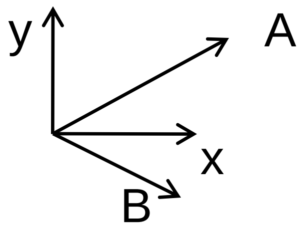
Lecture 5
(Speed and Velocity, Acceleration and Motion in 1D)

Physics 160-01 Fall 2012

Douglas Fields

CPS Question 4-2

- What is $\vec{A}\cdot\left(\vec{A}\times\vec{B}\right)=?$, $\vec{A},\vec{B}$ in the x-y plane



A. 0

B. $\left|\vec{A}\right|^2\left|\vec{B}\right|\sin 45^o$

C. $\left|\vec{A}\right|^2\left|\vec{B}\right|$ in the positive z-direction

D. $\left|\vec{A}\right|^2\left|\vec{B}\right|$ in the negative z-direction

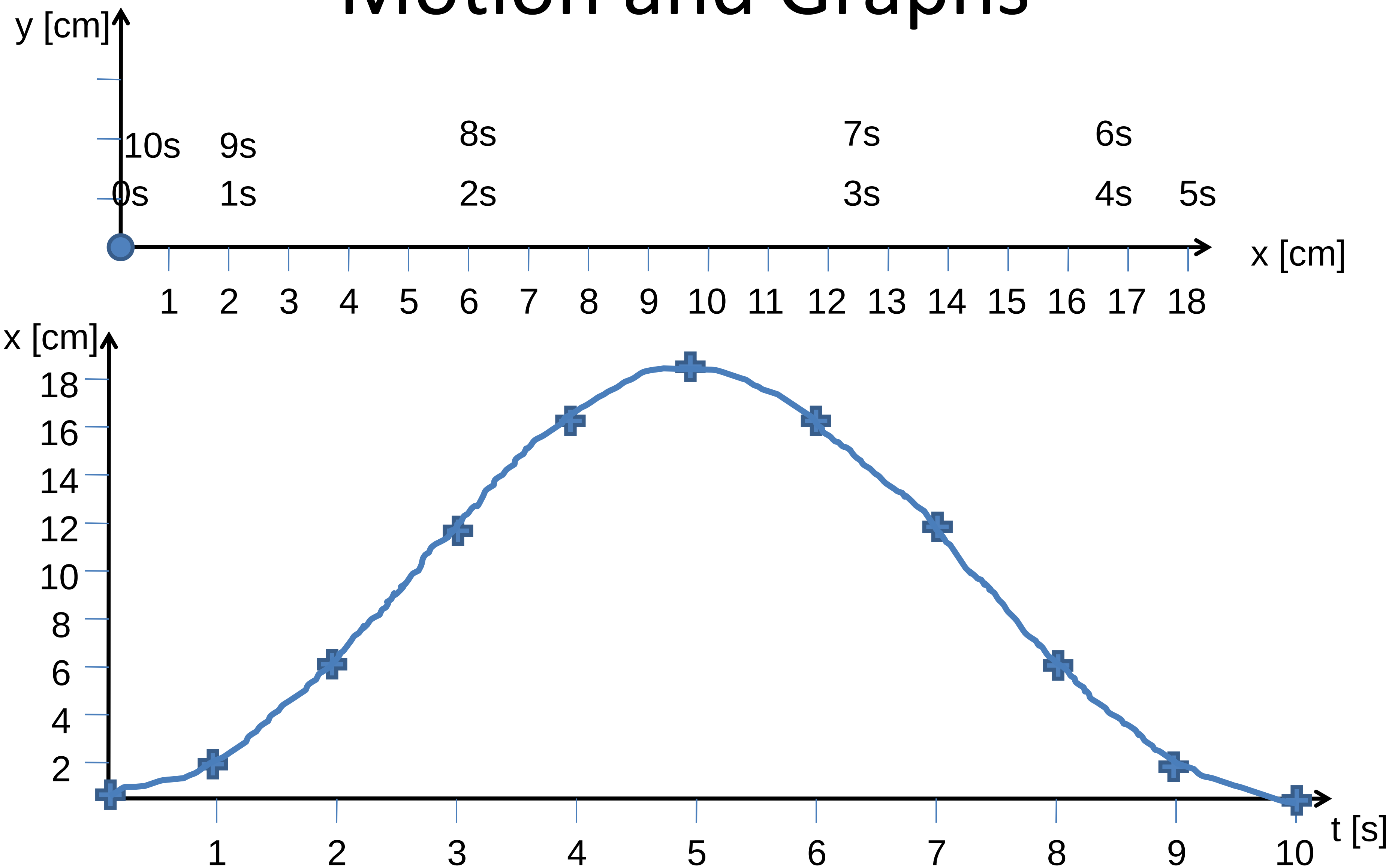
E. not enough information

Motion in One Dimension

- We need to define some terms:

– Distance	(scalar)	[m]
– Displacement	(vector)	[m]
– Speed	(scalar)	[m/s]
– Velocity	(vector)	[m/s]
– Acceleration	(vector)	[m/s^2]
– Time	(scalar)	[s]

