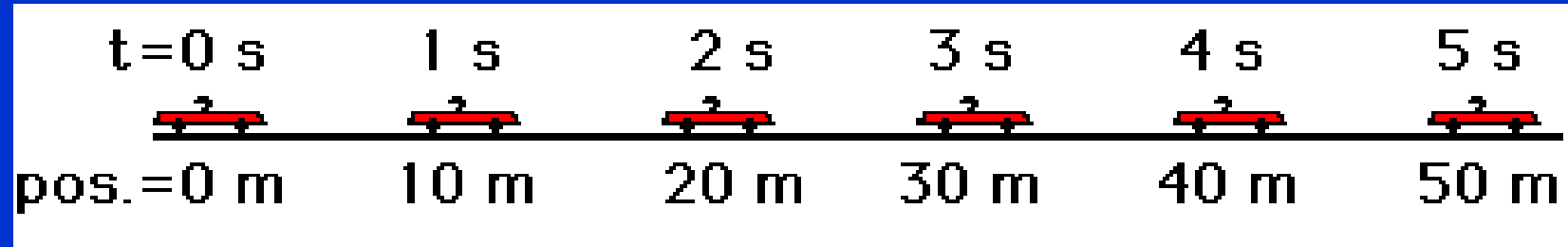
**...in which case, it is referred
to as a constant acceleration.**

**... or by a changing amount
each second ...**

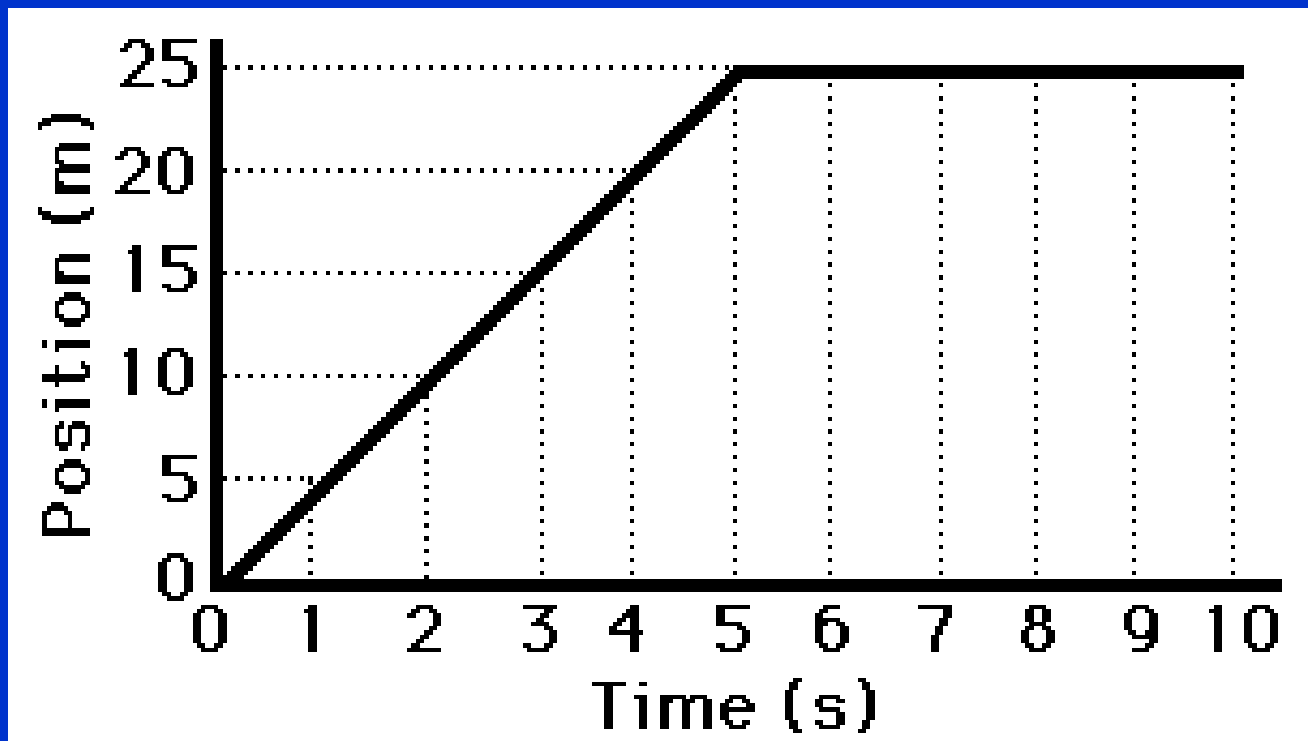
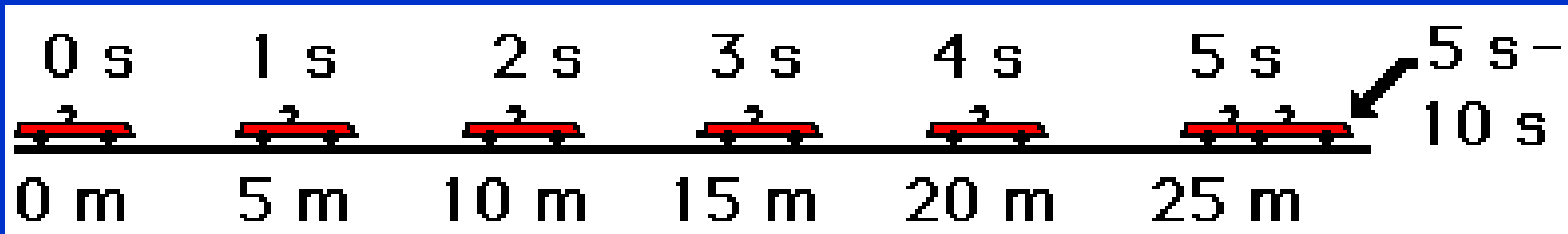
Time (s)	Velocity (m/s)
0	0
1	1
2	4
3	5
4	7

**...in which case, it is referred
to as a non-constant acceleration.**

Position - Time for Constant Velocity

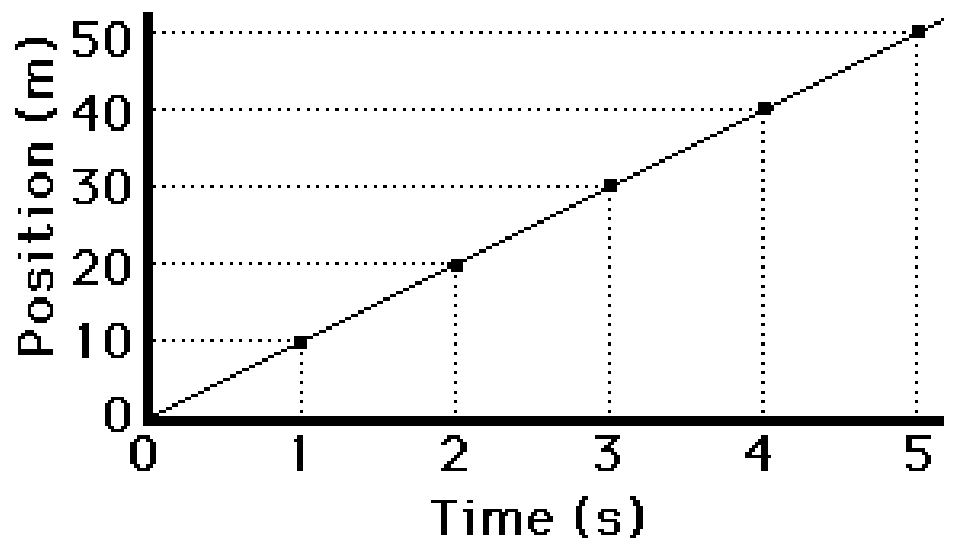


Slope of Position-Time



Slope of Position-Time Velocity

$$\text{slope} = \frac{\Delta y}{\Delta x} = \frac{y_2 - y_1}{x_2 - x_1} = \frac{\text{rise}}{\text{run}}$$



