Chapter 2: Motion Along a Straight Line

- ✓ **Position, Displacement and Distance**
- ✓ **Velocity and Speed**
- ✓ **Acceleration**
- ✓ **Finding Displacement and Velocity from Acceleration**
- ✓ **Motion with Constant Acceleration**
- ✓ **Free Fall**

Chapter 2: Motion Along a Straight Line

Session 2:

- ✓ Position, Displacement and Distance
- ✓ Velocity and Speed
- ✓ Acceleration
- ✓ Examples

Introduction

- Mechanics
  - Kinematics — Describe the motion of an object while ignoring the interactions with external agents
  - Dynamics — Relation of motion to its cause
  - Statics — Study of equilibrium

❖ In this chapter, we consider motion in one dimension (along a straight line)

❖ Motion represents a continual change in an object's position.

❖ Types of motion:

Translational (An example is a car traveling on a highway.)

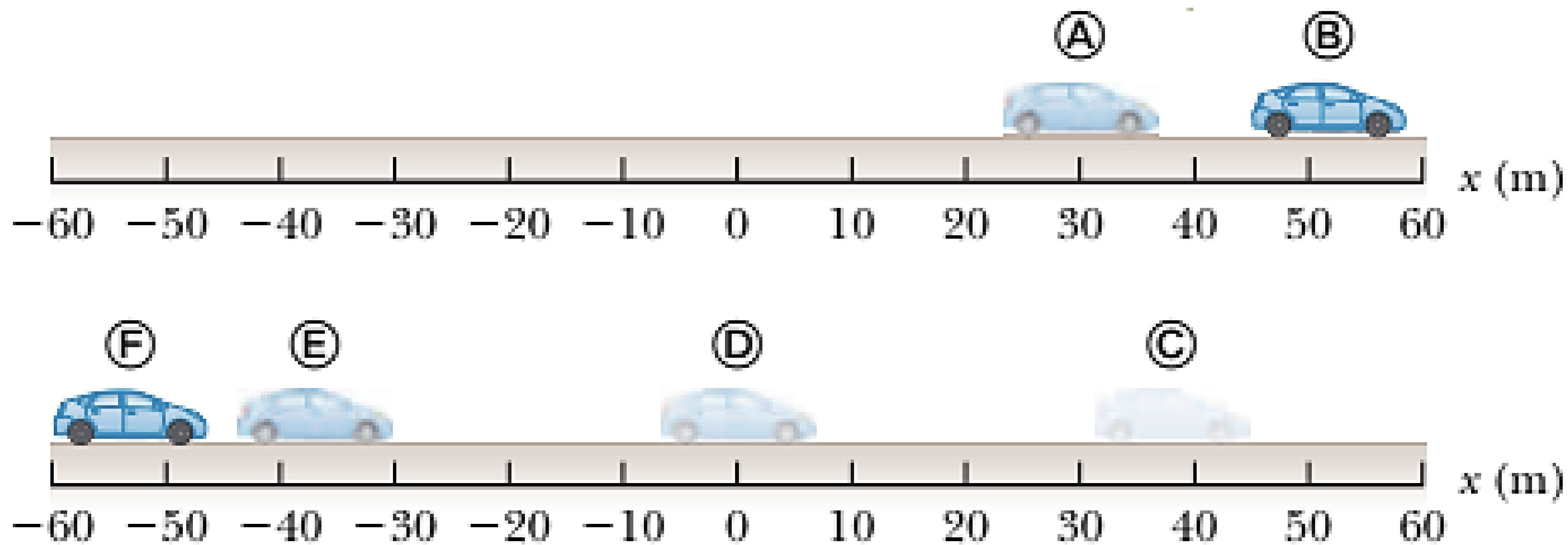
Rotational (An example is the Earth's spin on its axis.)

Vibrational (An example is the back-and-forth movement of a pendulum.)

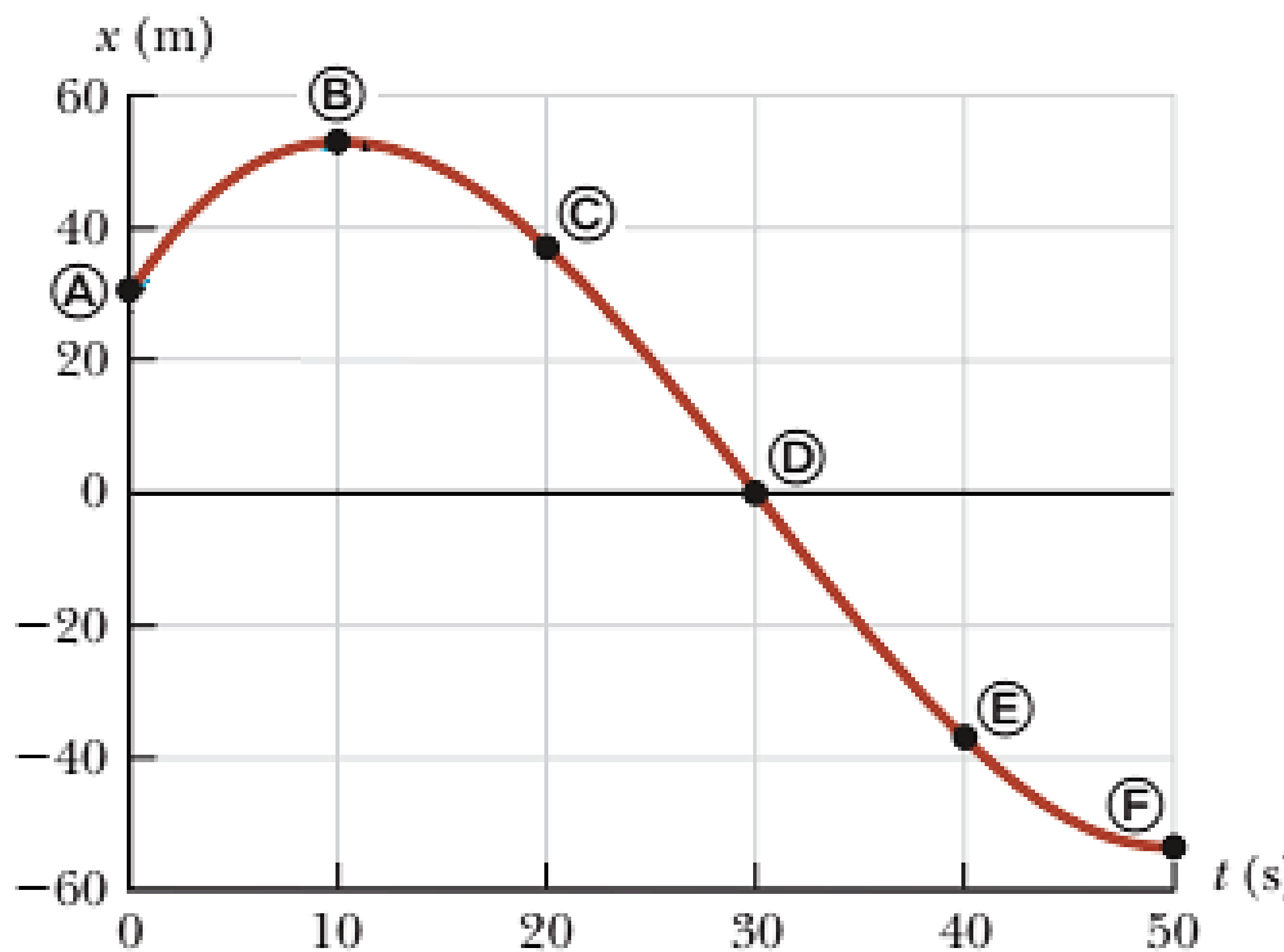
❖ We will use the particle model. A particle is a point-like object; has mass but infinitesimal size