Motion and Graphs



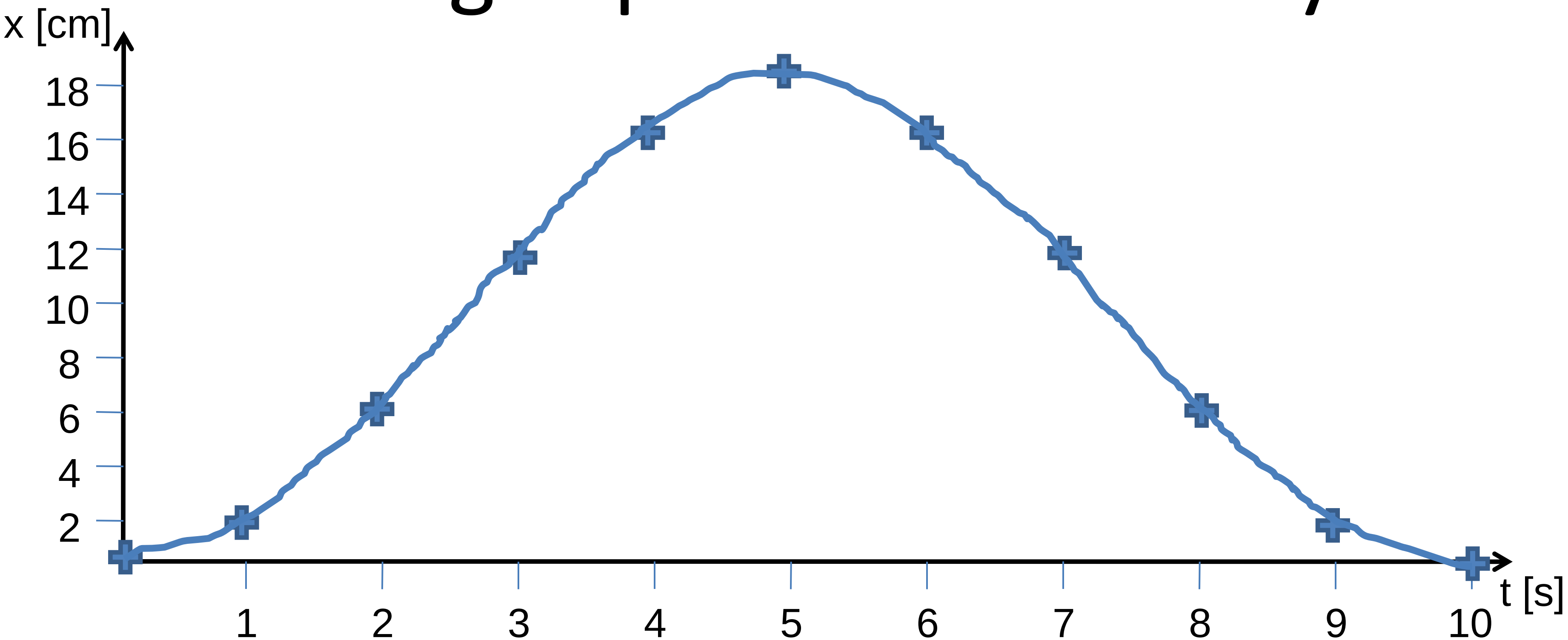
Average Speed and Velocity

- When we talk about speed and velocity, we are referring to changes in distance and displacement over a change in time.
- Important to be specific about these changes:

$$s_{\text{avg}} = \frac{\text{total distance}}{\text{total time}}$$

$$\vec{v}_{\text{avg}} = \frac{\text{total displacement}}{\text{total time}} = \frac{\Delta\vec{x}}{\Delta t} = \frac{\vec{x}_f - \vec{x}_i}{t_f - t_i}$$

Average Speed and Velocity



- What is the average speed from 0 – 5s? From 0 – 10s?
- What is the average velocity from 0 – 5s? From 0 – 10s?

CPS Question 5-1

- Someone walks 100m in what we will call the negative-x direction, then turns around and walks half way back, all at the same pace (speed). It takes 100s to walk the entire path. What is their average velocity?