For points (5 s, 50 m) and (0 s, 0 m):

$$\text{slope} = \frac{50 \text{ m} - 0 \text{ m}}{5 \text{ s} - 0 \text{ s}} = 10 \text{ m/s}$$

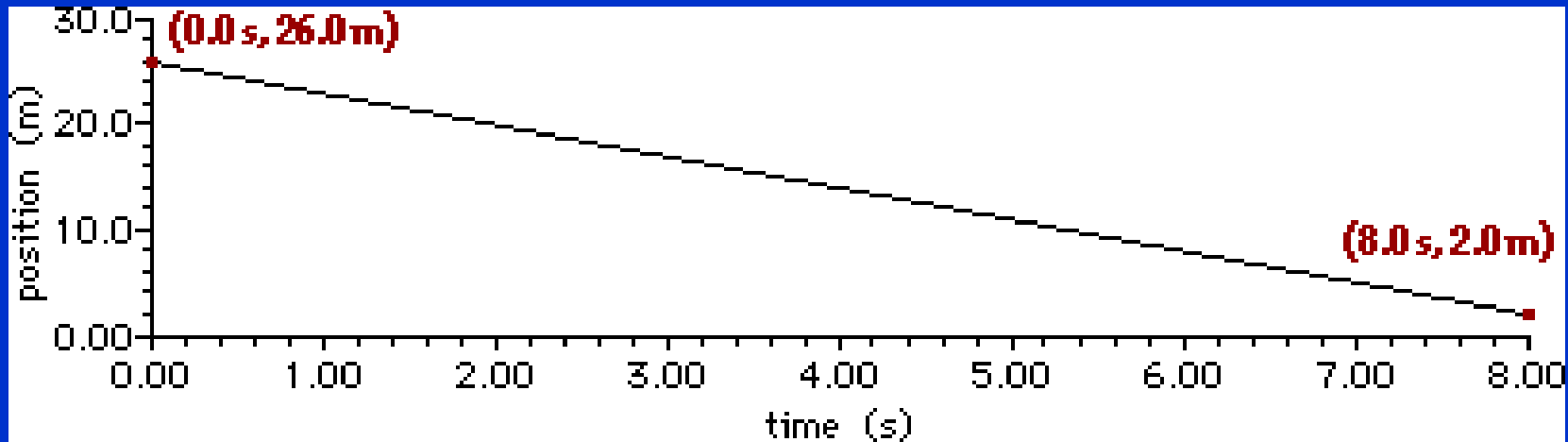
For points (5 s, 50 m) and (2 s, 20 m):

$$\text{slope} = \frac{50 \text{ m} - 20 \text{ m}}{5 \text{ s} - 2 \text{ s}} = 10 \text{ m/s}$$

For points (4 s, 40 m) and (3 s, 30 m):

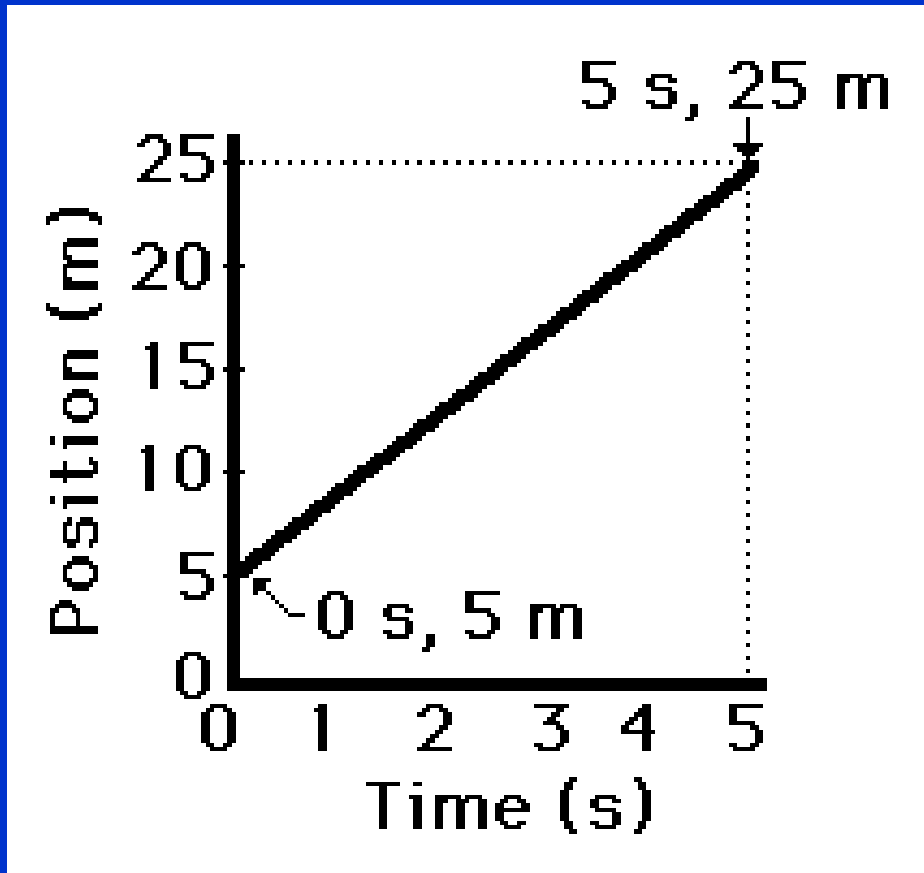
$$\text{slope} = \frac{40 \text{ m} - 30 \text{ m}}{4 \text{ s} - 3 \text{ s}} = 10 \text{ m/s}$$

