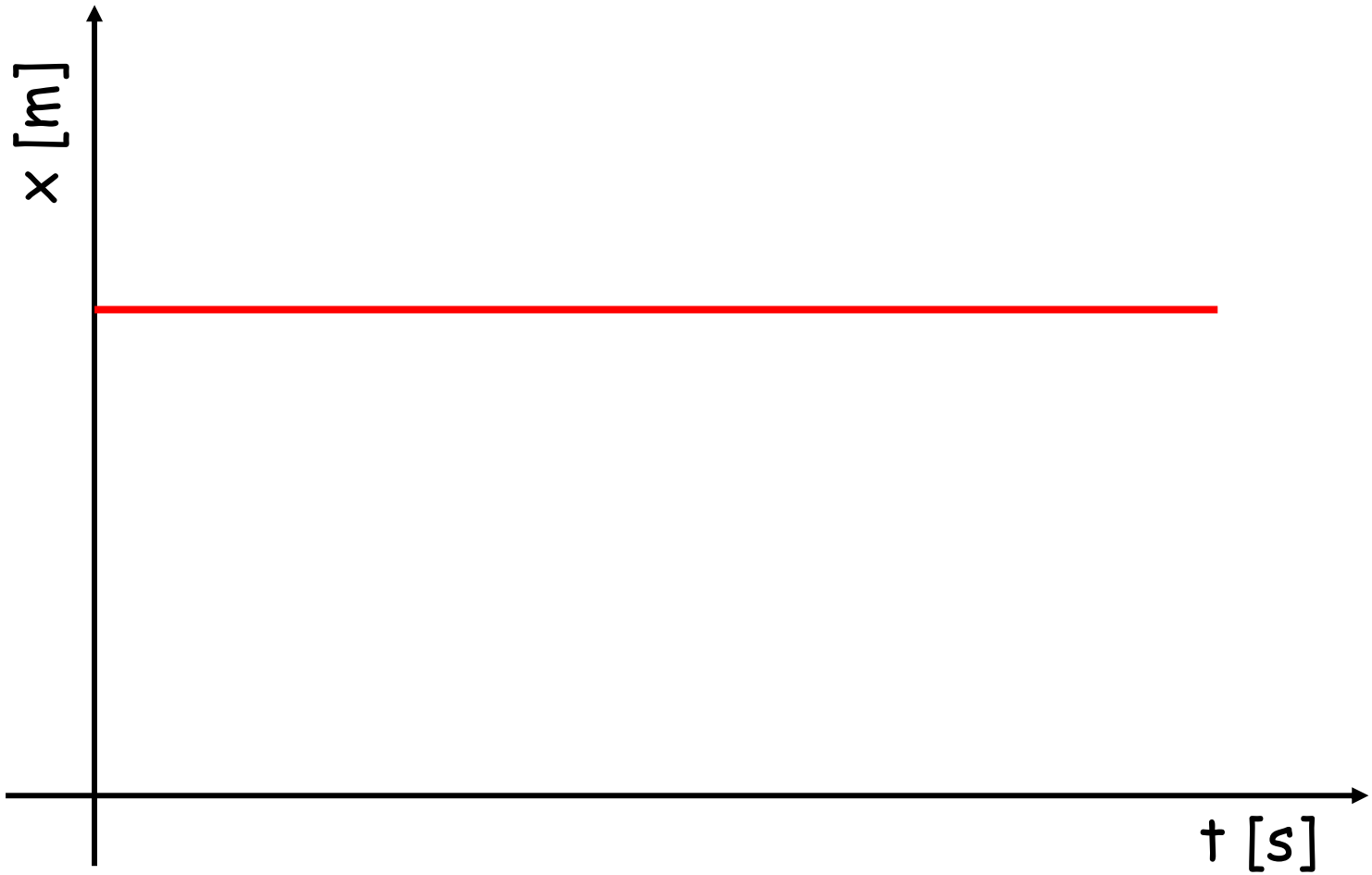
Kinematics: Graphically

- Position versus time
- Velocity versus time
- Acceleration versus time

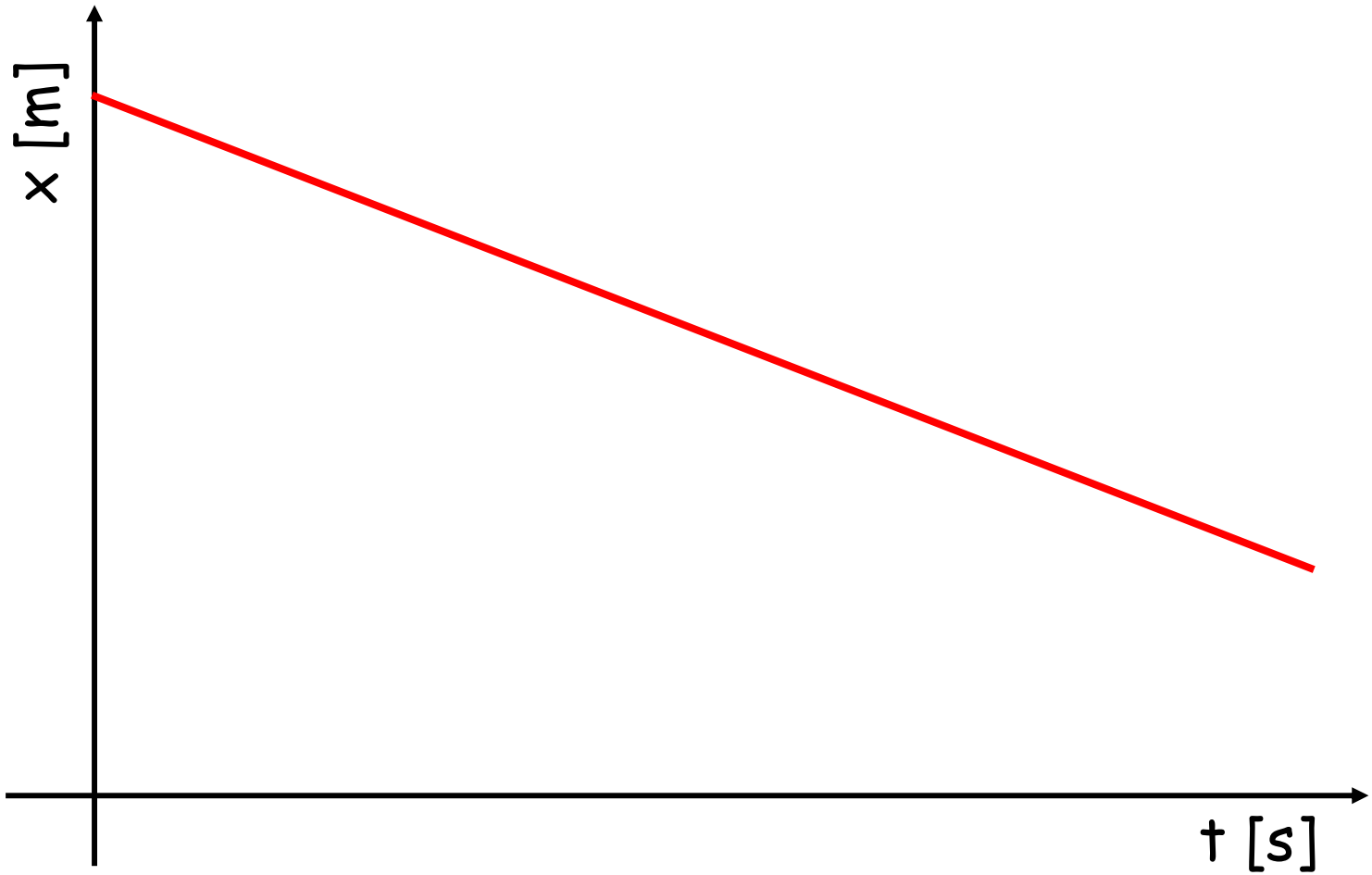
Kinematics in 1 dimension

- Kinematics is all about predicting where an object will be in the future
- 1-D motion describes motion that is constrained to move along a line
- To describe motion in 1 dimension, a coordinate system must be created