A. 1.5m/s

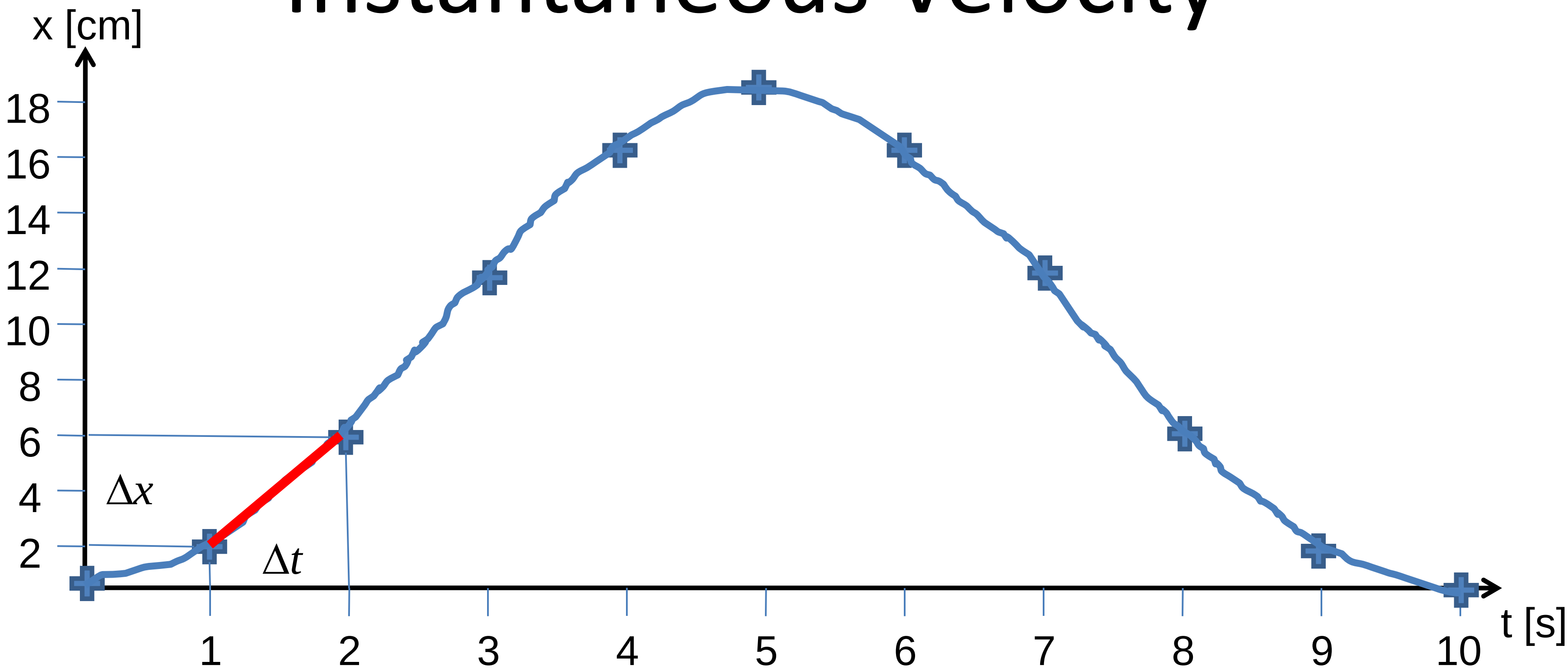
B. 1.5m/s in the +x direction

C. 0.5m/s

D. 0.5m/s in the -x direction

E. 1.0m/s in the -x direction

Instantaneous Velocity

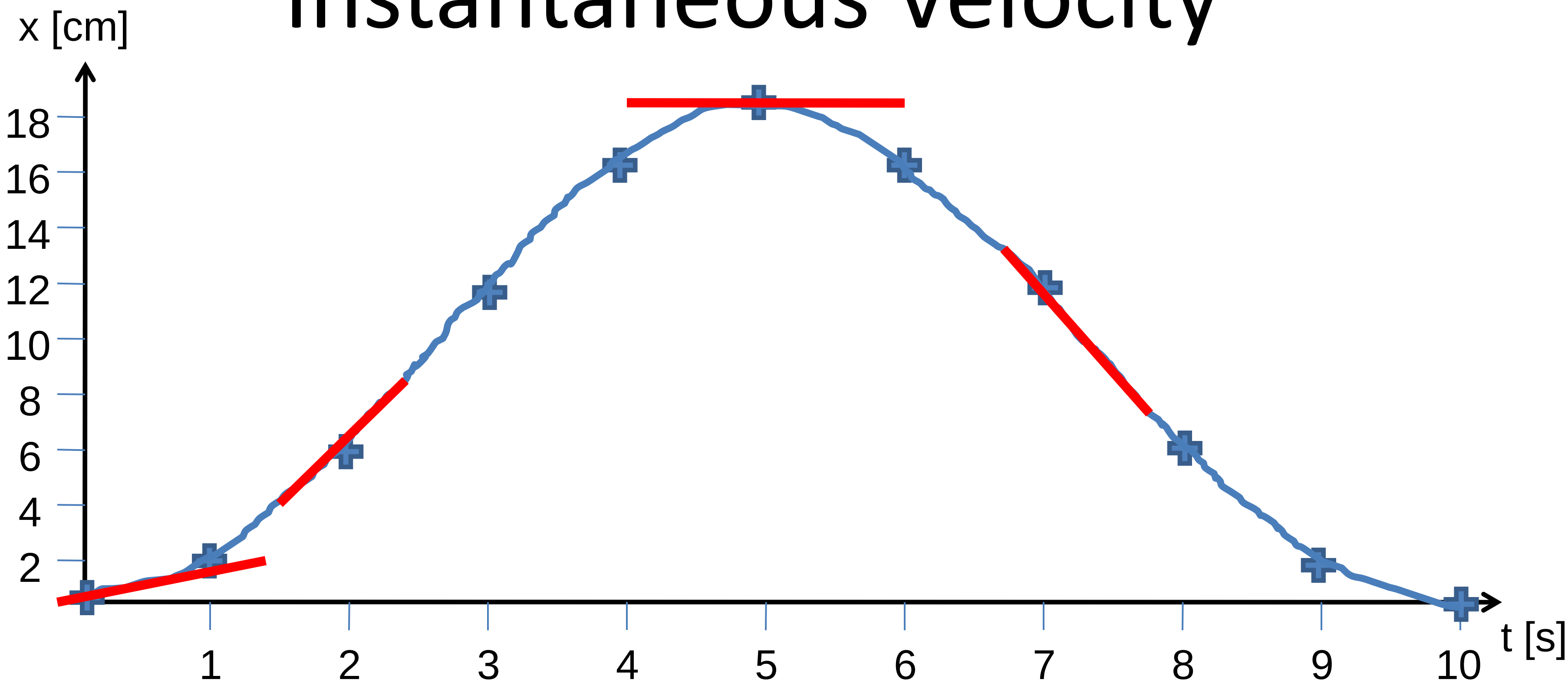


- What is the average velocity from 1 – 2s?

$$\vec{v}_{\text{avg}} = \frac{\Delta\vec{x}}{\Delta t} = \frac{\vec{x}_f - \vec{x}_i}{t_f - t_i} = \frac{(6cm)\hat{i} - (2cm)\hat{i}}{2s - 1s} = \left(4\frac{cm}{s}\right)\hat{i} = \left(4\frac{cm}{s}\right)\left(\frac{1m}{100cm}\right)\hat{i} = \left(0.04\frac{m}{s}\right)\hat{i}$$