Slope Practice 1



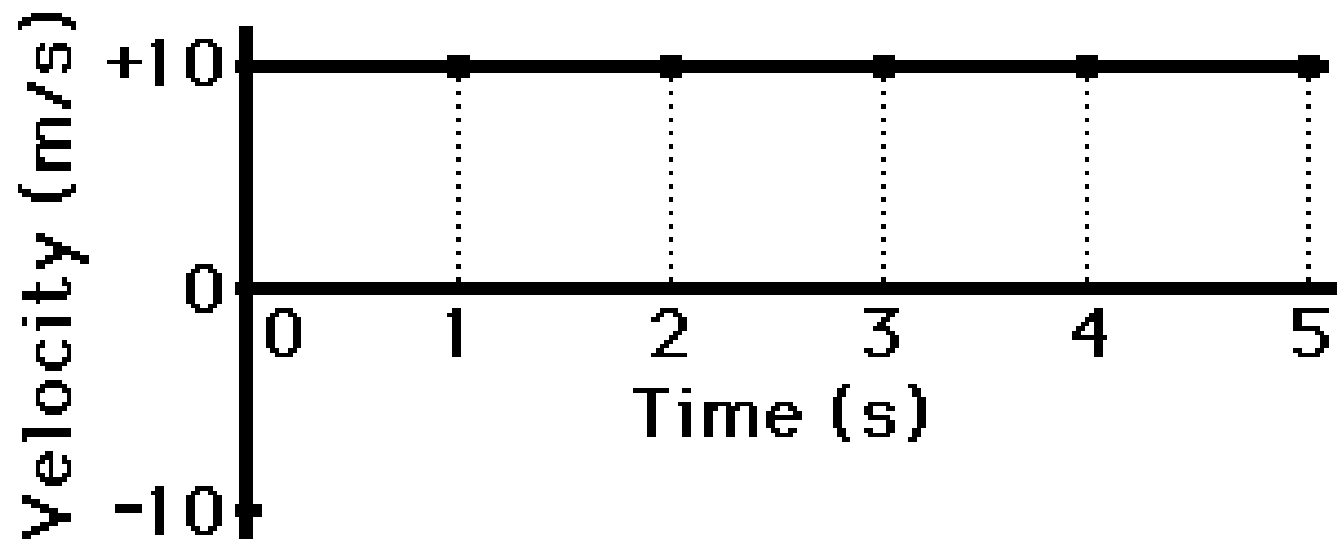
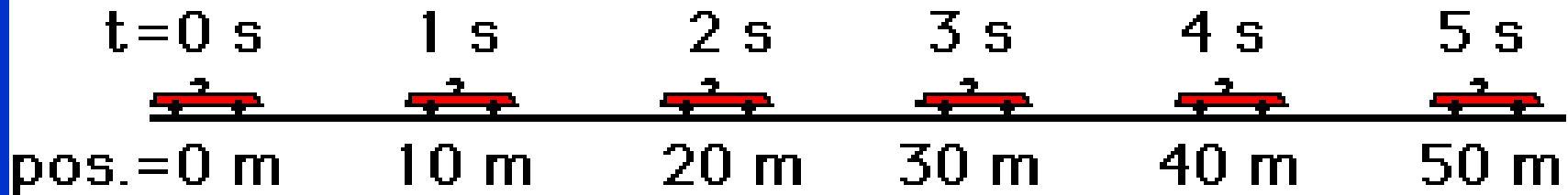
- Calculate the velocity of the object whose graph is shown above.
- $-24\text{m}/8\text{s} = -3 \text{ m/s}$

Slope Practice 2

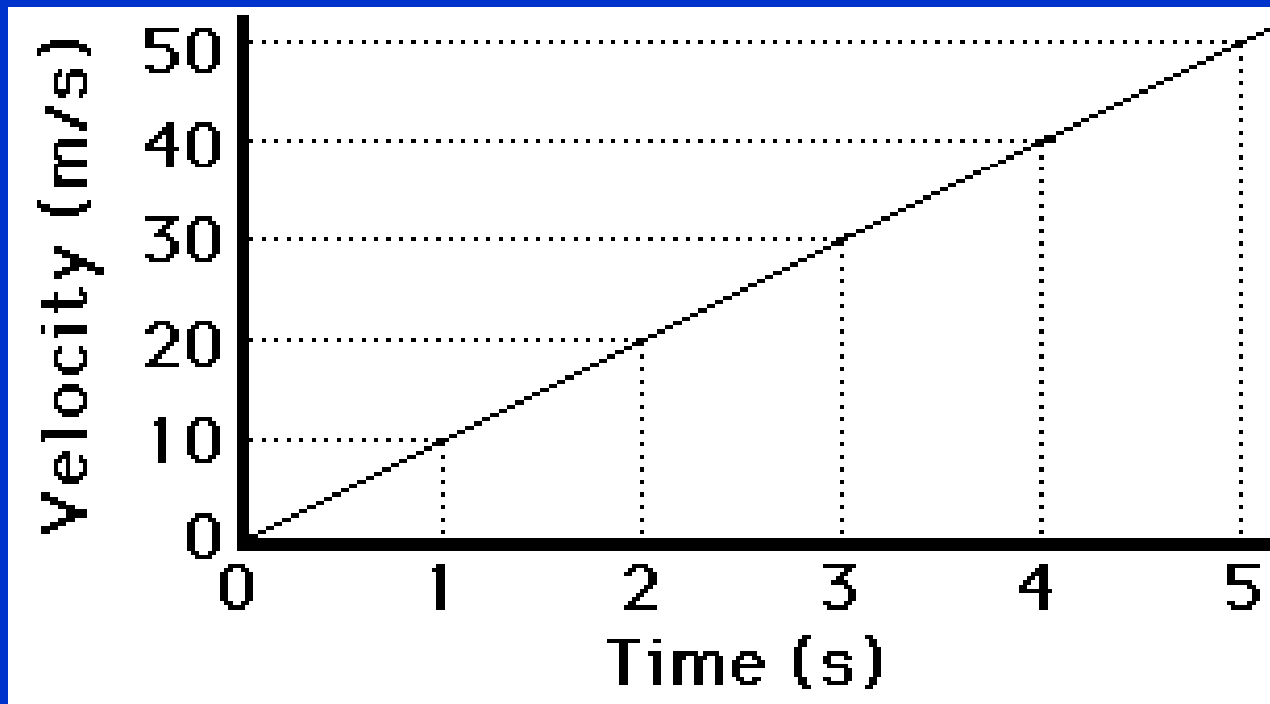
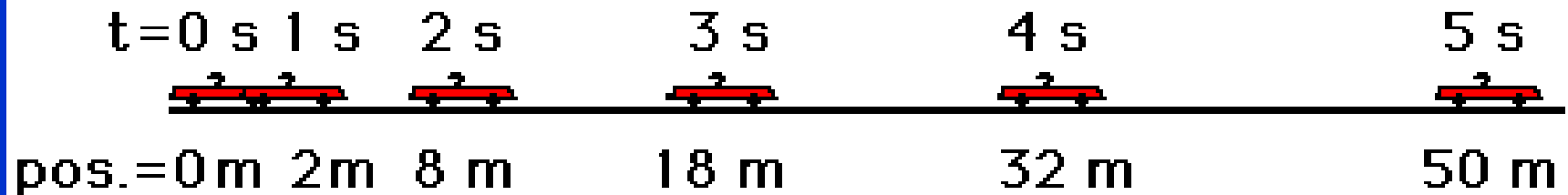


- Determine the velocity of the object whose motion is graphed at the left.
- $20\text{m}/5\text{s} = 4 \text{ m/s}$