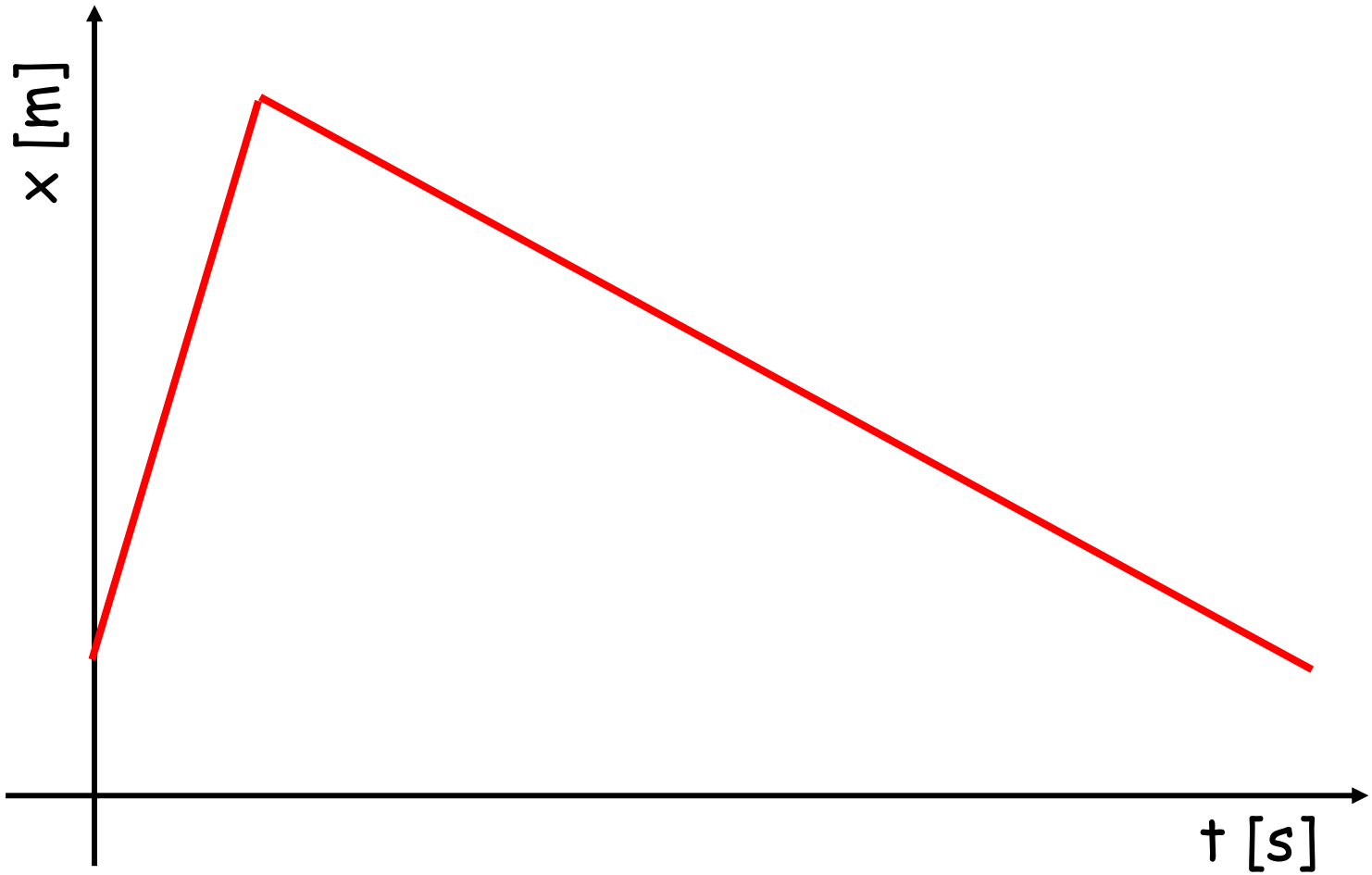
Walk the path



Walk the path

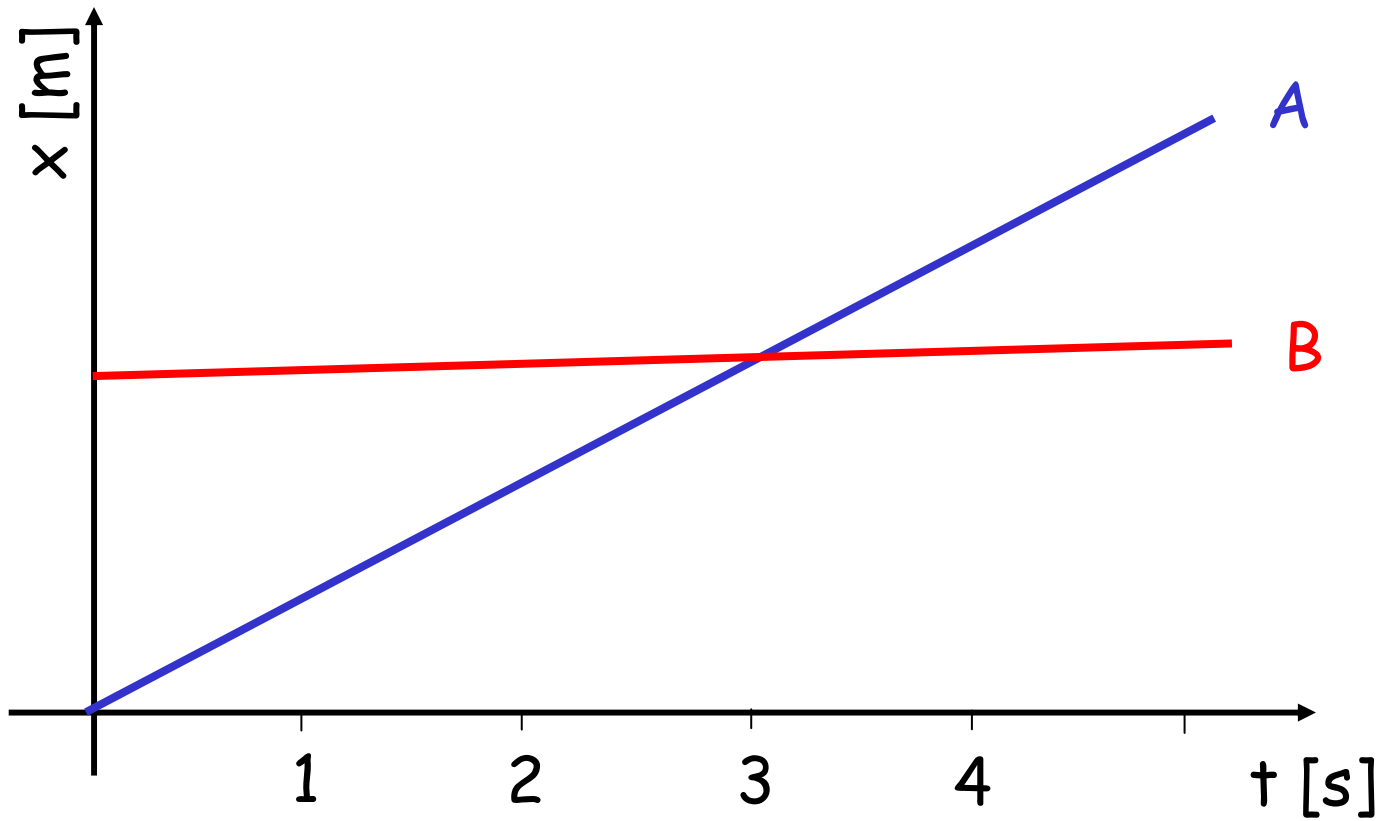


Walk the path



Quick Quiz 11

At what time do objects A and B have the same speed?

