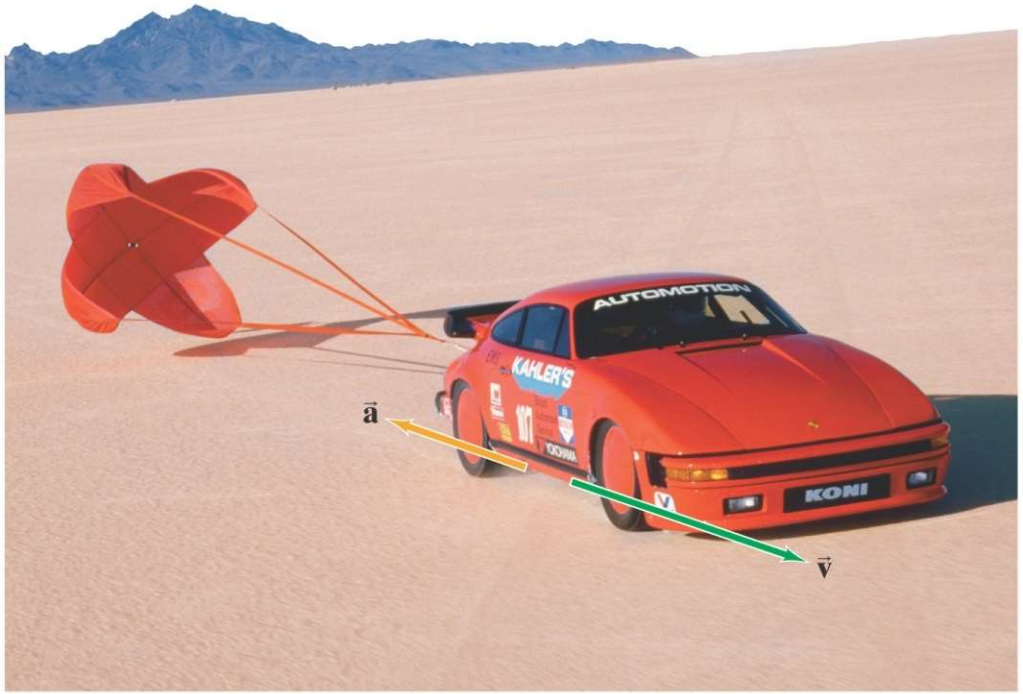
Lecture #2

Chapter 2
Motion in a Straight Line

2.1 Average Motion
2.2 Instantaneous Velocity
2.3 Acceleration



Physics of Motion

- Two Branches
  - **Kinematics**: deals with the concepts that are needed to describe motion, without any reference to forces (displacement, velocity, acceleration)
  - **Dynamics**: deals with the effect that forces have on motion (Force, mass, acceleration)
- Types of Motion
  - Translation
  - Rotation
  - Vibration

Kinematics

(is the description of motion)

It is the study of motion
without regard for the forces
causing the motion

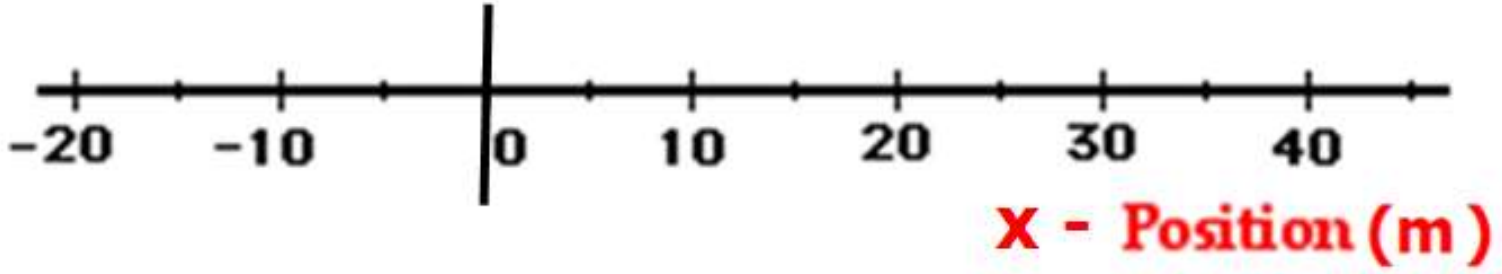
- Kinematic variables (position, velocity and acceleration)
- the **position** of an object is simply its location in space
  - changes in position can be described by **displacement**
- the **velocity** of an object is how fast it is changing its position
- the **acceleration** of an object is how fast the velocity is changing