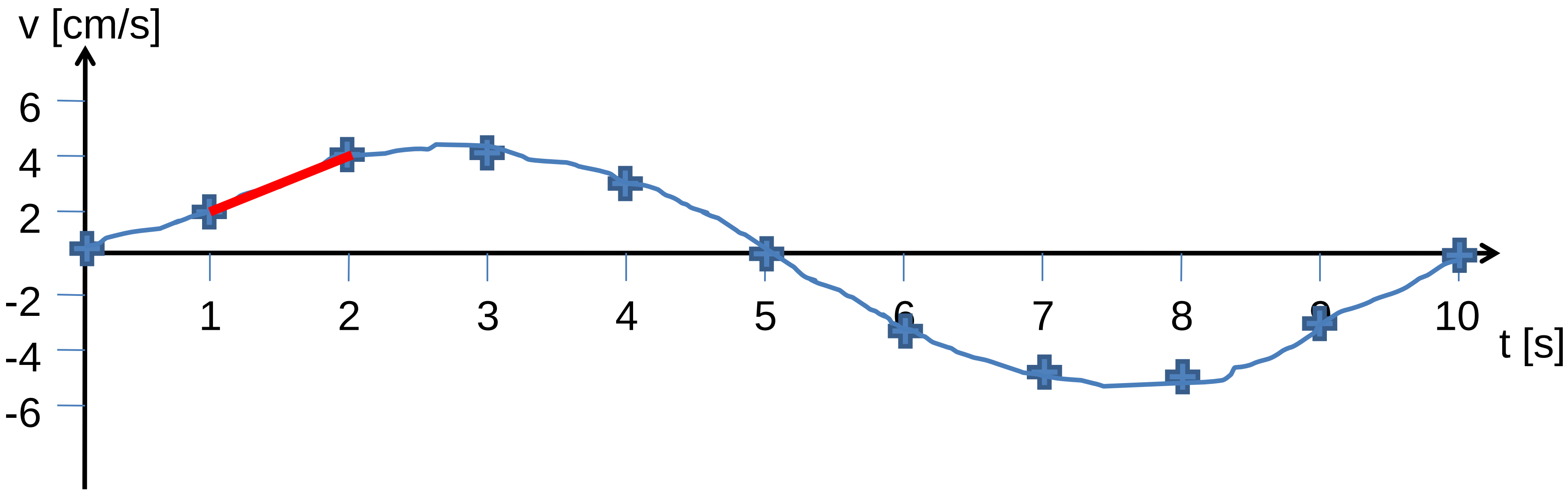
- Note that this is the slope of the line connecting these two points.

Instantaneous Velocity



- What is the velocity at 2s? $\vec{v}(t) = \lim_{\Delta t \to 0} \vec{v}_{\text{avg}} = \lim_{\Delta t \to 0} \frac{\Delta \vec{x}}{\Delta t} \equiv \frac{d\vec{x}}{dt}$
- This is the definition of the derivative of the function that describes the position as a function of time.
- It gives a the slope of the tangent line to the function at any point.