Velocity - Time Graph -- 1

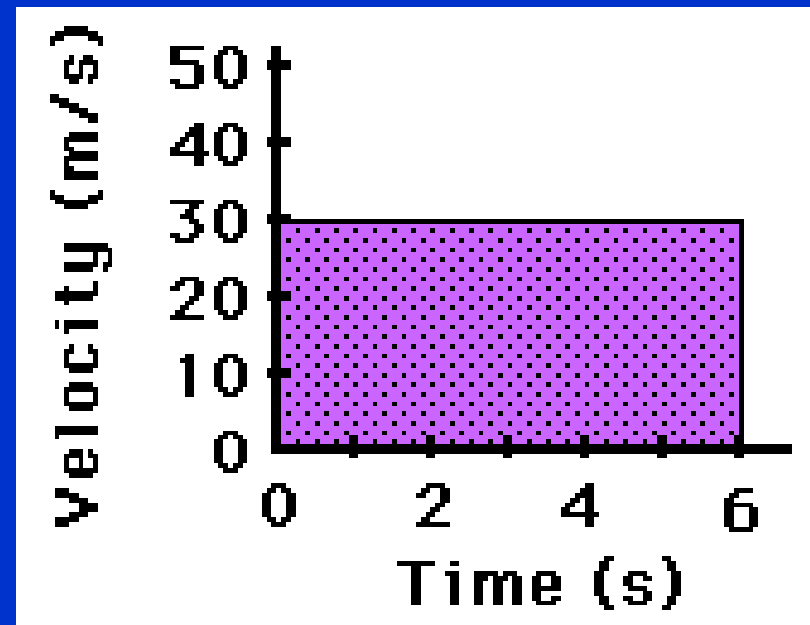


Velocity - Time Graph - 2



Area Under Velocity-Time Graph

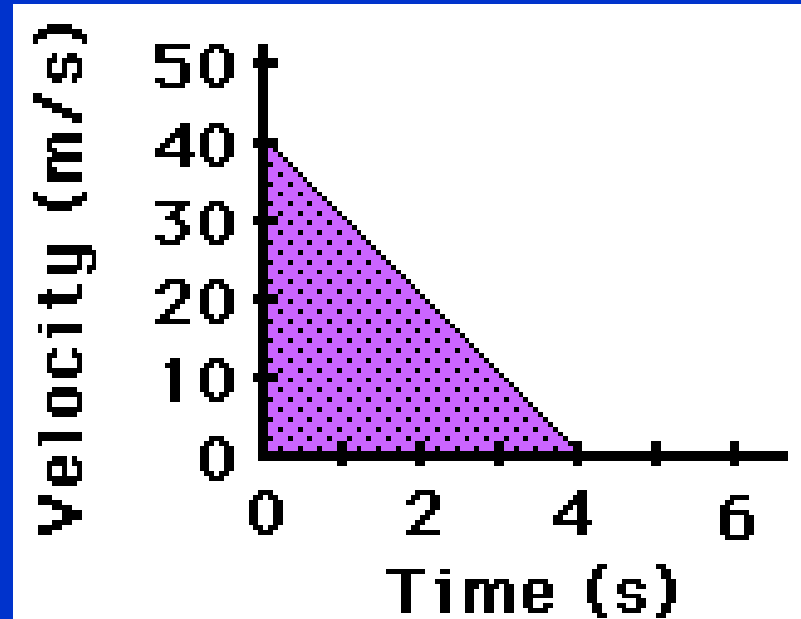
- shaded area represents the distance traveled during the time interval from 0 s to 6 s.
- What is the "height" of the rectangle?
 - 30 m/s
- What is the width of the rectangle?
 - 6 s
- What is the area of the rectangle?



$$\text{Area} = (30 \text{ m/s})(6 \text{ s}) = 180 \text{ m}$$

Area Under Velocity-Time Graph

- shaded area represents the distance traveled during the time interval from 0 seconds to 4 seconds.
- What is the area of the triangle?
 - $(0.5)(4 \text{ s})(40 \text{ m/s}) = 80 \text{ m}$

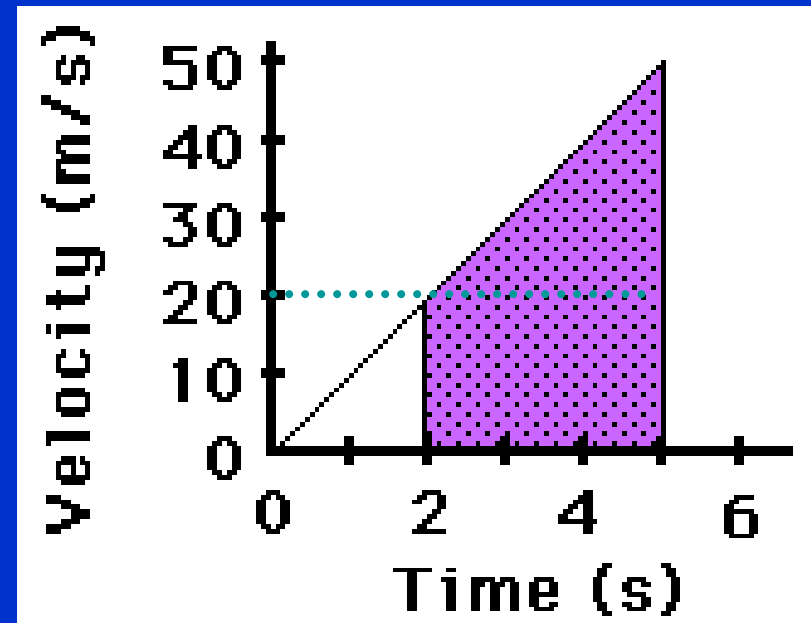


Area Under Velocity-Time Graph

- shaded area represents distance traveled time interval from 2 s to 5 s.
- Area of trapezoid can be broken up into a triangle and a rectangle.
- What is the area of the rectangle?
 - $(3 \text{ s})(20 \text{ m/s}) = 60 \text{ m}$
- What is the area of the triangle?
 - $(0.5)(3 \text{ s})(30 \text{ m/s}) = 45 \text{ m}$

What is the total area?

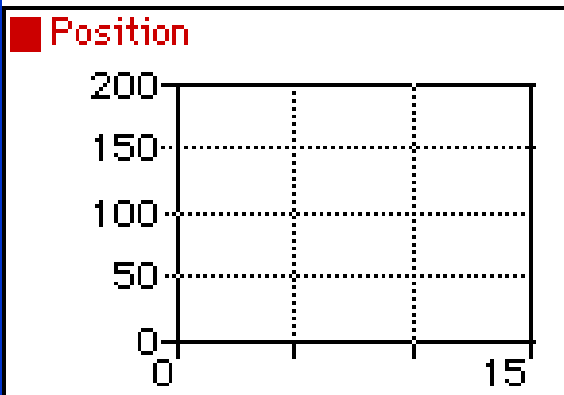
$$60 \text{ m} + 45 \text{ m} = 105 \text{ m}$$