Symbols, variables, and Units

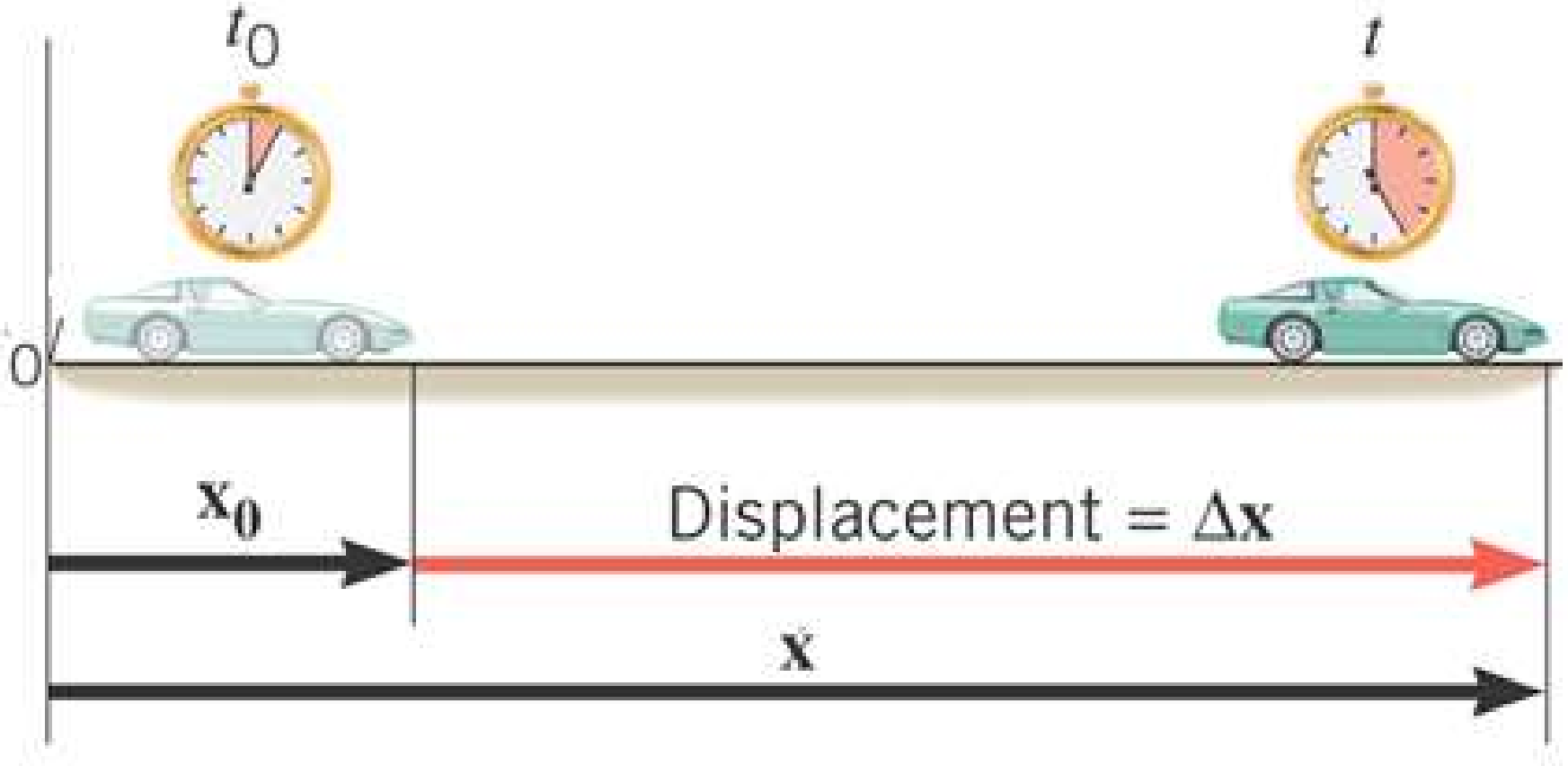
Symbol	Variable	Units
t	Time	s
a	Acceleration	m/s^2
x or y	Position	m
v_o	Initial velocity	m/s
v	Final velocity	m/s
g	Acceleration due to gravity	m/s^2

2.1 Average Motion

- Restrictions
  - Point mass motion (no rotation)
  - Restricted motion along one direction (x-axis)
- Reference Frames
  - Any measurement of position, distance, or speed must be made with respect to a reference frame.