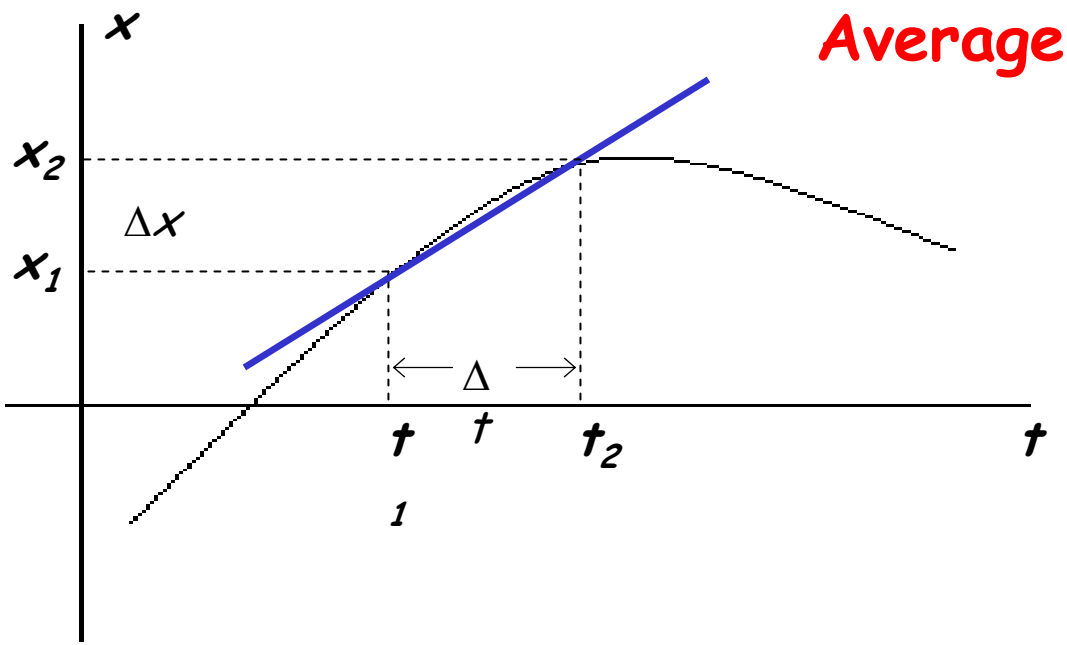


A) 1 s B) 2 s C) 3 s D) 4 s E) never

Instantaneous Velocity

- Velocity is the rate of change in position
- Average velocity is averaged over some time interval
- If that time interval gets smaller and smaller, the average velocity starts to better represent the velocity at a particular point in time
- Once the time interval gets small enough that the velocity appears to be constant over that time interval, the average velocity is the same as an instantaneous velocity

Displacement : $\Delta x \equiv x_2 - x_1$



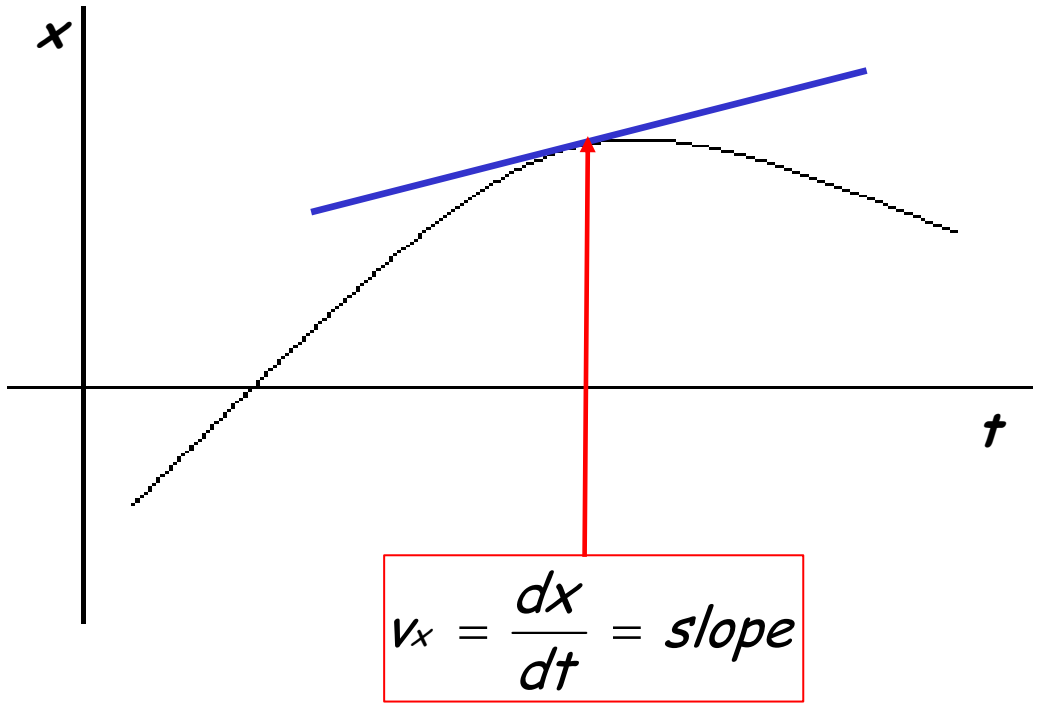
Average velocity : $\bar{v}_x \equiv \Delta x / \Delta t$

- **Instantaneous velocity** is the average over an 'infinitesimal' time interval :

$$\Delta t \to 0 \qquad \frac{\Delta x}{\Delta t} \to \frac{dx}{dt} \equiv v_x$$

- **Instantaneous velocity** at a point on the position versus time graph is given by the derivative of the path at that point

- That means that the slope of the tangent at that point is the instantaneous velocity