Instantaneous Velocity

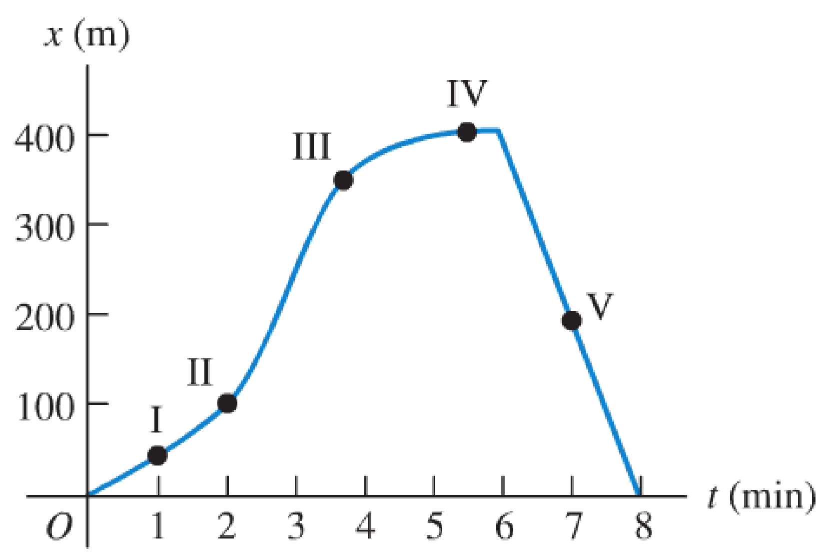


- We can now plot the velocity as a function of time.
- Notice that the velocity also changes.
- So, we can ask, what is the change in velocity as a function of time?
- This is known as the acceleration.

Exercise 2.10

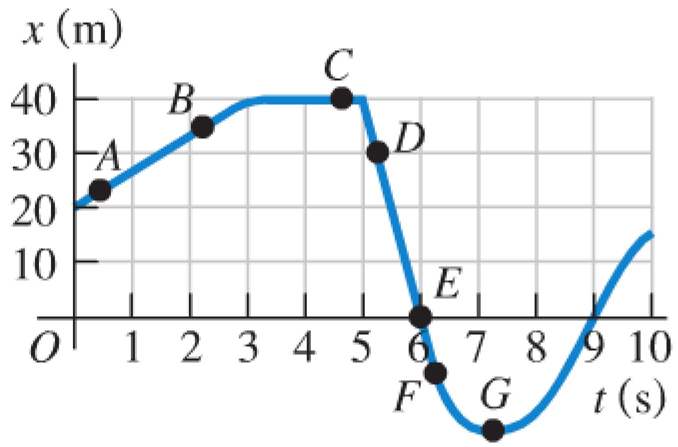
2.10 • A physics professor leaves her house and walks along the sidewalk toward campus. After 5 min it starts to rain and she returns home. Her distance from her house as a function of time is shown in Fig. E2.10. At which of the labeled points is her velocity (a) zero? (b) constant and positive? (c) constant and negative? (d) increasing in magnitude? (e) decreasing in magnitude?

Figure **E2.10**



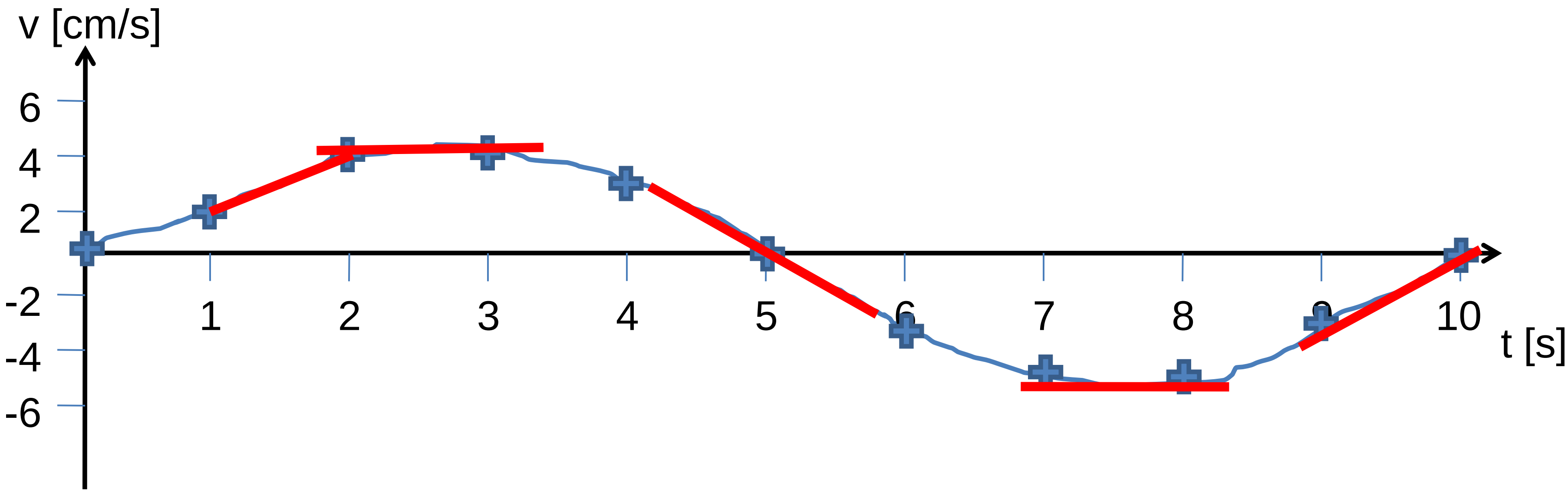
Exercise 2.11

Figure **E2.11**



2.11 •• A test car travels in a straight line along the x-axis. The graph in Fig. E2.11 shows the car's position x as a function of time. Find its instantaneous velocity at points A through G.