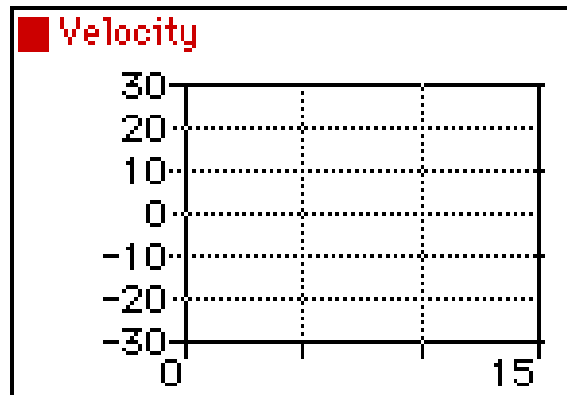
Constant Positive Velocity



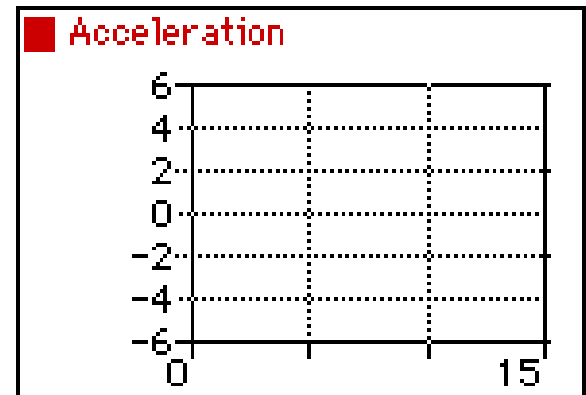
Position-Time Graph



Velocity-Time Graph



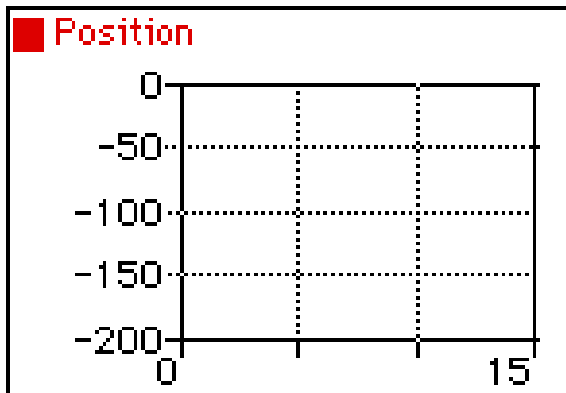
Acceleration-Time Graph



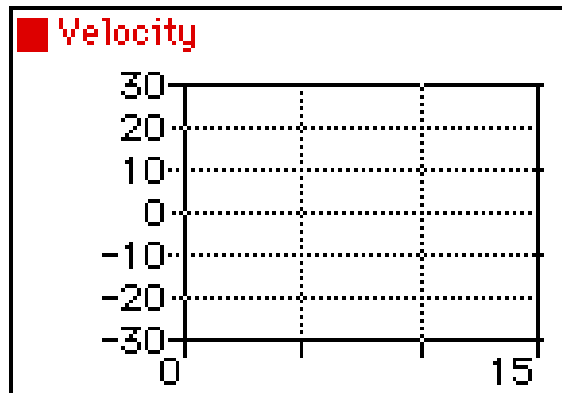
Constant Negative Velocity



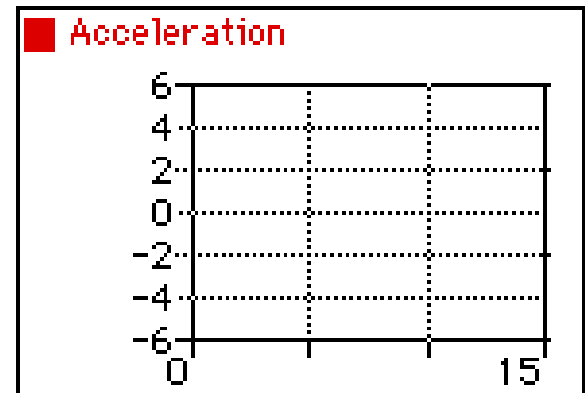
Position-Time Graph