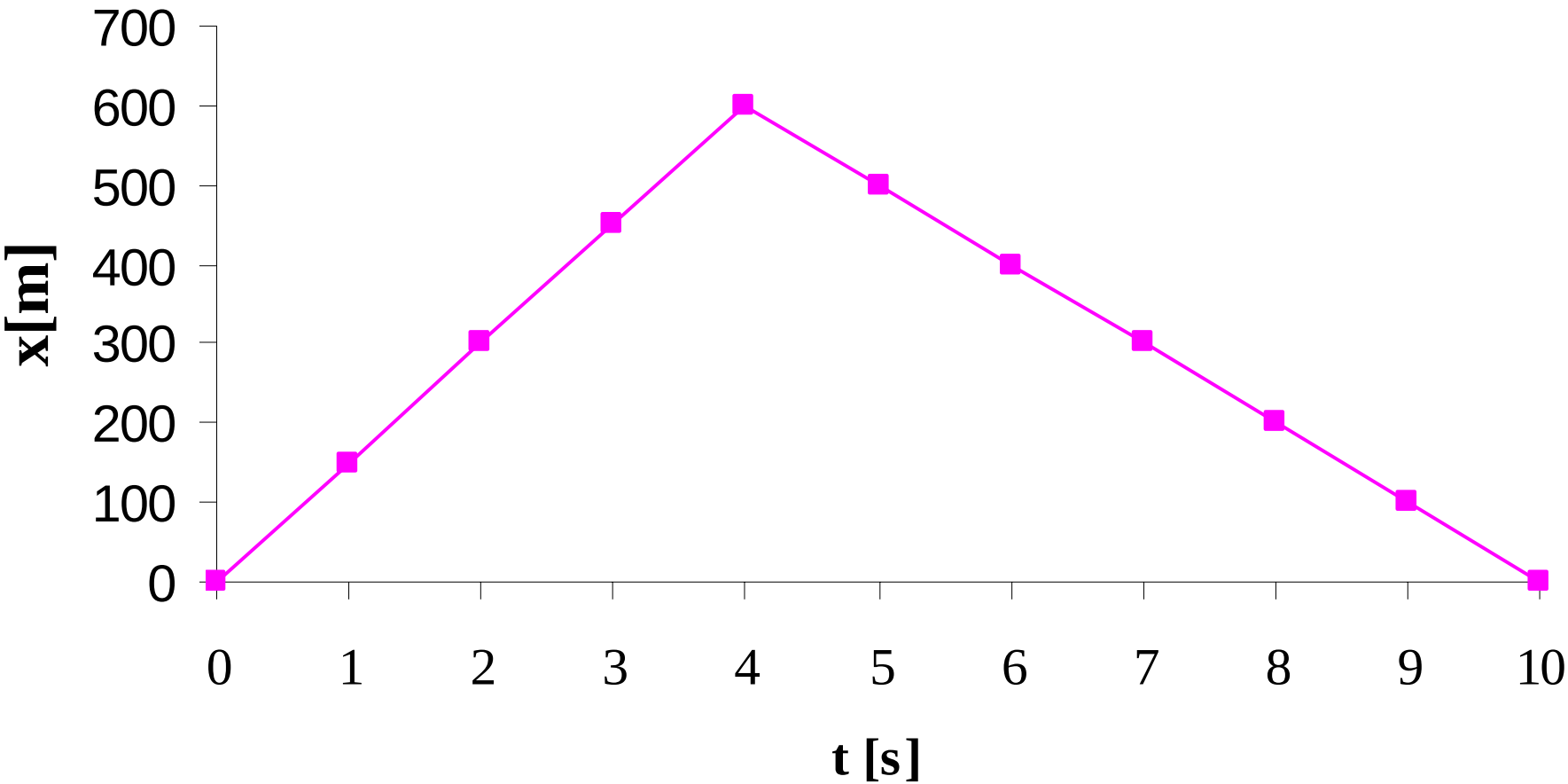


Quick Quiz 12

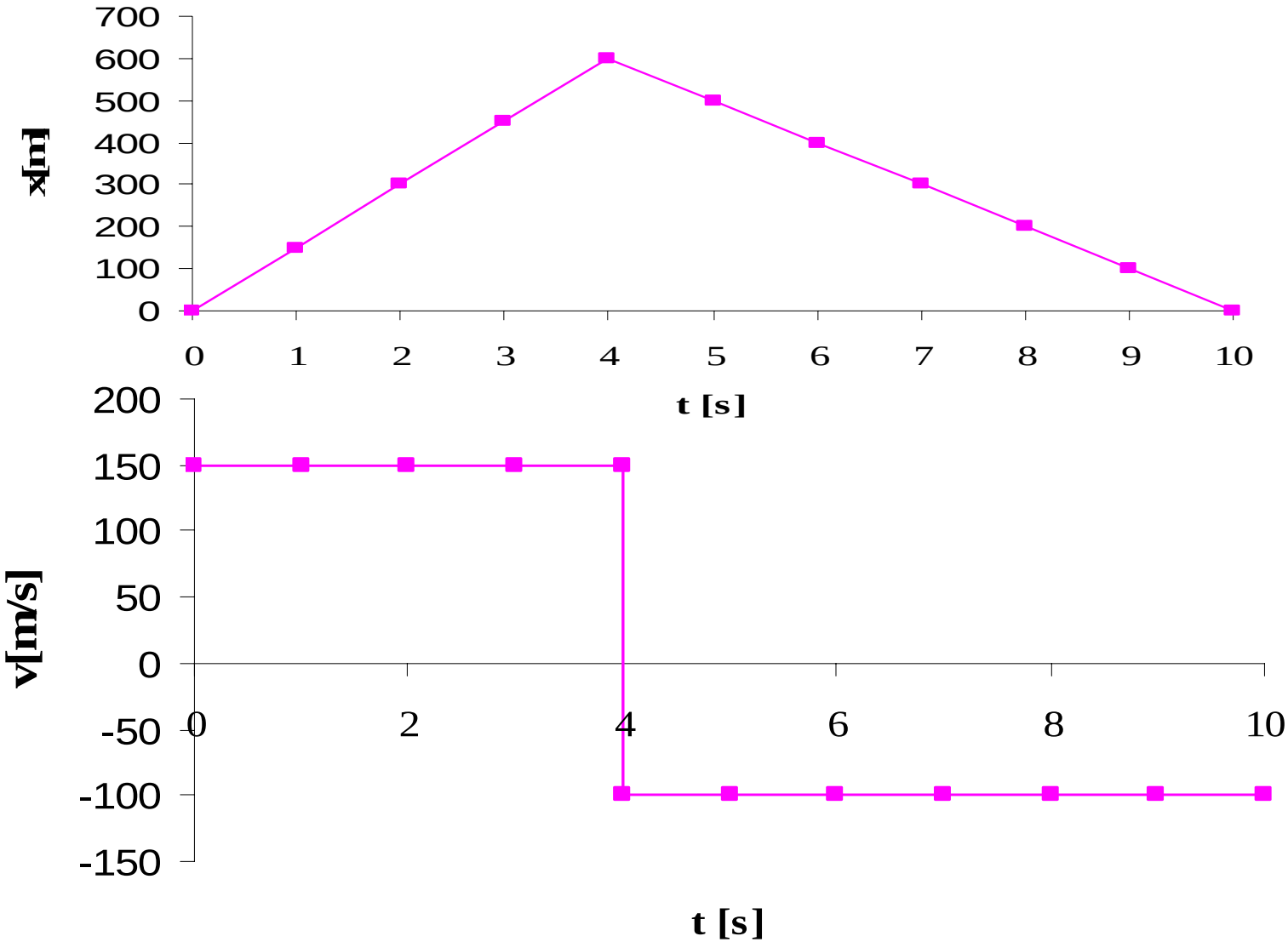
You're driving along the highway at a steady speed of 100 km/h when another car decides to pass you. At the moment when the front of his car is exactly even with the front of your car, do the two cars have equal velocities?

A) Yes B) No

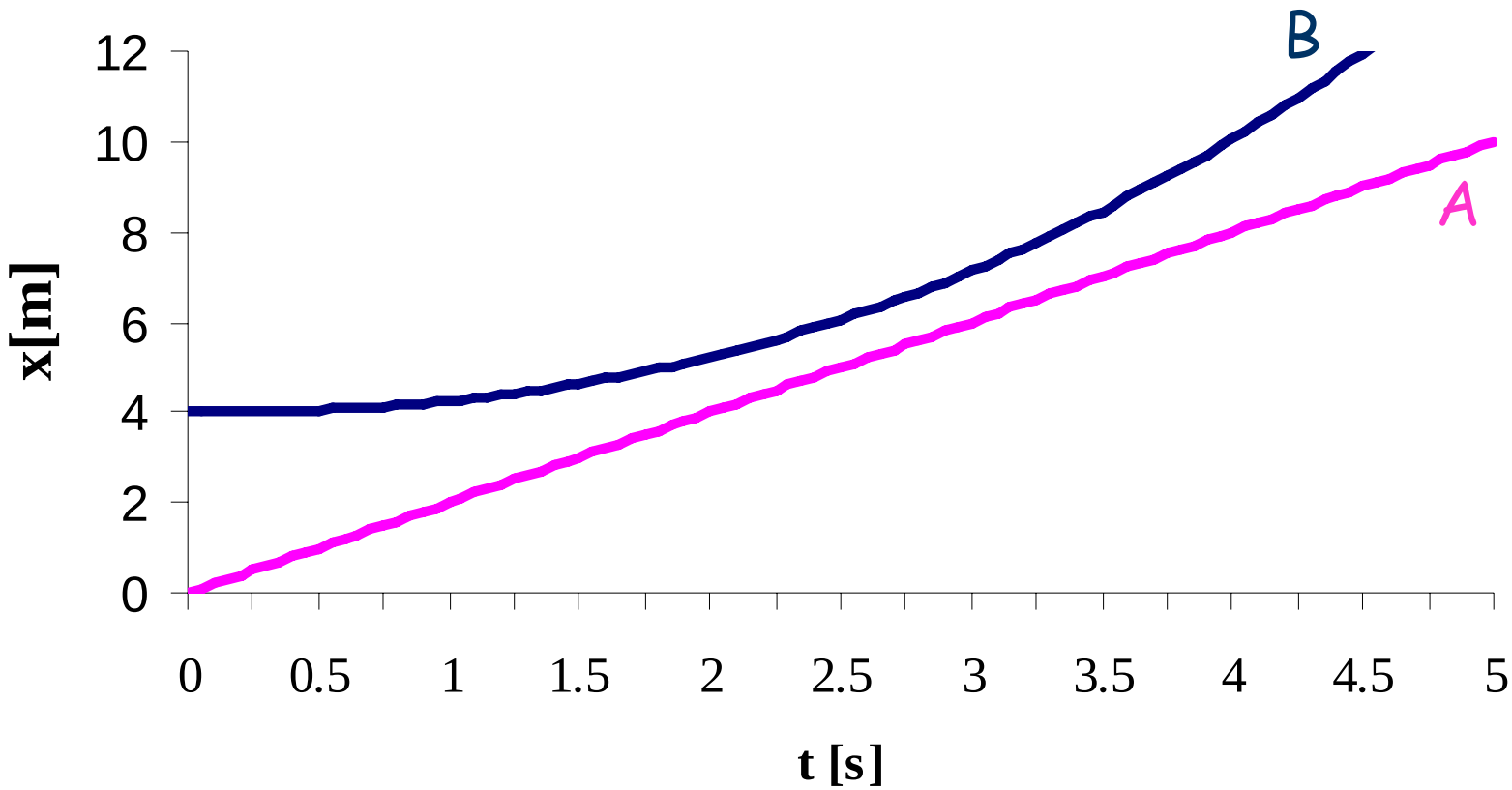
Finding velocity from a potion versus time graph



The slope at each point of the position versus time graph is the velocity at each point of the velocity versus time graph


x[m]
700
600
500
400
300
200
100
0
0
1
2
3
4
5
6
7
8
9
10
t [s]
v[m/s]
200
150
100
50
0
-50
-100
-150
0
2
4
6
8
10
t [s]