Instantaneous Acceleration

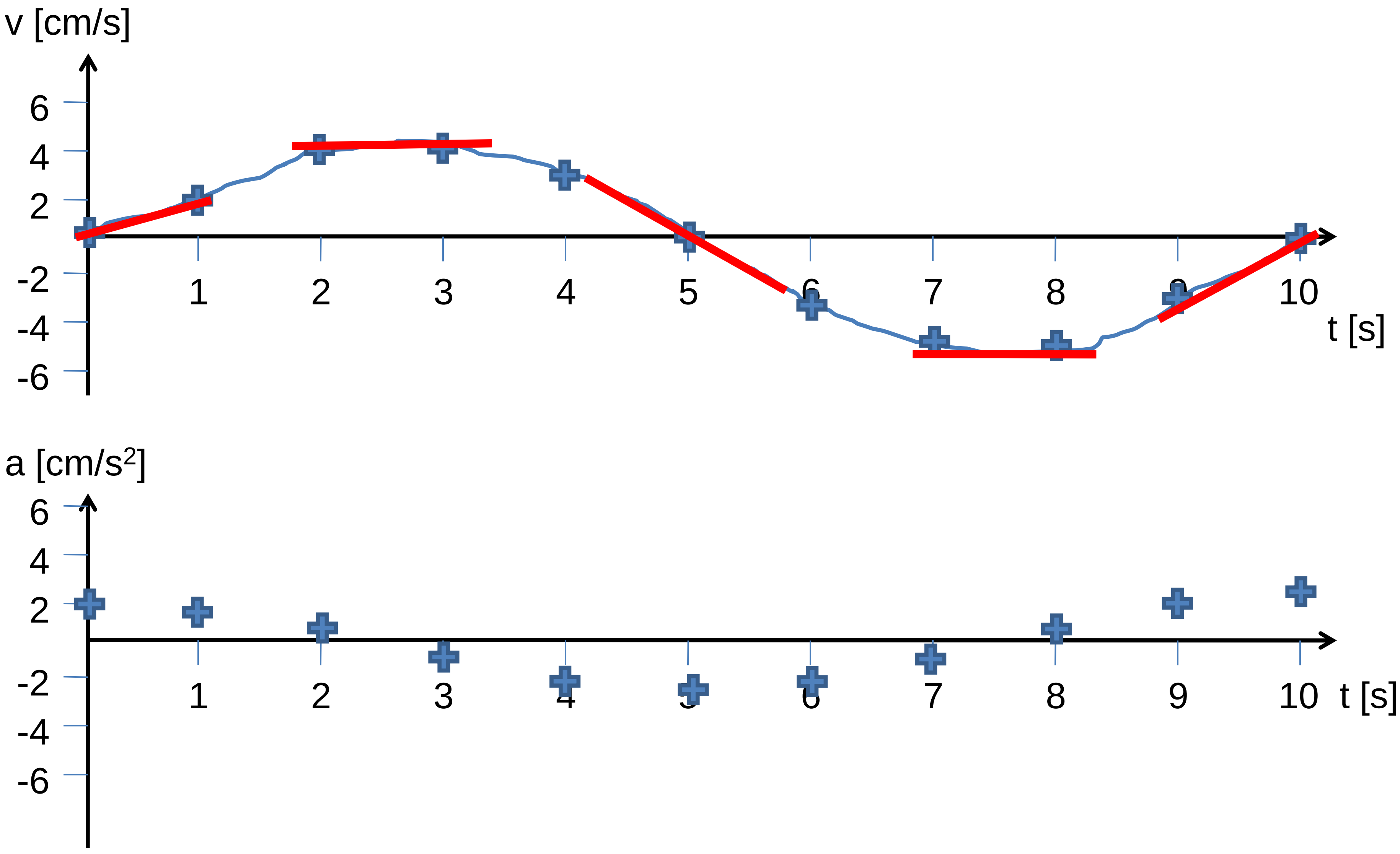


- The acceleration is just given by the derivative of the velocity function.