Position

➢ **The object's position is its location with respect to a chosen reference point.**



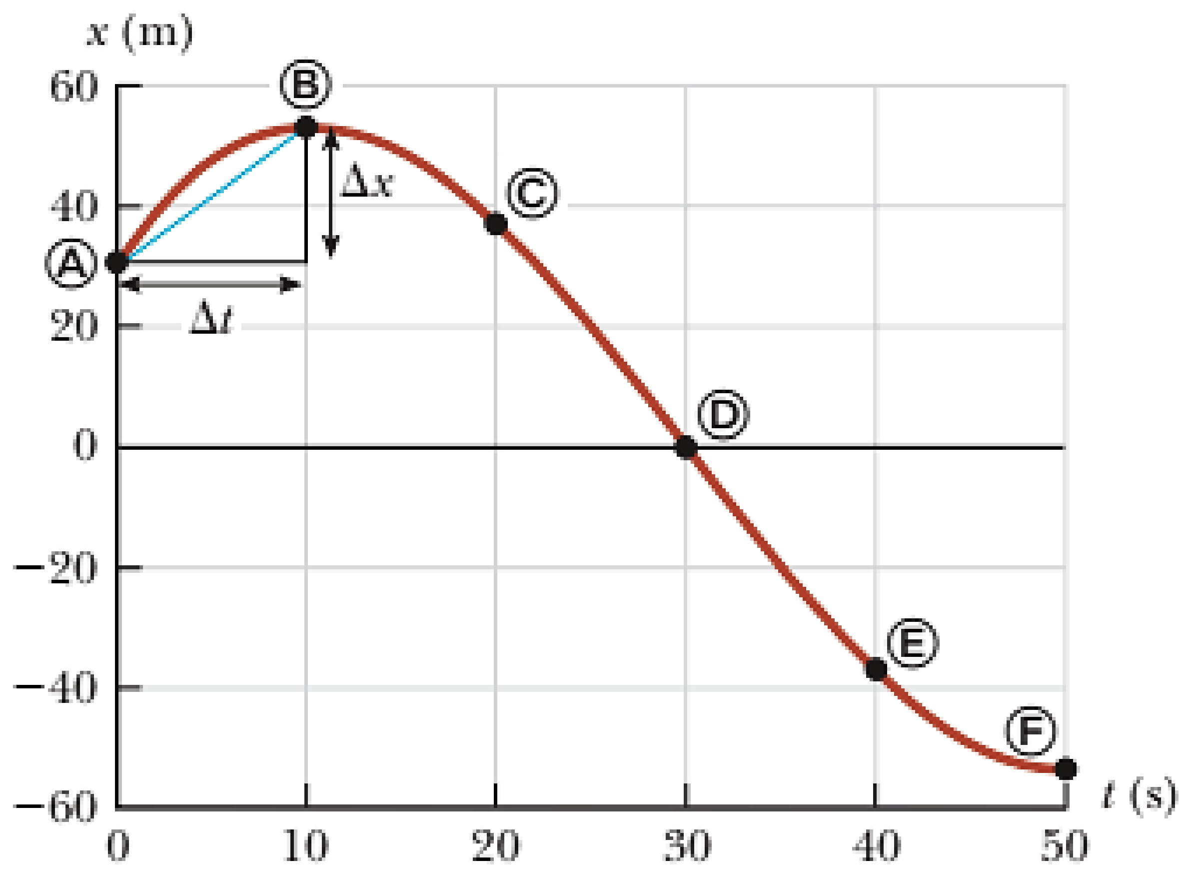
Position	t (s)	x (m)
Ⓐ	0	30
Ⓑ	10	52
Ⓒ	20	38
Ⓓ	30	0
Ⓔ	40	−37
Ⓕ	50	−53



The position-time graph shows the motion of the particle (car).