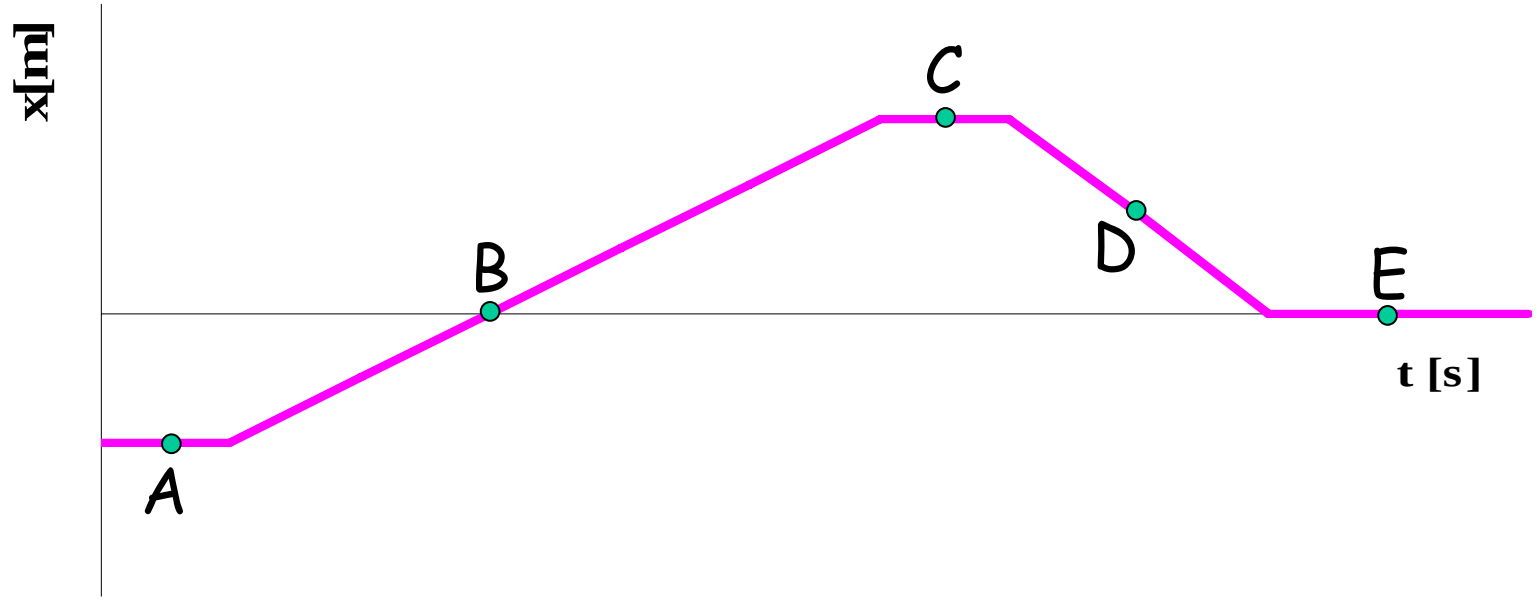
Quick Quiz 13



At t = 1 s, the speed of A is: (A) Greater than the speed of B
(B) Less than the speed of B
(C) The same as the speed of B

Quick Quiz 14:

A position versus time graph for a moving object. The positions above the time axis are to the right of the origin.

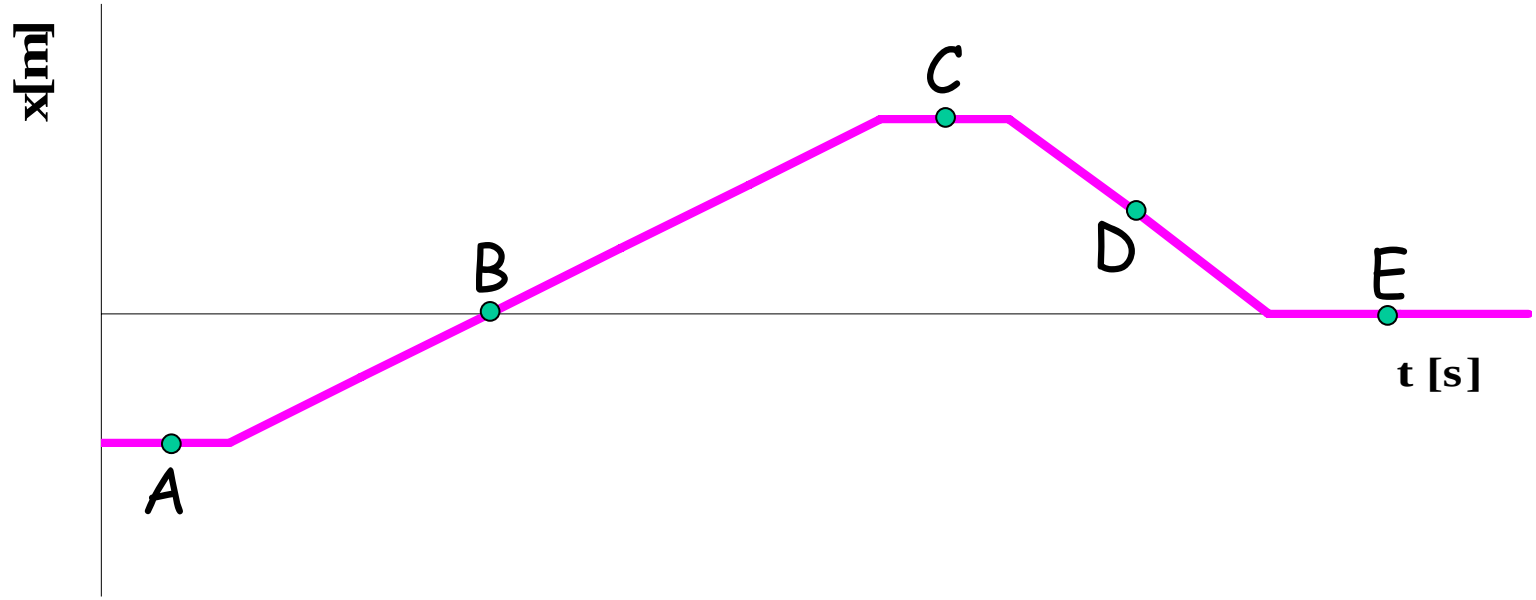


At which lettered point or points is the object at rest?

(A) Points A, C and E
(B) Points B and D
(C) Point E
(D) Point D
(E) Point A and C

Quick Quiz 15:

A position versus time graph for a moving object. The positions above the time axis are to the right of the origin.