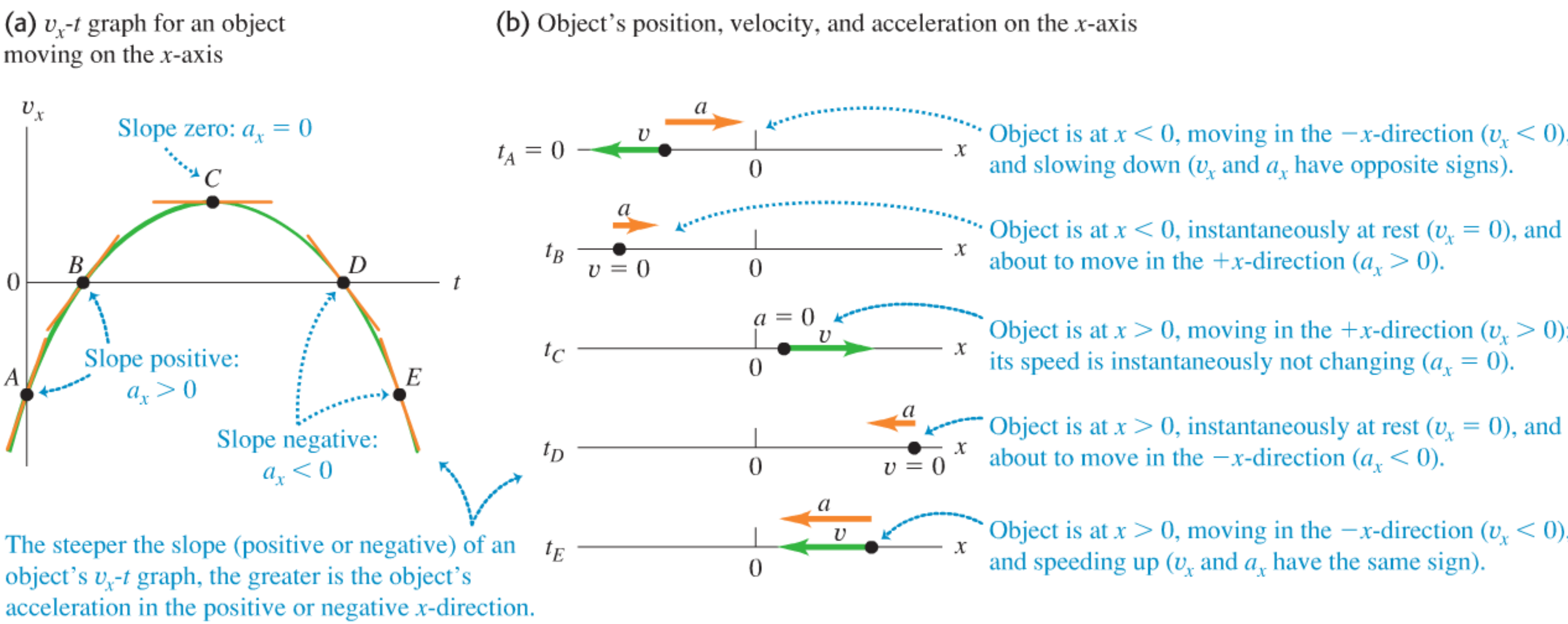
$$\vec{a}(t) = \lim_{\Delta t \to 0} \vec{a}_{\text{avg}} = \lim_{\Delta t \to 0} \frac{\Delta \vec{v}}{\Delta t} \equiv \frac{d\vec{v}}{dt} = \frac{d}{dt}\left(\frac{d\vec{x}}{dt}\right) \equiv \frac{d^2\vec{x}}{dt^2}$$

- So, it is also the second derivative of the position function.