Displacement and Distance

- ➢ **Displacement is defined as the change in position during some time interval.**
- ➢ **Represented as Δx**
  - $\Delta x \equiv x_f - x_i$
  - **SI units are meters (m)**
  - **Δx can be positive, negative or zero.**



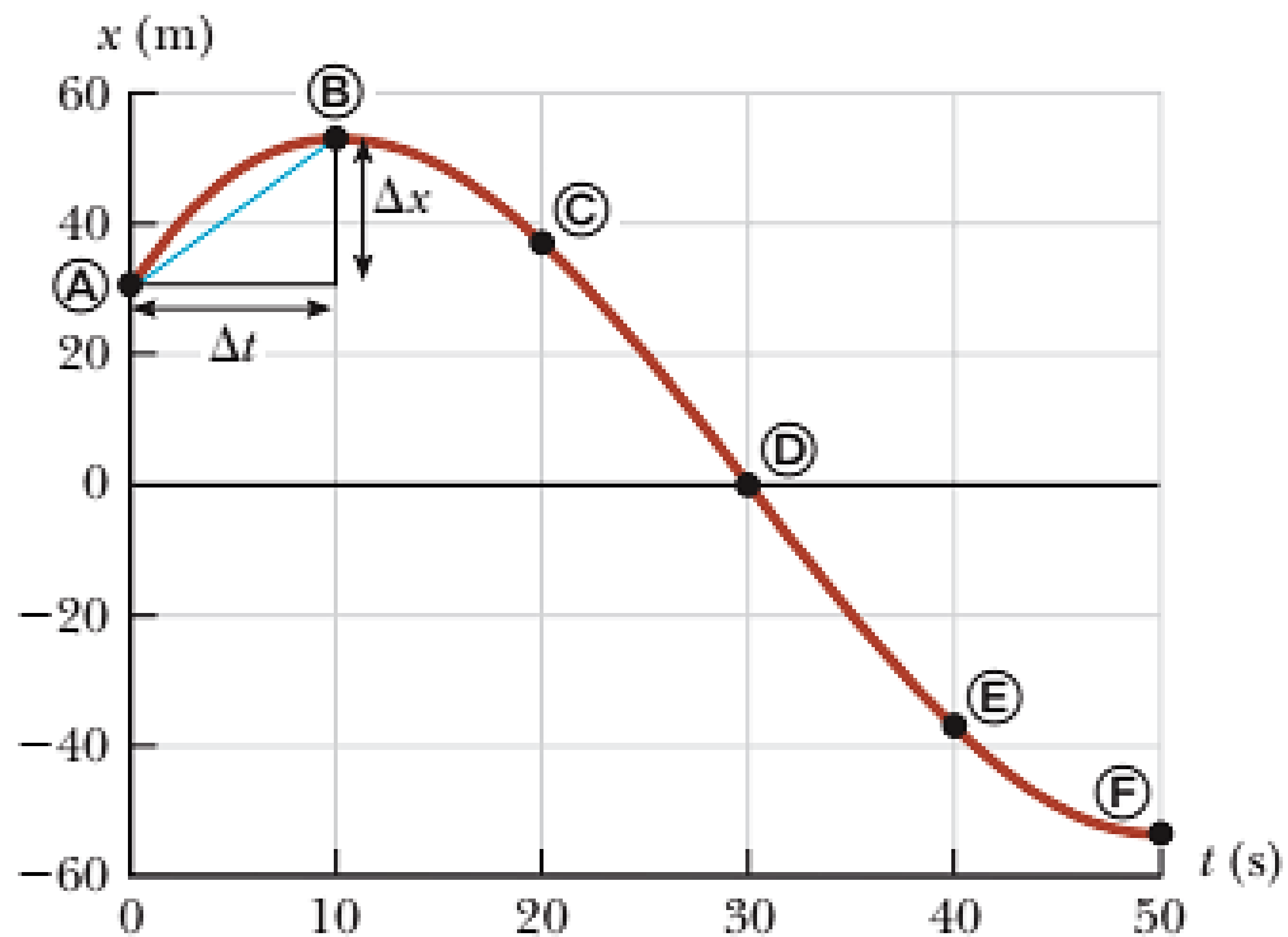
- ➢ **Displacement is different than distance.**
- ➢ **Distance is the length of a path followed by a particle.**
- ➢ **Distance is always positive.**

Velocity and Speed

- The **average velocity** is rate at which the displacement occurs.

$$\boxed{v_{avg} \equiv \frac{\Delta x}{\Delta t} = \frac{x_f - x_i}{\Delta t}}$$

- SI units are (m/s)
- Is also the **slope of the line** in the position – time graph



- **Speed** is a scalar quantity.
- Has the same units as velocity (m/s)
- Defined as total distance / total time:

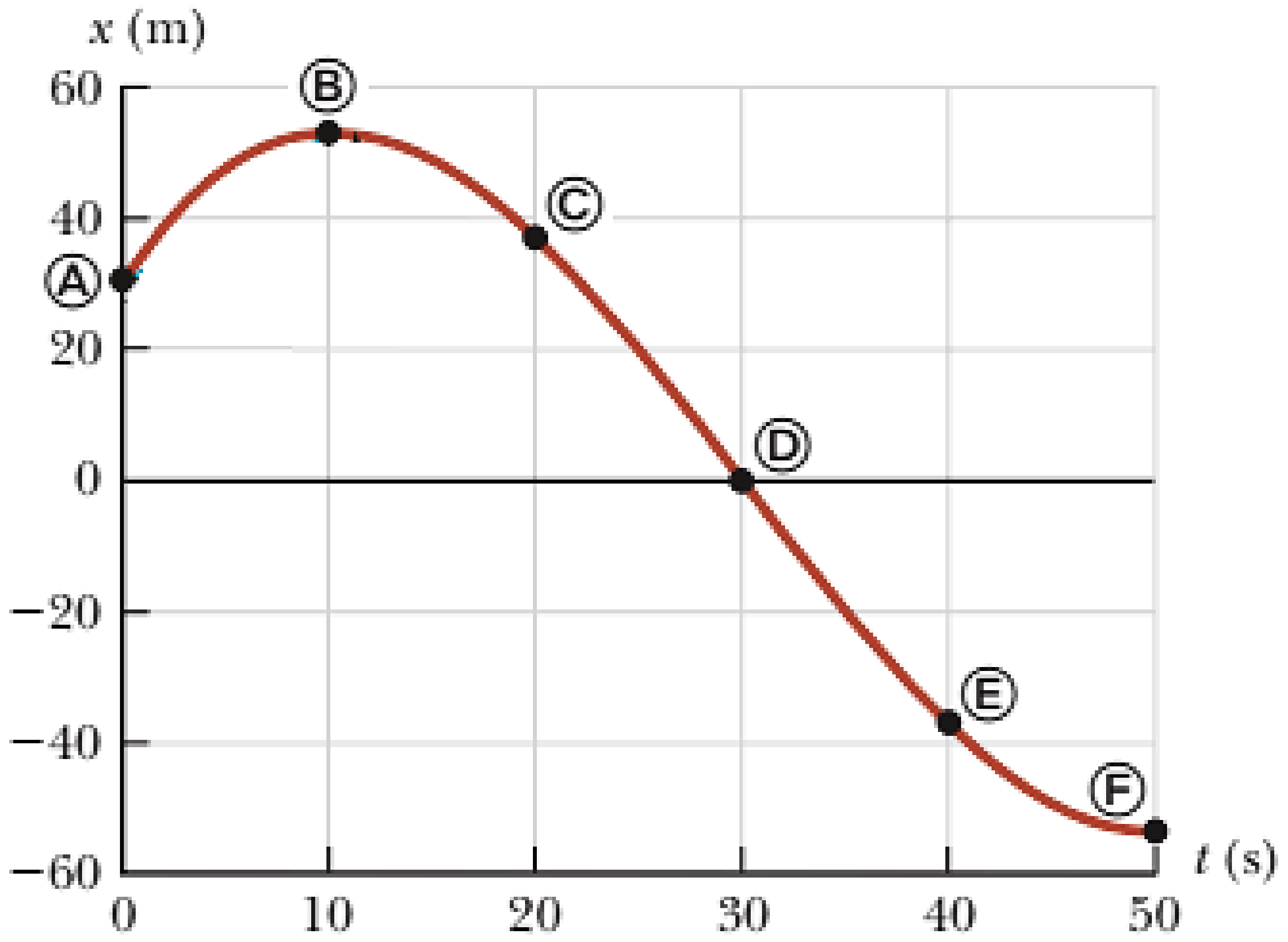
$$\boxed{s_{avg} \equiv \frac{d}{t}}$$

- The average speed is <u>not</u> the magnitude of the average velocity. ($s_{avg} \neq |v_{avg}|$)

Velocity and Speed

Ex 1: Find the average velocity and average speed of the car in between positions A and F.

Position	t (s)	x (m)
Ⓐ	0	30
Ⓑ	10	52
Ⓒ	20	38
Ⓓ	30	0
Ⓔ	40	−37
Ⓕ	50	−53



$$v_{avg} \equiv \frac{\Delta x}{\Delta t} = \frac{x_F - x_A}{\Delta t} = \frac{-53-30}{50} = \frac{-83}{50} = -1.7 \ \ (m/s)$$

$$s_{avg} = \frac{d}{t} = \frac{d_{A-B} + d_{B-F}}{t} = \frac{22+105}{50} = 2.5 \ \ (m/s)$$