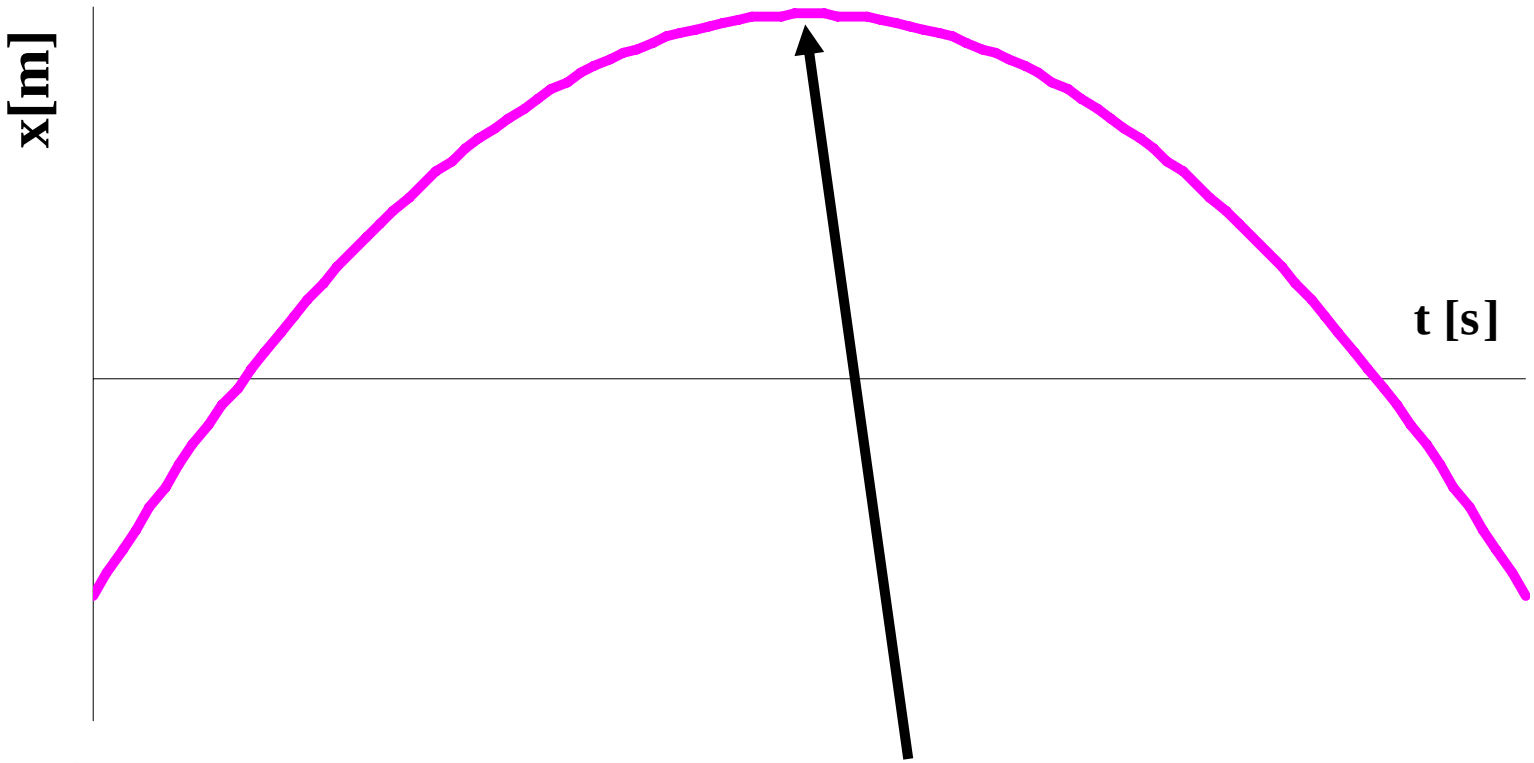


At which lettered point or points is the object moving to the left?

(A) Points A, C and E
(B) Points B and D
(C) Point E
(D) Point D
(E) Point A and C

Turning Points

- When graphing, there are important points that can help you to quickly show the character of a curve
- The point at which the position versus time graph goes from heading in one direction to heading in another is a turning point
- A turning point on the position versus time graph is associated with a zero-crossing point on the velocity versus time graph



At a turning point on the position versus time graph, the velocity goes from positive to negative and therefore must go through zero

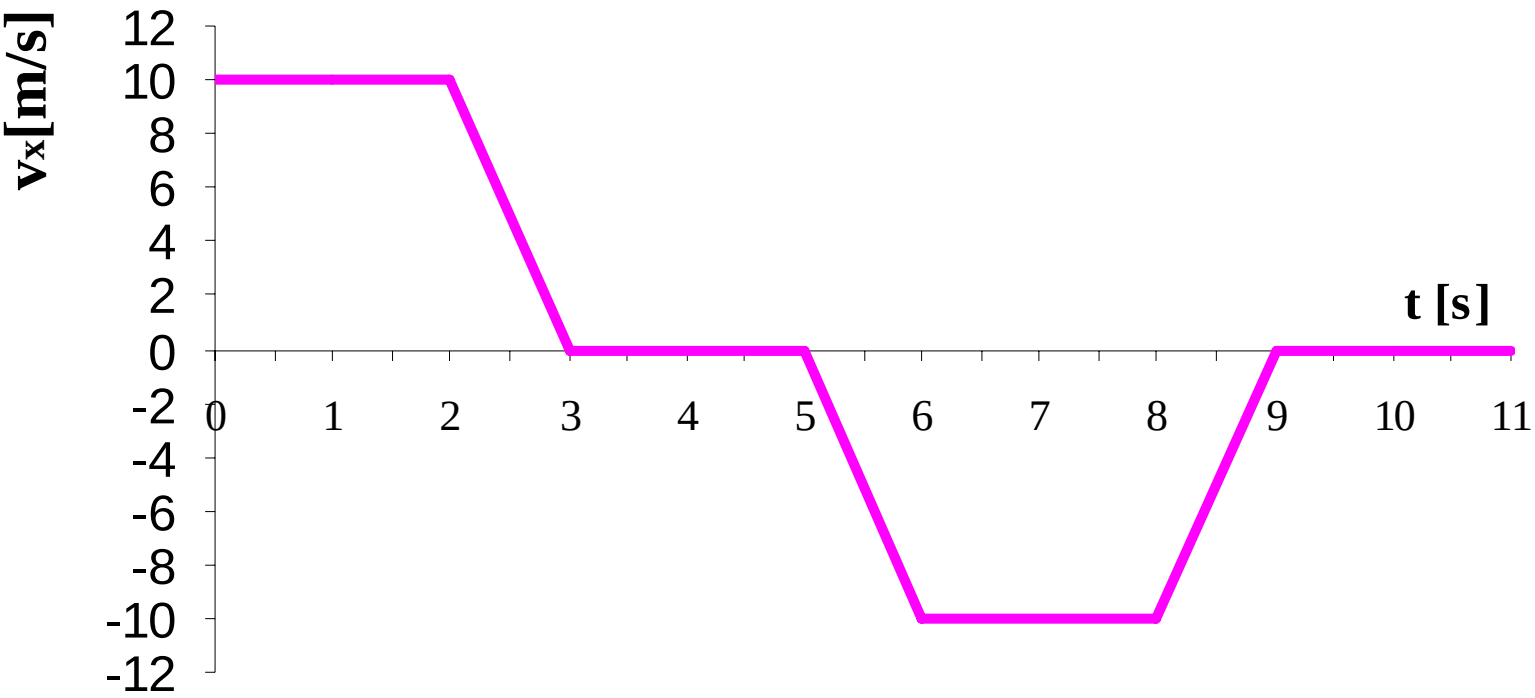
Finding Position from Velocity

We can find the position of an object if we are given its starting position, as well as information about its velocity:

$$\vec{r}_2 = \vec{r}_1 + (\vec{v}_{avg}\Delta t)$$

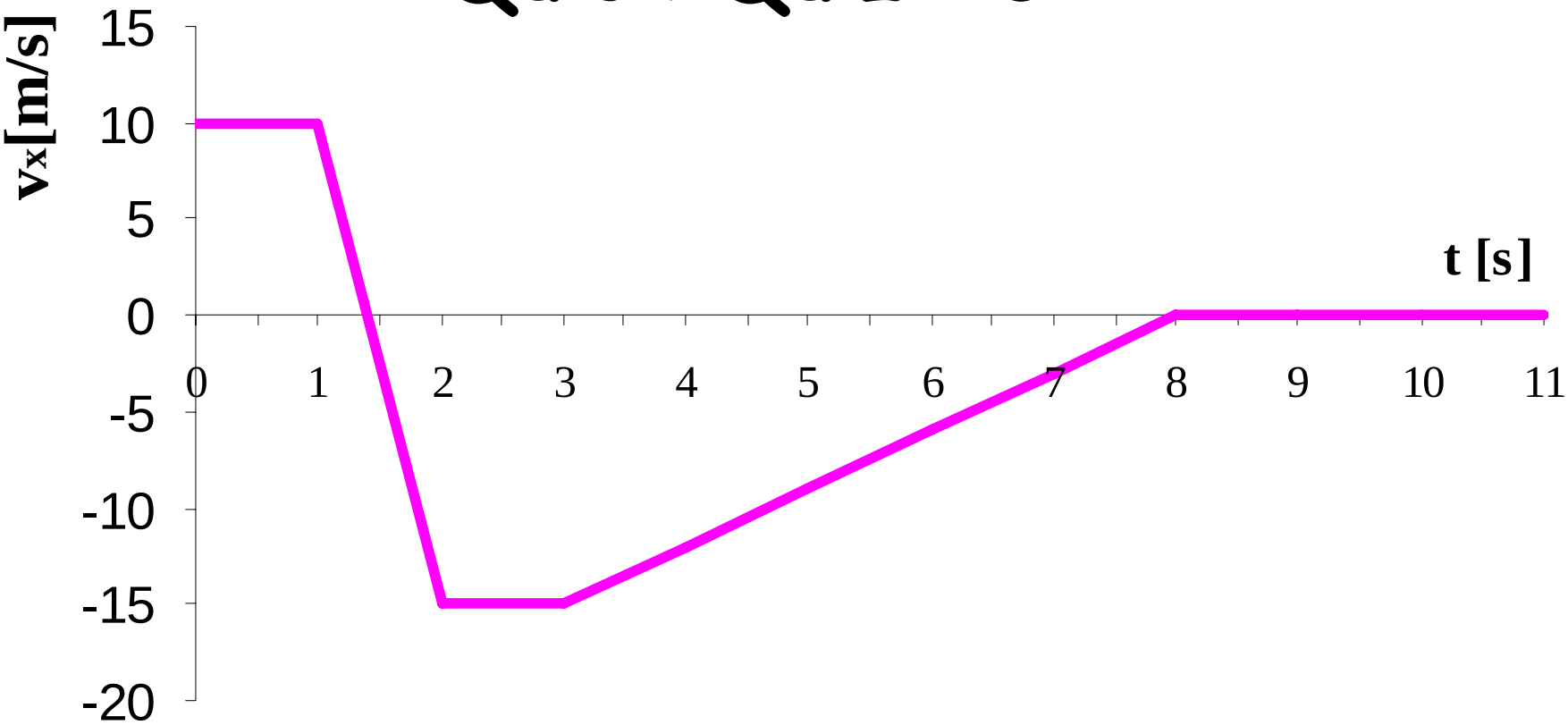
That means that if we know an objects initial position, we can use its velocity versus time graph to find its position at later times.