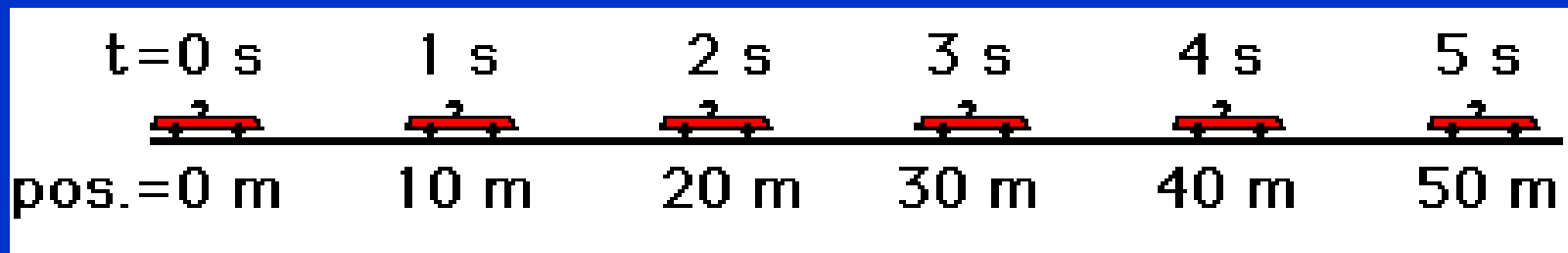
Velocity-Time Graph



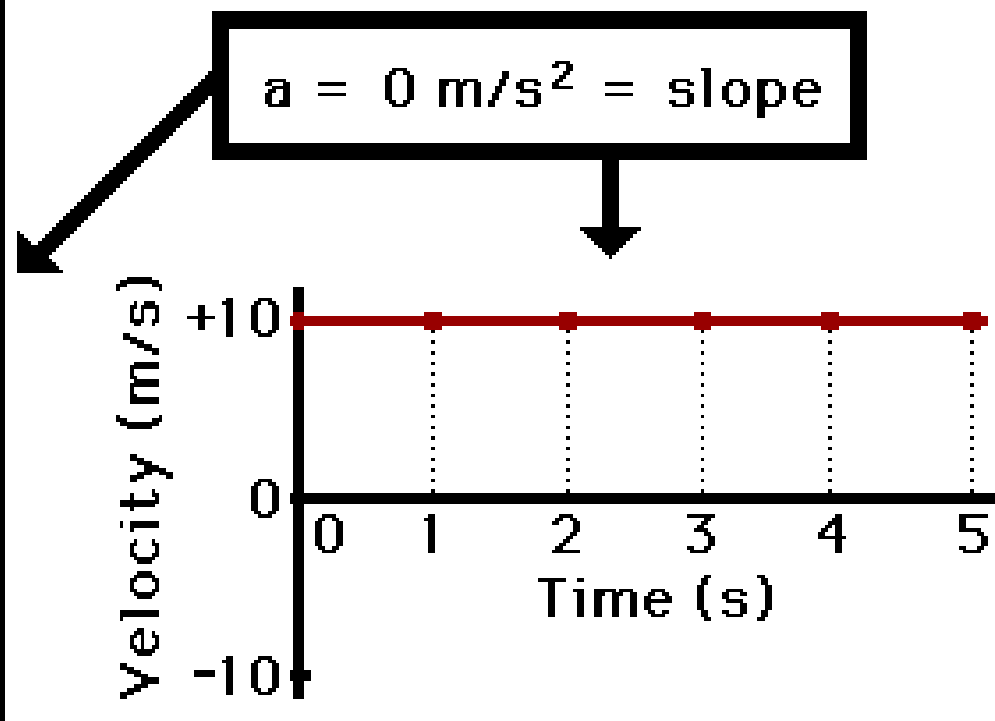
Acceleration-Time Graph



Acceleration - Slope of V-T - 1

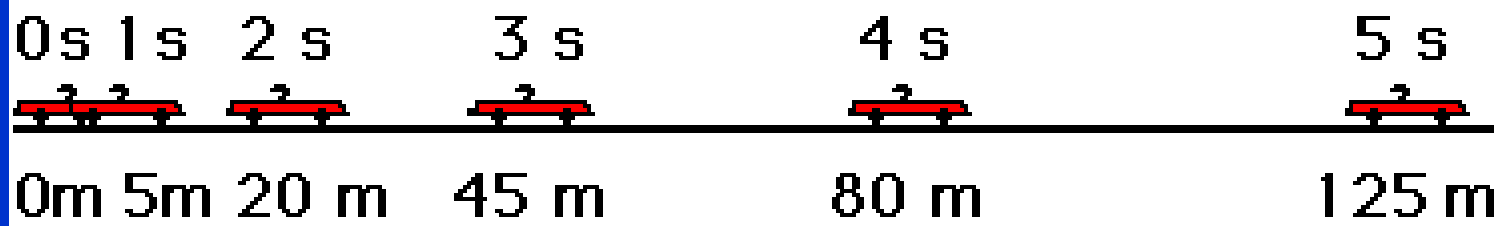


Time (s)	Velocity (m/s)
0	10
1	10
2	10
3	10
4	10
5	10

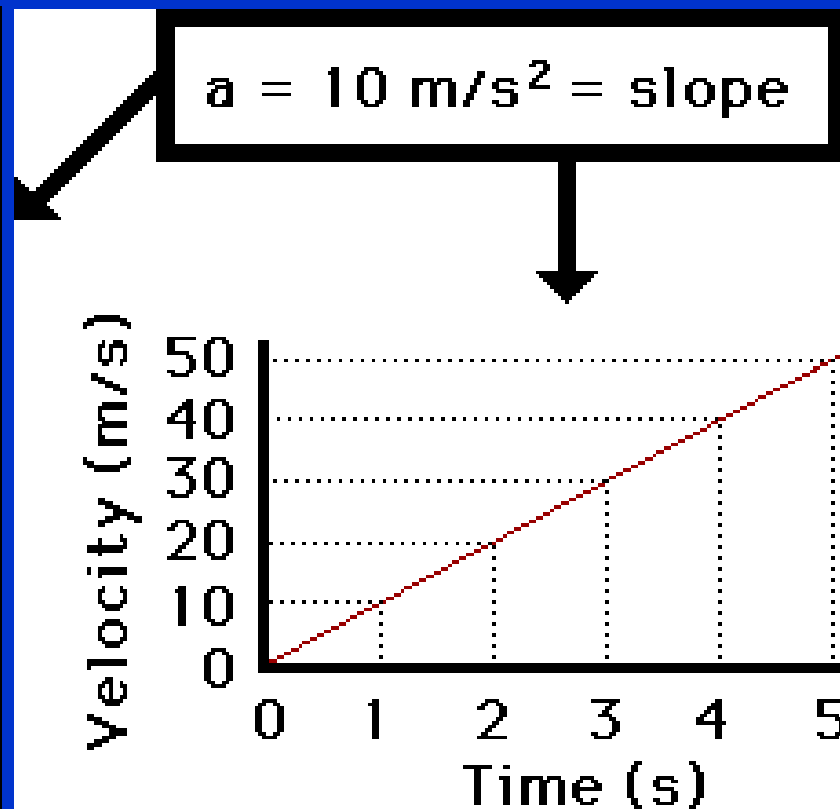


Acceleration - Slope of $V-t$

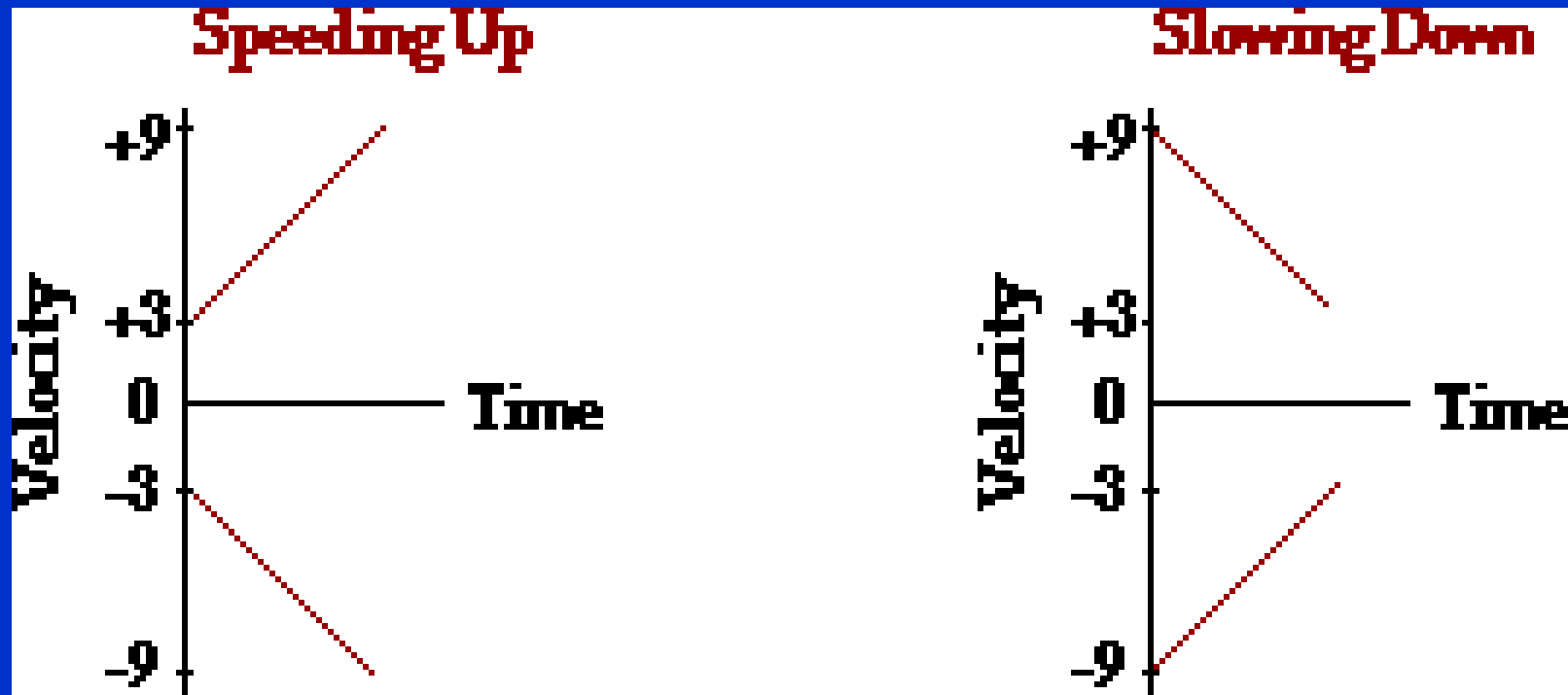
-- ?