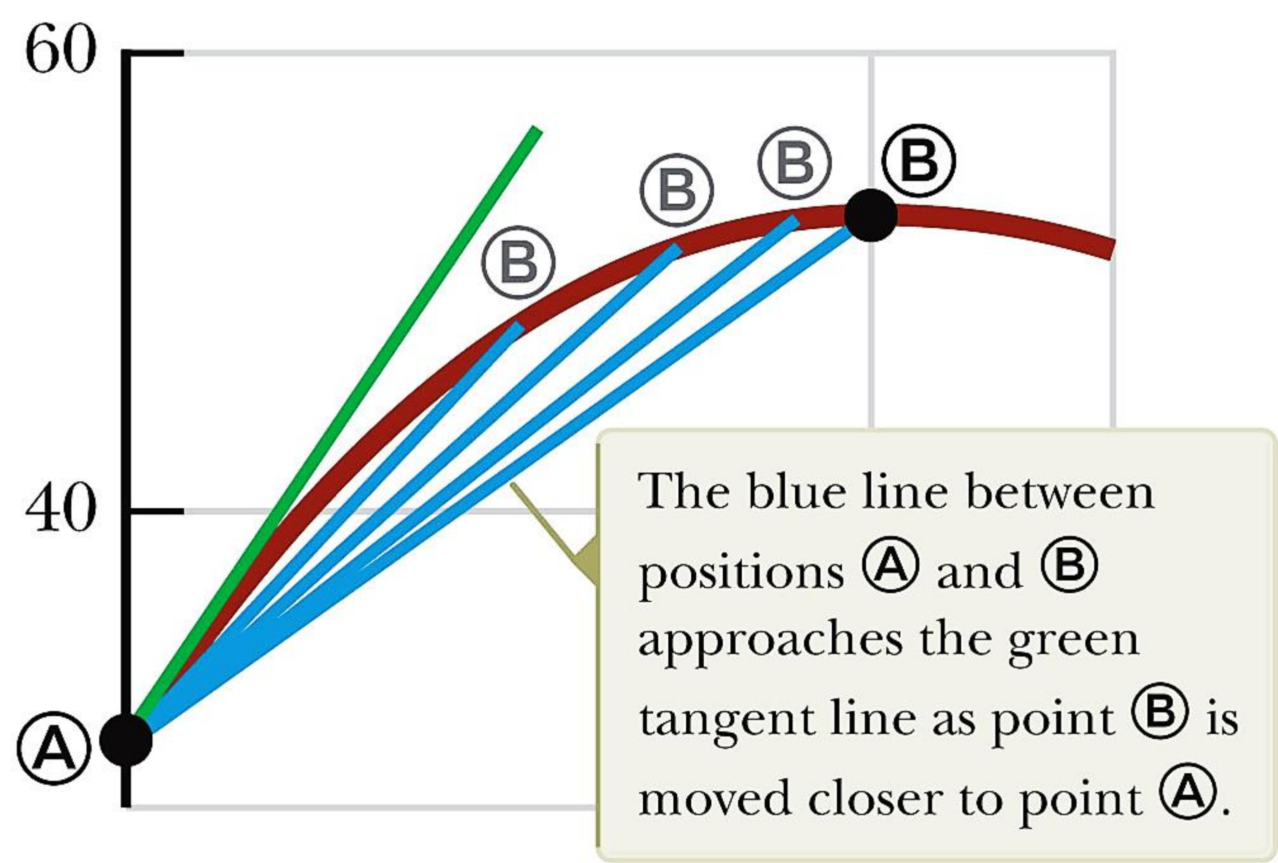
Velocity and Speed

- The instantaneous velocity indicates what is happening at every point of time.

$$\boxed{v=\lim_{\Delta t\to 0}\frac{\Delta x}{\Delta t}=\frac{dx}{dt}}$$

- The instantaneous velocity is the slope of the line tangent to the *x* vs. t curve.

- The instantaneous velocity can be positive, negative, or zero.



- The instantaneous speed is the magnitude of the instantaneous velocity.

Acceleration

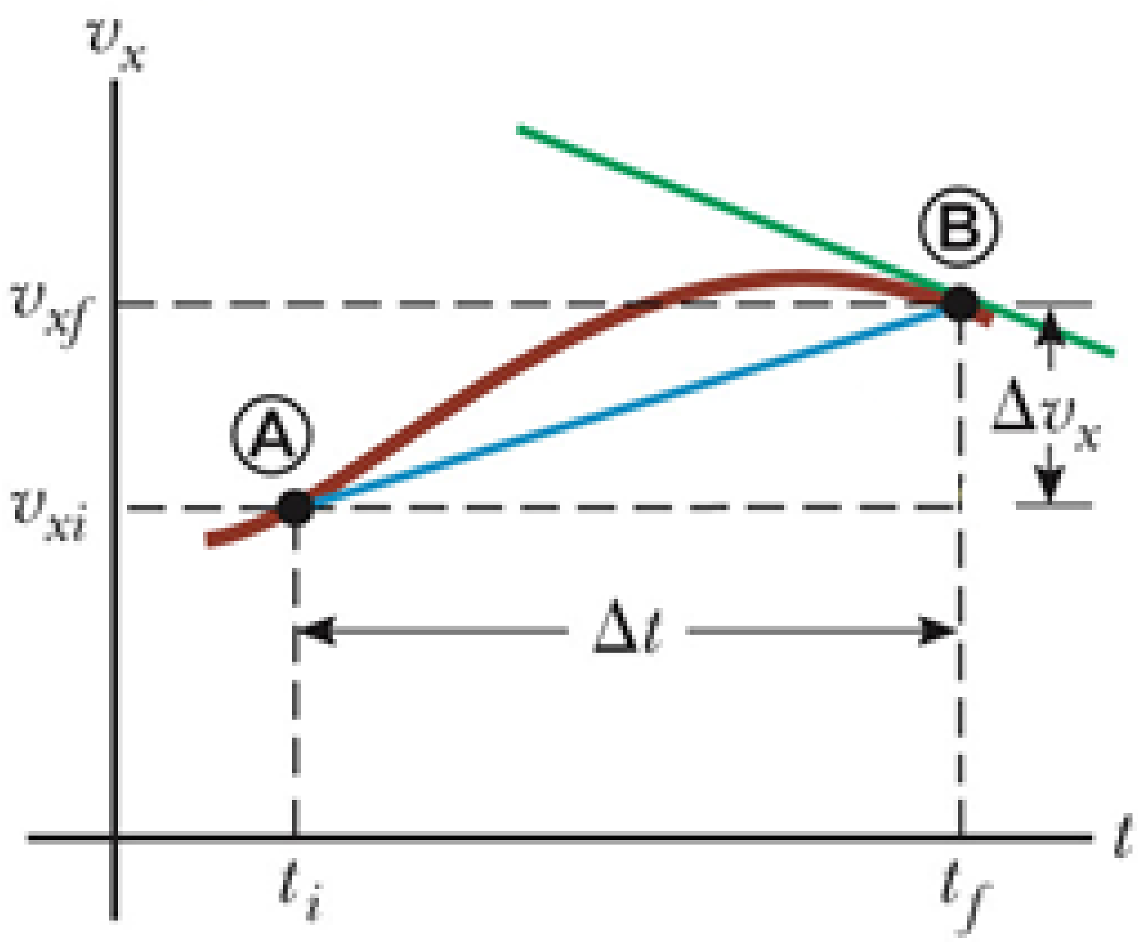
- **Acceleration is the rate of change of the velocity.**

$$a_{avg} \equiv \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{t_f - t_i}$$