Instantaneous Acceleration



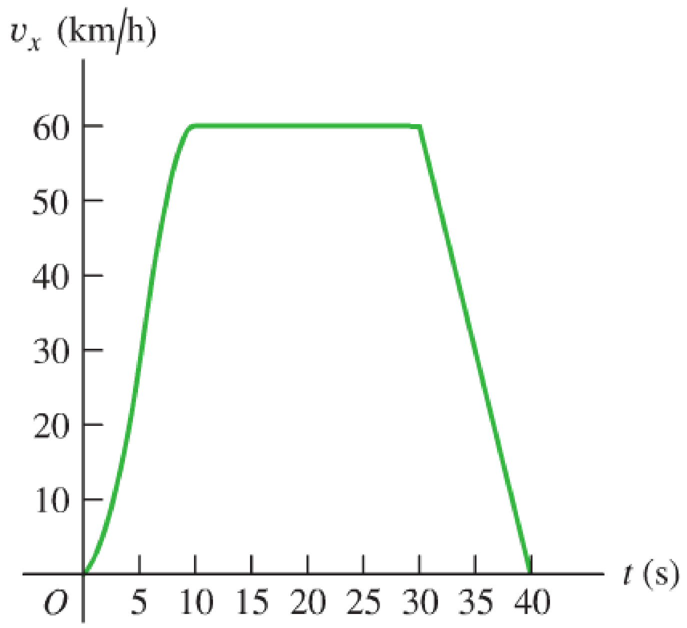
Velocity and acceleration



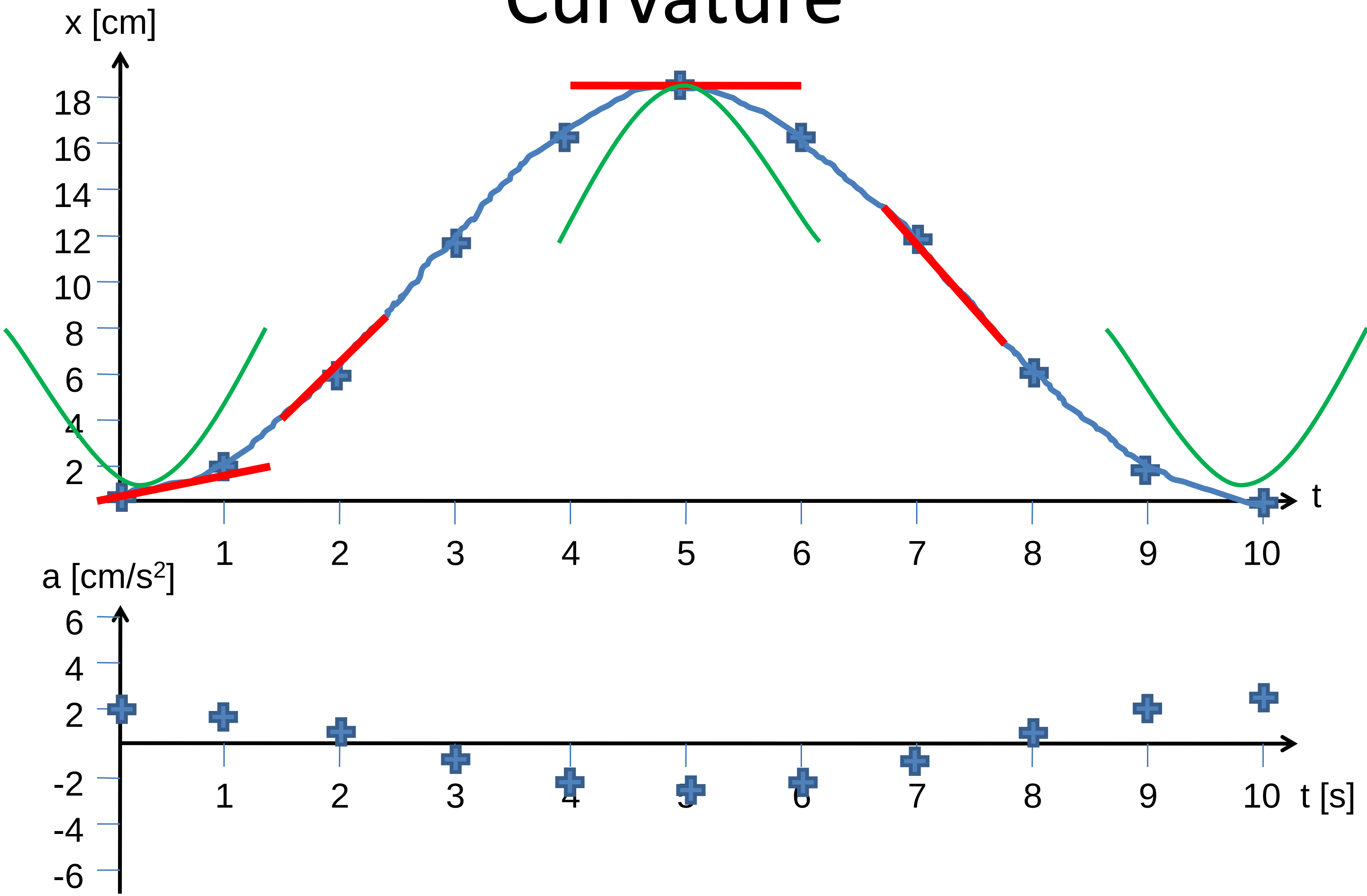
Exercise 2.12

2.12 • Figure E2.12 shows the velocity of a solar-powered car as a function of time. The driver accelerates from a stop sign, cruises for 20 s at a constant speed of 60 km/h, and then brakes to come to a stop 40 s after leaving the stop sign. (a) Compute the average acceleration during the following time intervals: (i) $t = 0$ to $t = 10$ s; (ii) $t = 30$ s to $t = 40$ s; (iii) $t = 10$ s to $t = 30$ s; (iv) $t = 0$ to $t = 40$ s. (b) What is the instantaneous acceleration at $t = 20$ s and at $t = 35$ s?

Figure **E2.12**



Curvature


x [cm]
18
16
14
12
10
8
6
4
2
t
1
2
3
4
5
6
7
8
9
10
a [cm/s²]
6
4
2
-2
-4
-6
1
2
3
4
5
6
7
8
9
10
t [s]

Spherical Cows

- http://en.wikipedia.org/wiki/Spherical_cow
- Milk production at a dairy farm was low, so the farmer wrote to the local university, asking for help from academia. A multidisciplinary team of professors was assembled, headed by a theoretical physicist, and two weeks of intensive on-site investigation took place. The scholars then returned to the university, notebooks crammed with data, where the task of writing the report was left to the team leader. Shortly thereafter the physicist returned to the farm, saying to the farmer "I have the solution, but it only works in the case of spherical cows in a vacuum."