Time (s)	Velocity (m/s)
0	0
1	10
2	20
3	30
4	40
5	50

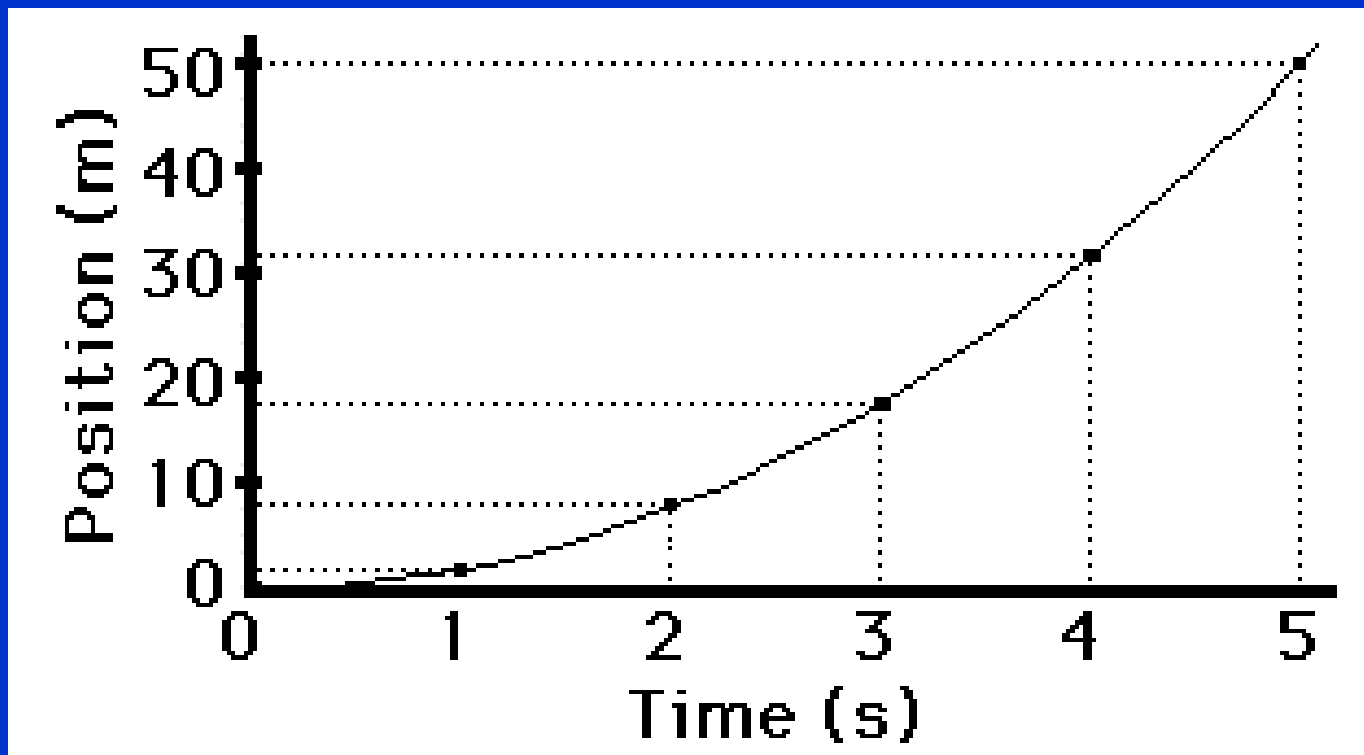
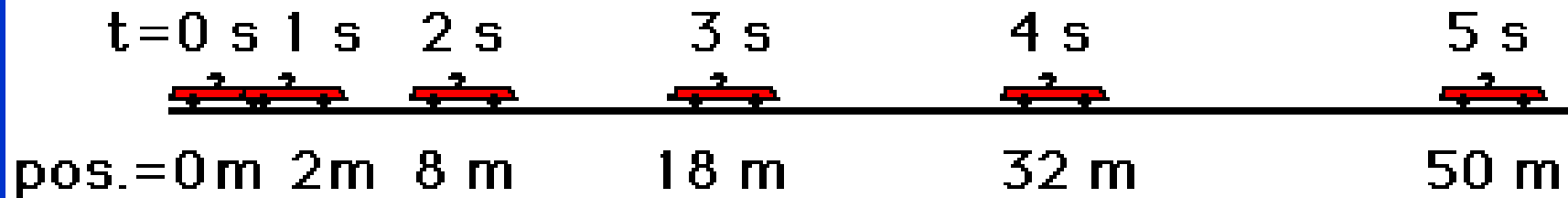


Speeding Up & Slowing Down



Negative acceleration can mean speeding up or slowing down. The same is true with positive acceleration.