- **SI units are m/s²**

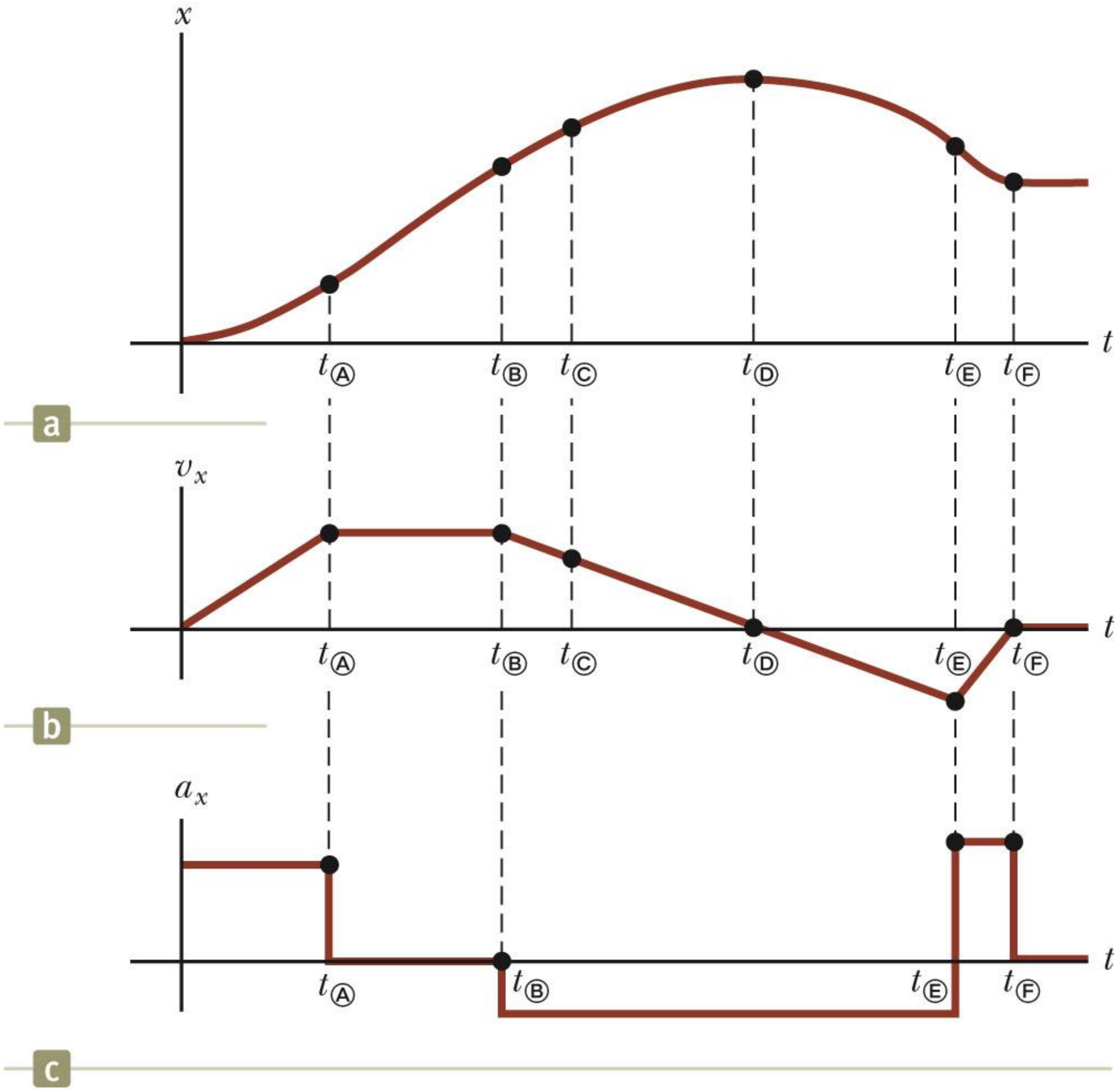
- **The instantaneous acceleration:**

$$a = \lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t} = \frac{dv}{dt} = \frac{d^2 x}{dt^2}$$