Displacement

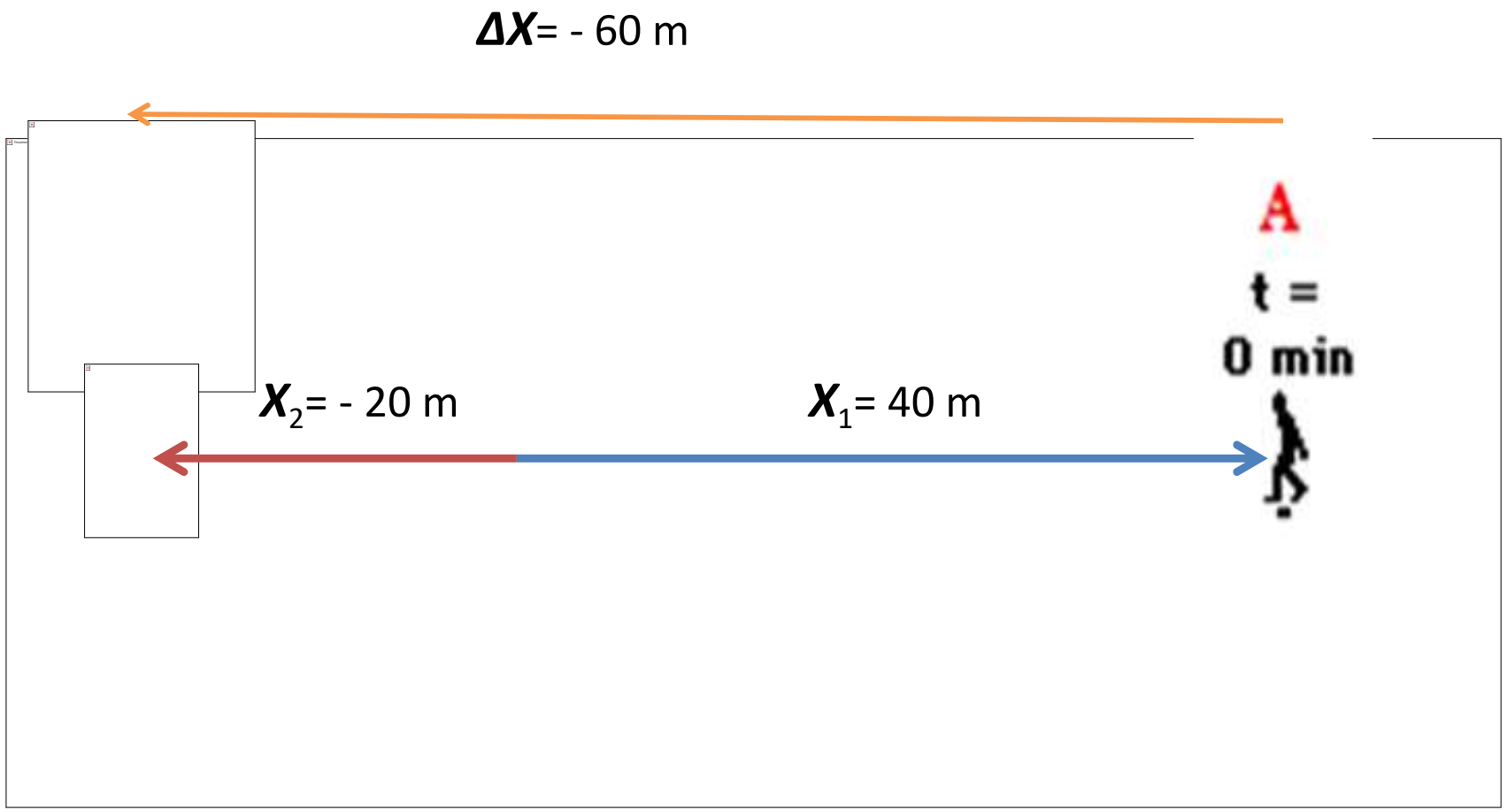


x_o = initial position x = final position

$$\Delta x = x - x_o = \text{displacement}$$

SI Unit of Displacement: meter (m)