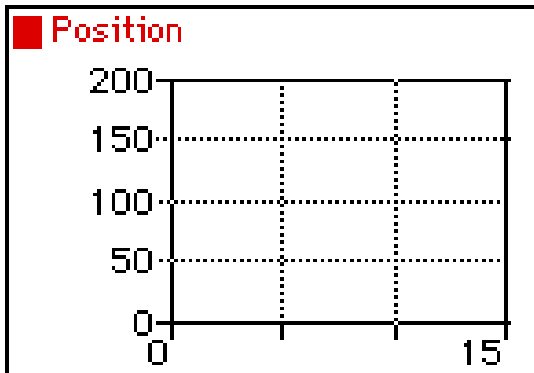
Position - Time for Acceleration



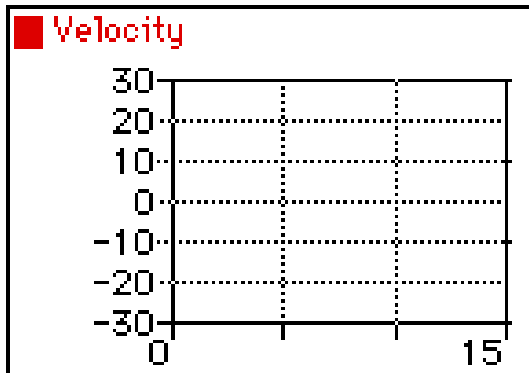
Positive Velocity Positive Acceleration



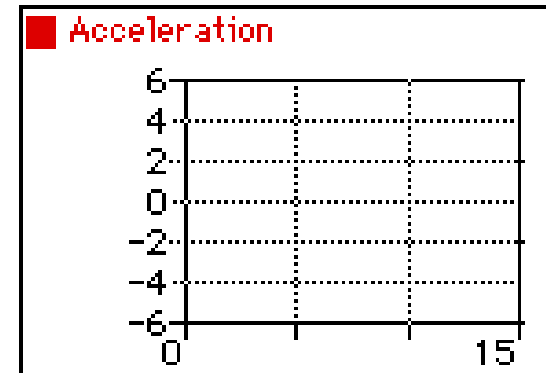
Position-Time Graph



Velocity-Time Graph



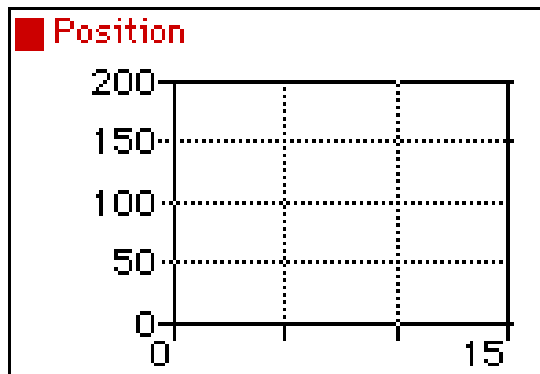
Acceleration-Time Graph



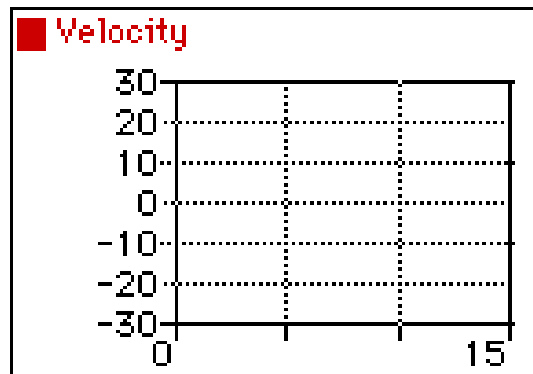
Positive Velocity Negative Acceleration



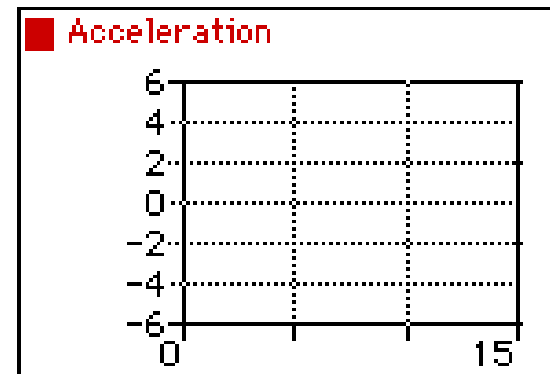
Position-Time Graph



Velocity-Time Graph



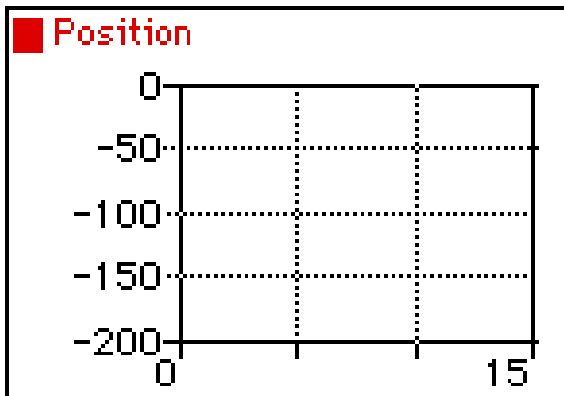
Acceleration-Time Graph



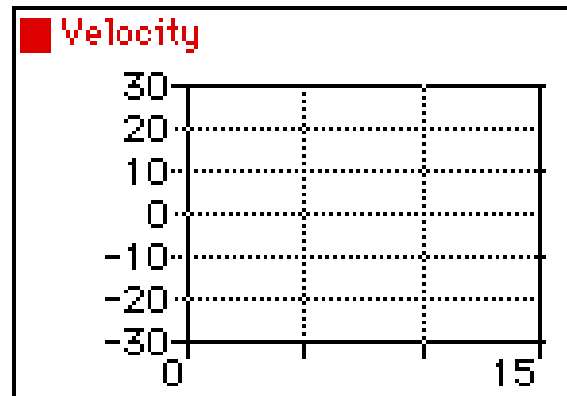
Negative Velocity Negative Acceleration



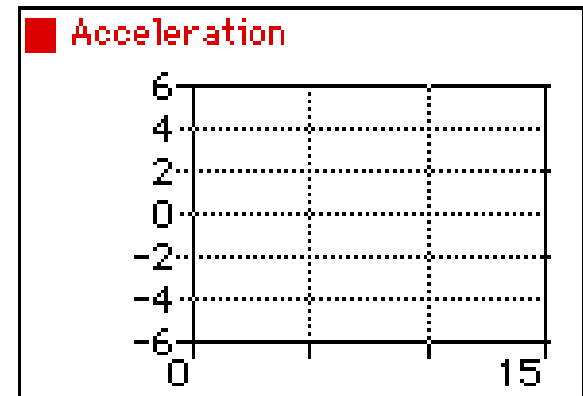
Position-Time Graph



Velocity-Time Graph



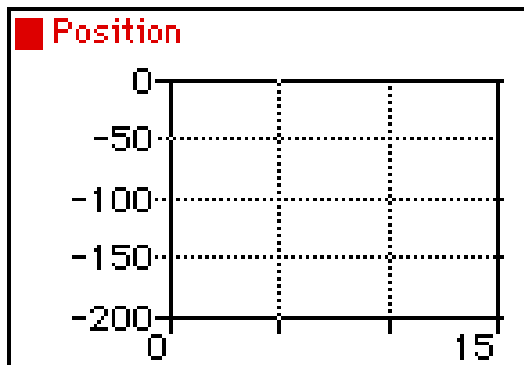
Acceleration-Time Graph



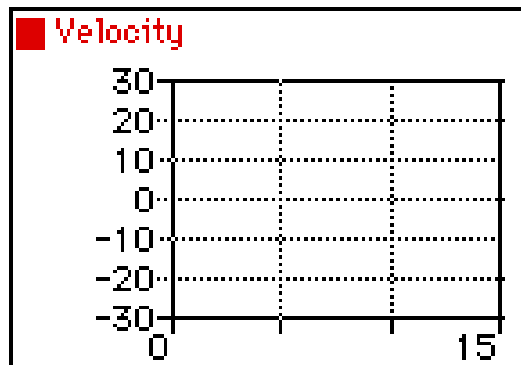
Negative Velocity Positive Acceleration



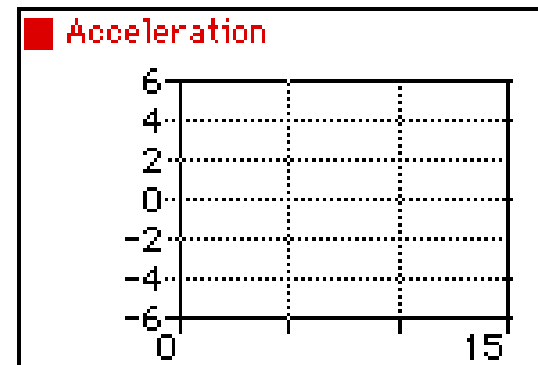
Position-Time Graph



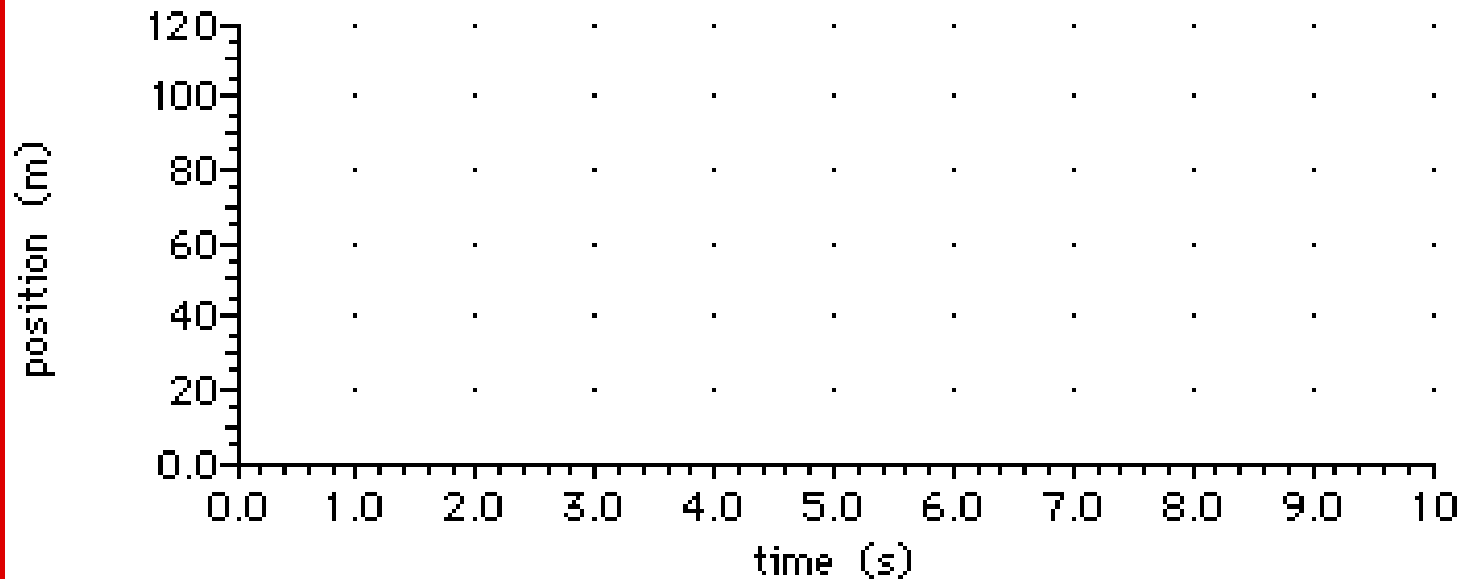
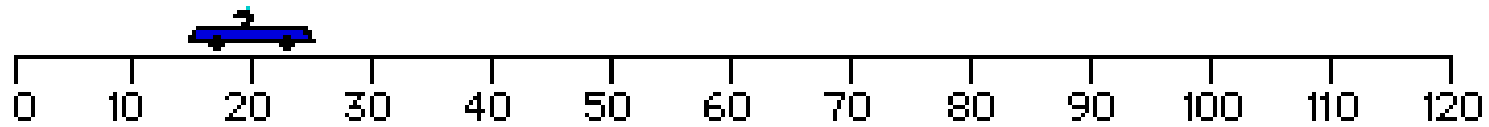
Velocity-Time Graph



Acceleration-Time Graph



Passing Lane - Position-Time



Passing Lane - Velocity-Time