Example: Finding position from a velocity versus time graph



If an object starts at an initial position x = 10 m, where is the object at t = 10 s?

Quick Quiz 16



The object starts at an initial position x = 10 m. Its final position is approximately:

A) x = -35 m B) x = -10 m C) x = 0 m D) x = 15 m

Acceleration

- Acceleration is the rate of change of velocity

$$\vec{a}_{avg} = \frac{\Delta \vec{v}_{avg}}{\Delta t}$$

The acceleration vector ALWAYS points in the same direction as the CHANGE in velocity.

Acceleration

- Negative acceleration doesn't always mean slowing down!
- Positive acceleration doesn't always mean speeding up!

What matters is whether the acceleration is pointing in the direction of the motion:

speeding up	slowing down
$a_x > 0$ and $v_x > 0$	$a_x < 0$ and $v_x > 0$
$a_x < 0$ and $v_x < 0$	$a_x > 0$ and $v_x < 0$

Quick Quiz 17

A particle (in one dimension) is initially moving. A few seconds later it is stopped (not moving).

During that time interval:

A. The particle's average acceleration is positive
B. The particle's average acceleration is negative
C. Not enough information to tell

Quick Quiz 18

A rubber ball is dropped and bounces off the floor.

Define displacement x to be x = 0 at the floor, and x increases upward.

At the *highest point* of the first bounce, what are *v* and *a*?:

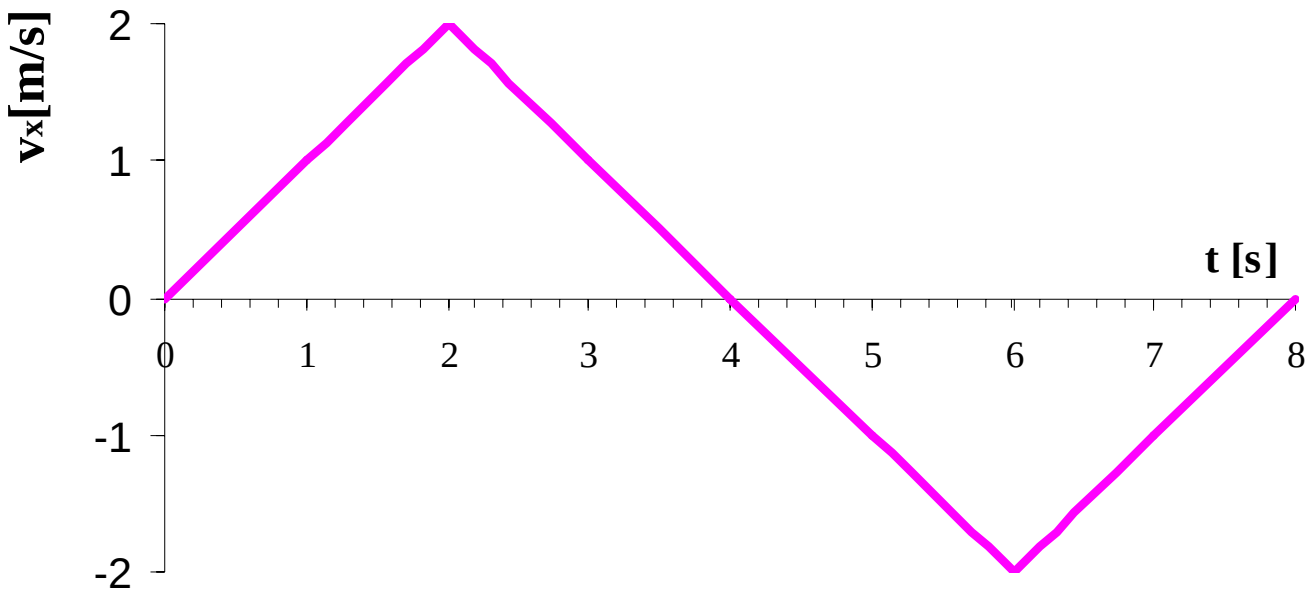
a) $v = 0$ and $a = 0$

b) $v = 0$ and $a \neq 0$

c) $v \neq 0$ and $a = 0$

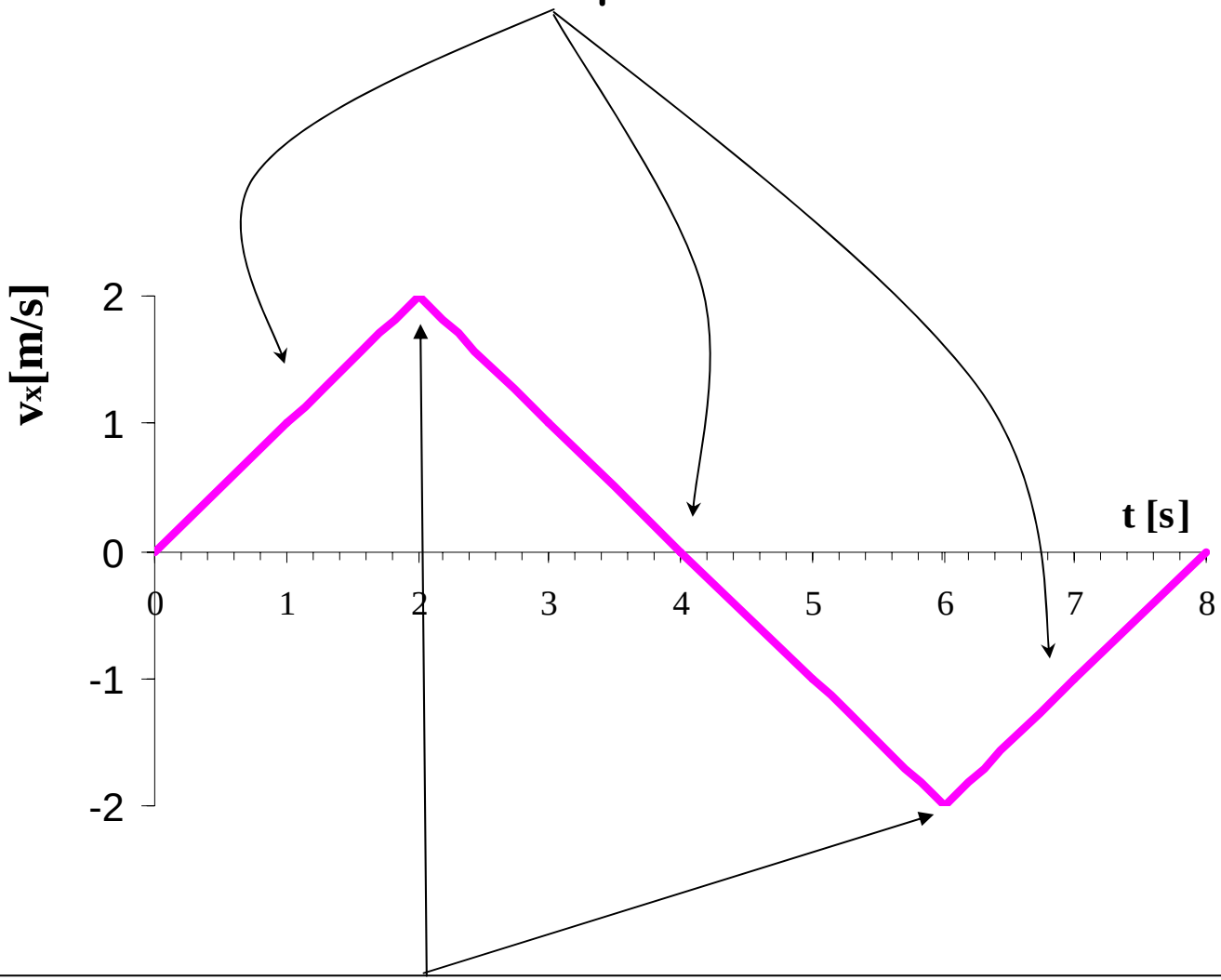
d) $v \neq 0$ and $a \neq 0$

Worked Example:

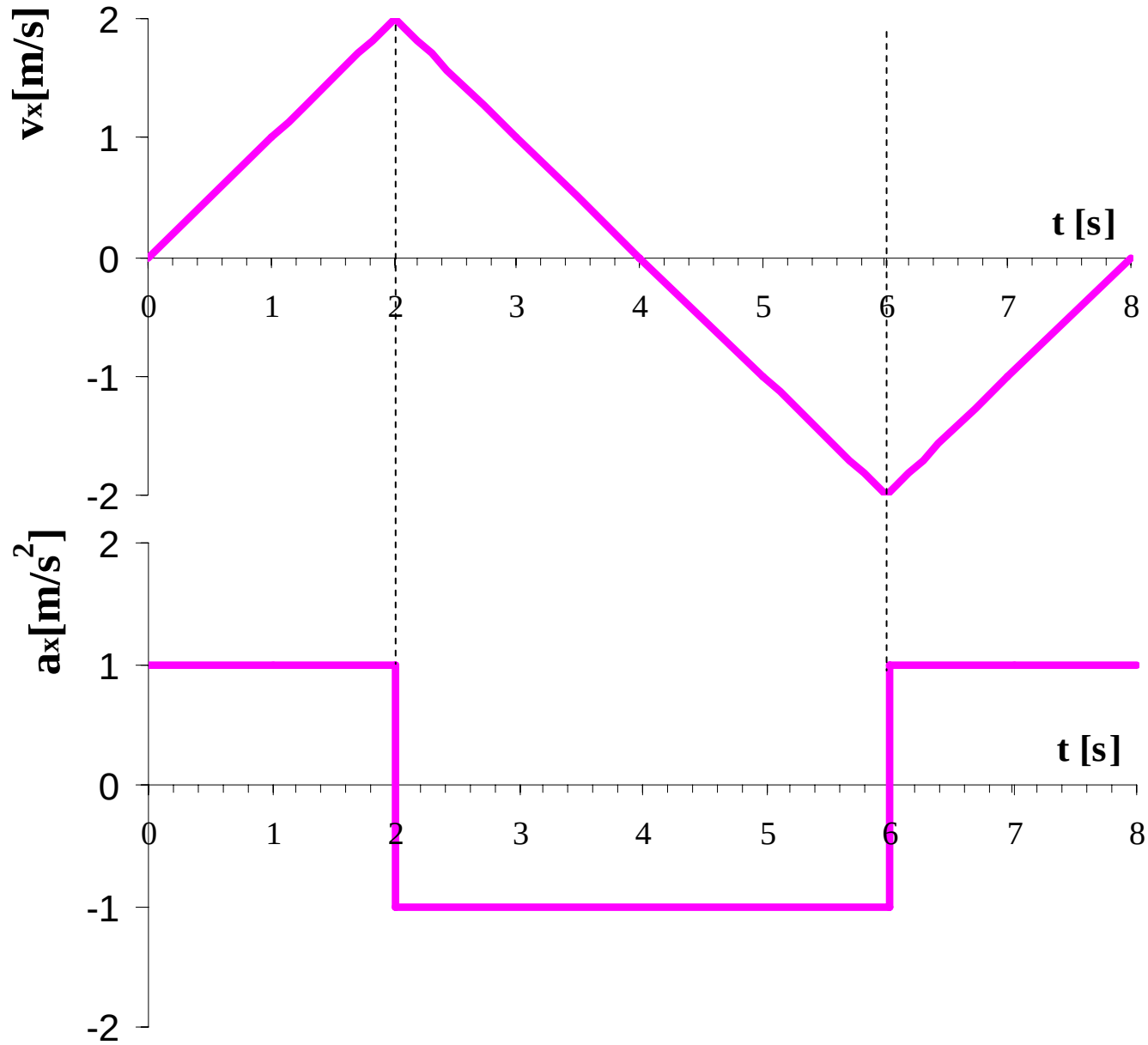


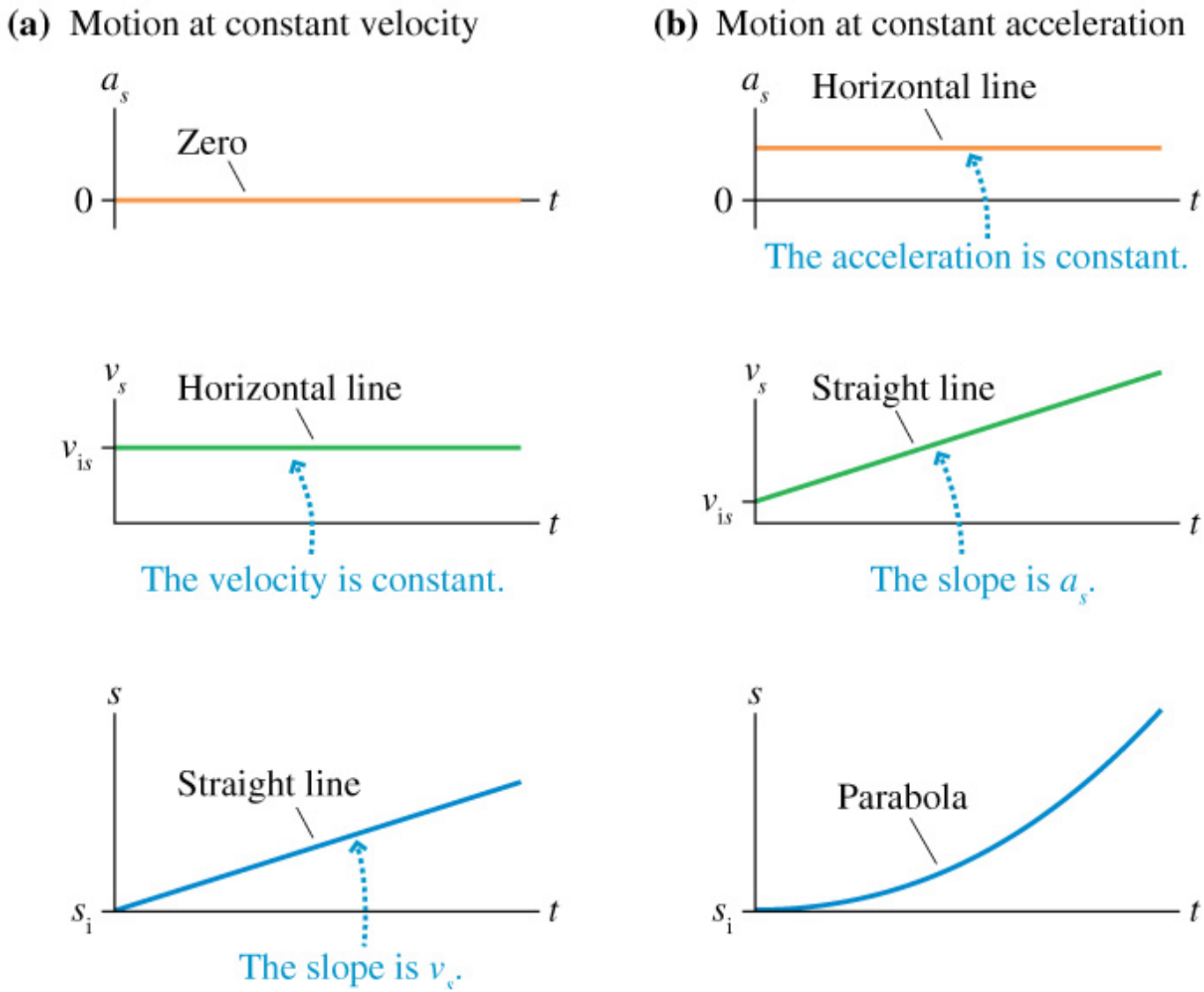
What is the acceleration versus time graph for an object that has this velocity versus time graph?

$$\vec{a}_{avg} = \frac{\Delta \vec{v}_{avg}}{\Delta t}$$ ➔ So look at the slopes



Turning Points means that acceleration changes sign


v_x[m/s]
2
1
0
-1
-2
t [s]
0
1
2
3
4
5
6
7
8
a_x[m/s^2]
2
1
0
-1
-2
t [s]
0
1
2
3
4
5
6
7
8



Going from here to there