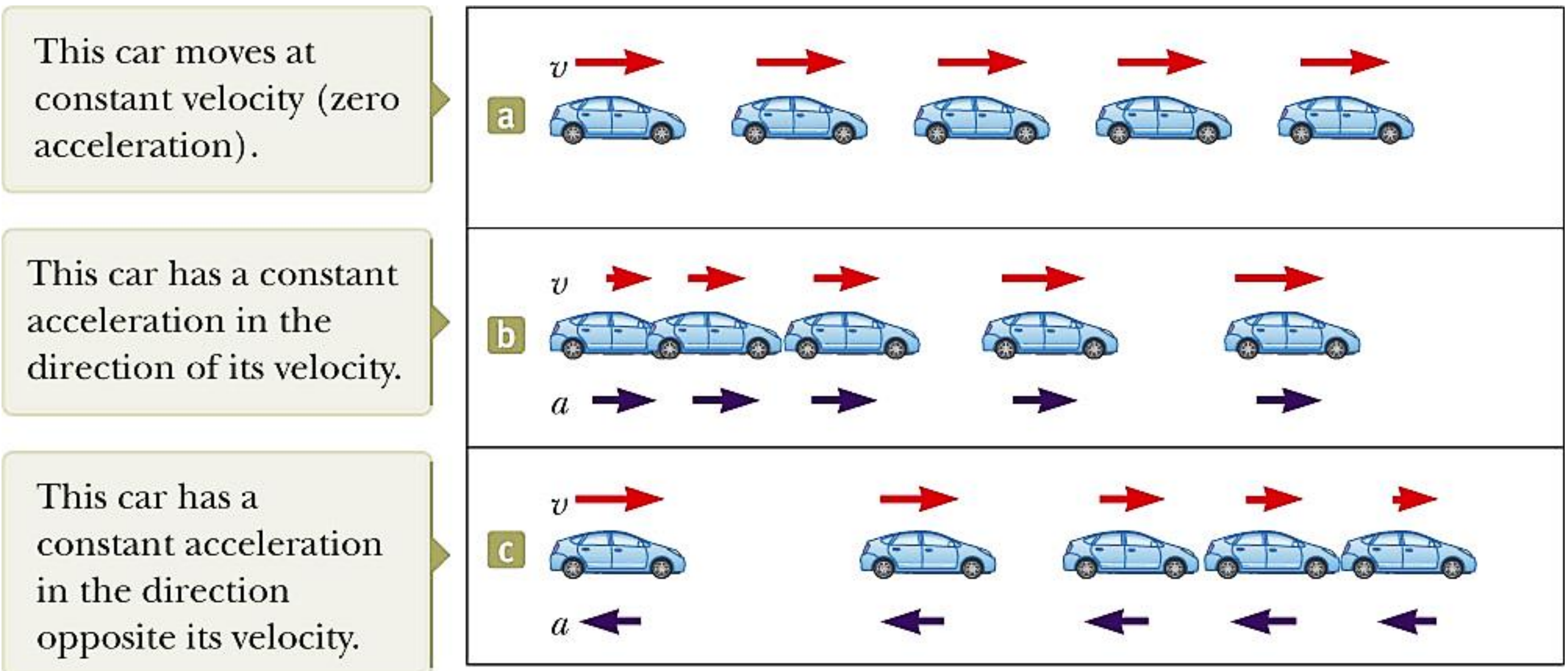
Acceleration

➢ **Graphical Comparison.**



Acceleration

- When an object's velocity and acceleration are in the same direction, the object is speeding up. (v.a > 0)
- When an object's velocity and acceleration are in the opposite direction, the object is slowing down. (v.a < 0)



Ex 2: (Problem 2.2 Halliday)

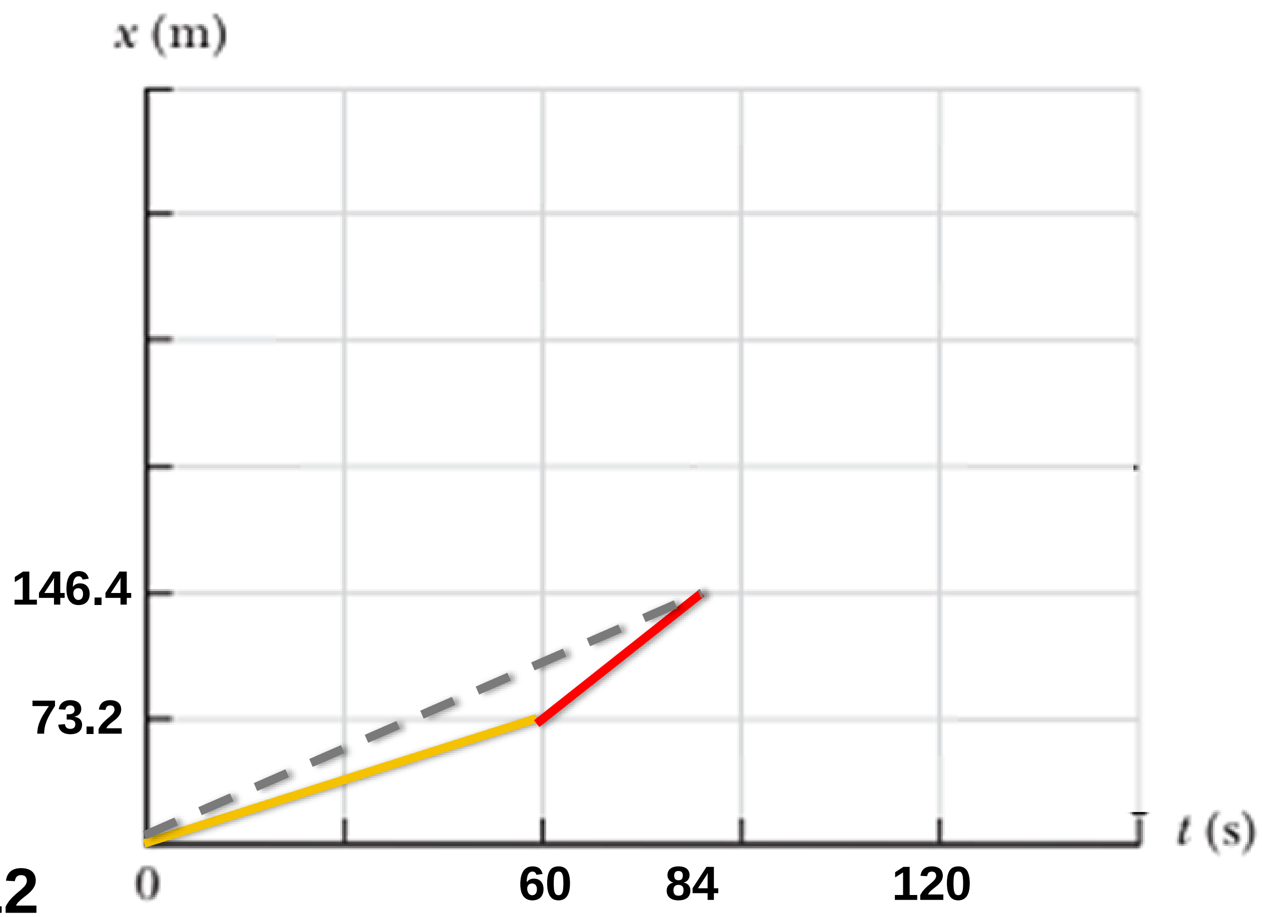
Compute your average velocity in the following two cases:

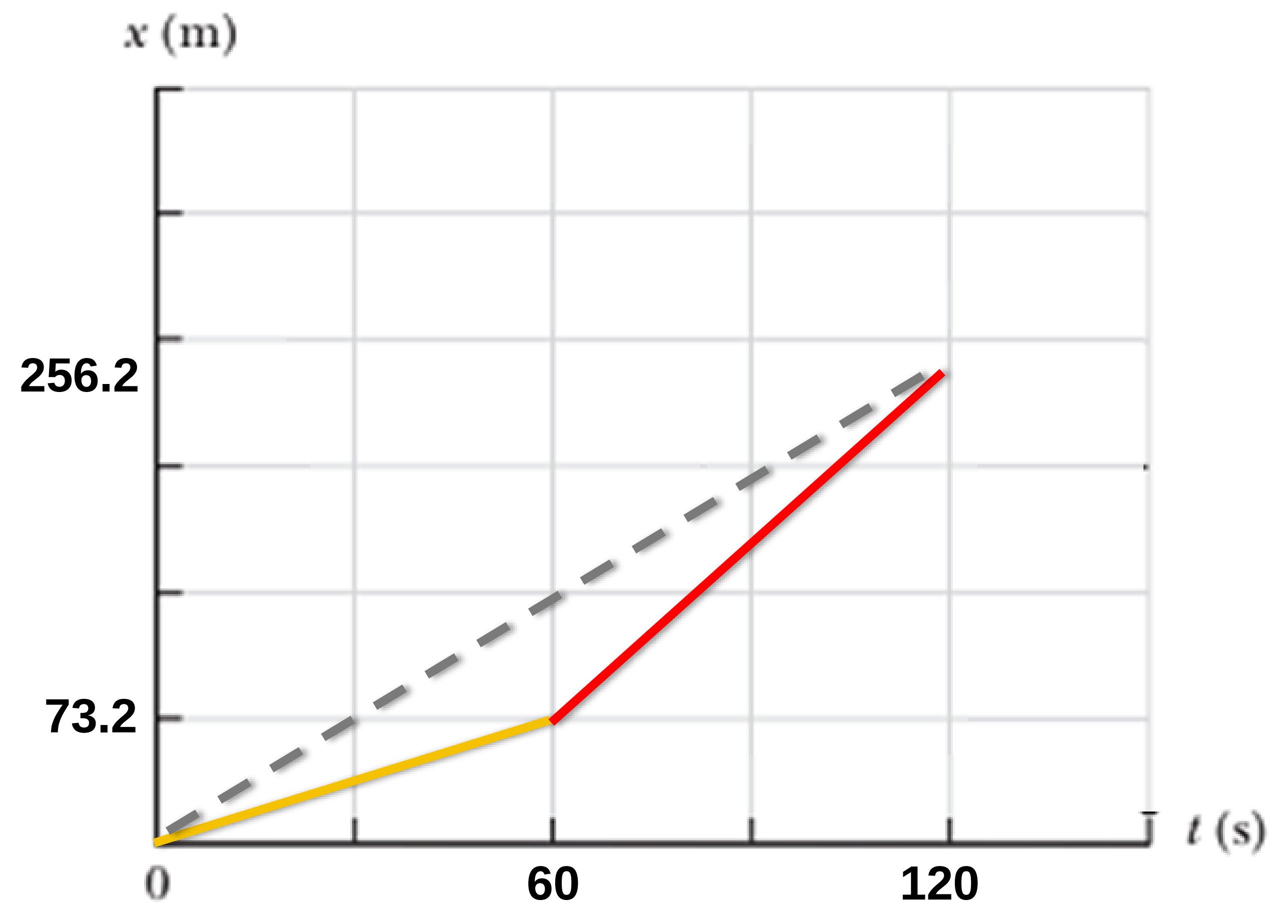
(a) You walk **73.2 m** at a speed of **1.22 m/s** and then run **73.2 m** at a speed of **3.05 m/s** along a straight track. (b) You walk for **1.00 min** at a speed of **1.22 m/s** and then run for **1.00 min** at **3.05 m/s** along a straight track. (c) Graph *x* versus *t* for both cases and indicate how the average velocity is found on the graph.

$$v_{avg} \equiv \frac{\Delta x}{\Delta t} = \frac{\Delta x_1 + \Delta x_2}{\Delta t_1 + \Delta t_2}$$

$$v_{avg} \equiv \frac{73.2+73.2}{\dfrac{73.2}{1.22}+\dfrac{73.2}{3.05}} = \frac{73.2+73.2}{60+24} = 1.74 \quad m/s$$

$$v_{avg} \equiv \frac{1.22(60)+3.05(60)}{60+60} = \frac{73.2+183}{60+60} = 2.14 \quad m/s$$





Ex 3: (Problem 2.22 Halliday)

The position of a particle moving along the x axis depends on the time according to the equation **x = ct² - bt³**, where x is in meters and t in seconds. What are the units of (a) constant **c** and (b) constant **b**? Let their numerical values be **3.0** and **2.0**, respectively. (c) At what time does the particle reach its maximum positive x position? From **t = 0.0 s** to **t= 4.0 s**, (d) what is its average velocity and (e) average speed?. Find its acceleration at times (e) **0.0 s** and (f) **1.0 s**.

$$\boxed{c:(\frac{m}{s^2})\ ;\ b:(\frac{m}{s^3})}$$

$$x = 3t^2 - 2t^3 \Rightarrow \boxed{v = \frac{dx}{dt} = 6t - 6t^2}$$

$$\boxed{v = 6t - 6t^2 = 0 \Rightarrow 6t(1-t) = 0 \Rightarrow t = 0, t = 1s}$$

$$\boxed{\Delta x = x(t=4) - x(t=0) = -80 - 0 = -80\,m}$$

$$\boxed{d = 1 + 1 + 80 = 82\,m}$$

$$\left\{ \boxed{\begin{array}{l} v_{avg} \equiv \dfrac{\Delta x}{\Delta t} = \dfrac{-80}{4} = -20\ m/s \\ s_{avg} \equiv \dfrac{d}{\Delta t} = \dfrac{82}{4} = 20.5\ m/s \end{array}} \right.$$

$$\boxed{a = \frac{dv}{dt} = 6 - 12t \Rightarrow a(t=0) = 6\ m/s^2\ ,\ \ a(t=1) = -6\ m/s^2}$$