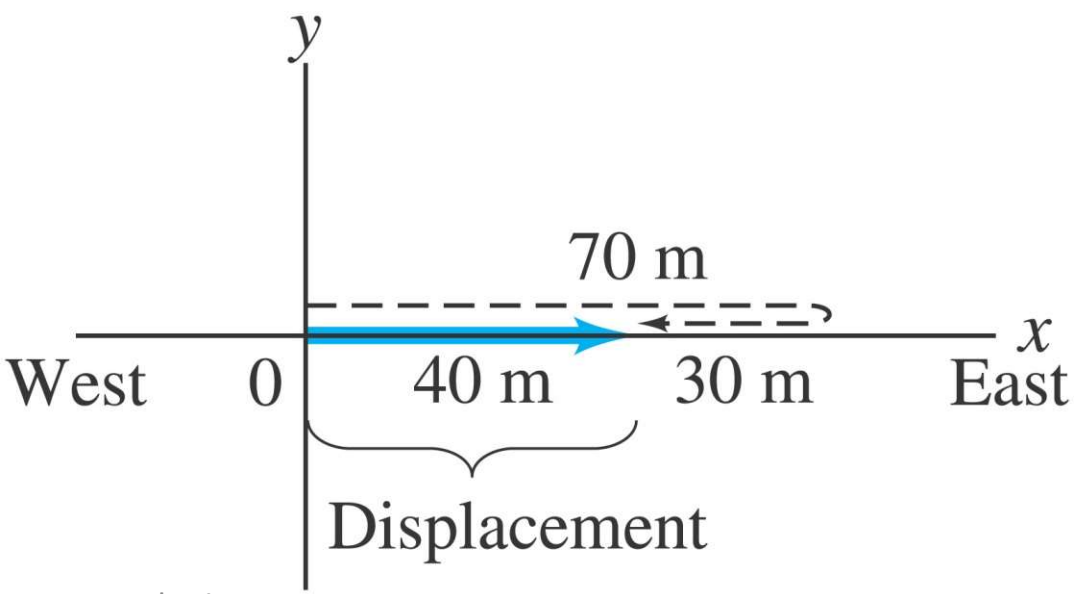
Example : Position and displacement



$$Displacement : \Delta x = x_2 - x_1 \qquad = \text{-20 -40 =-60 m}$$

Distance vs. Displacement

- We make a distinction between distance and displacement.
- Displacement (blue line) is how far the object is from its starting point, regardless of how it got there.
- Distance traveled (dashed line) is measured along the actual path.

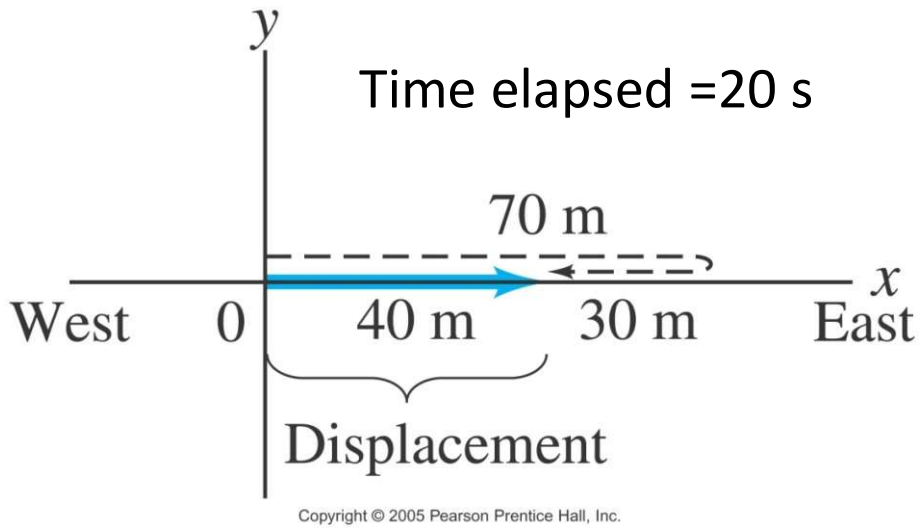


Average Velocity and average speed

$$\text{Average velocity} = \frac{\text{Displacement}}{\text{Elapsed time}}$$

$$\bar{v} = \frac{x - x_o}{t - t_o} = \frac{\Delta x}{\Delta t} = \frac{40\ m}{20\ s} = 2\ \text{m/s}$$

$$\bar{S} = \frac{d}{t - t_o} = \frac{100\ m}{20\ s} = 5\ m/s$$

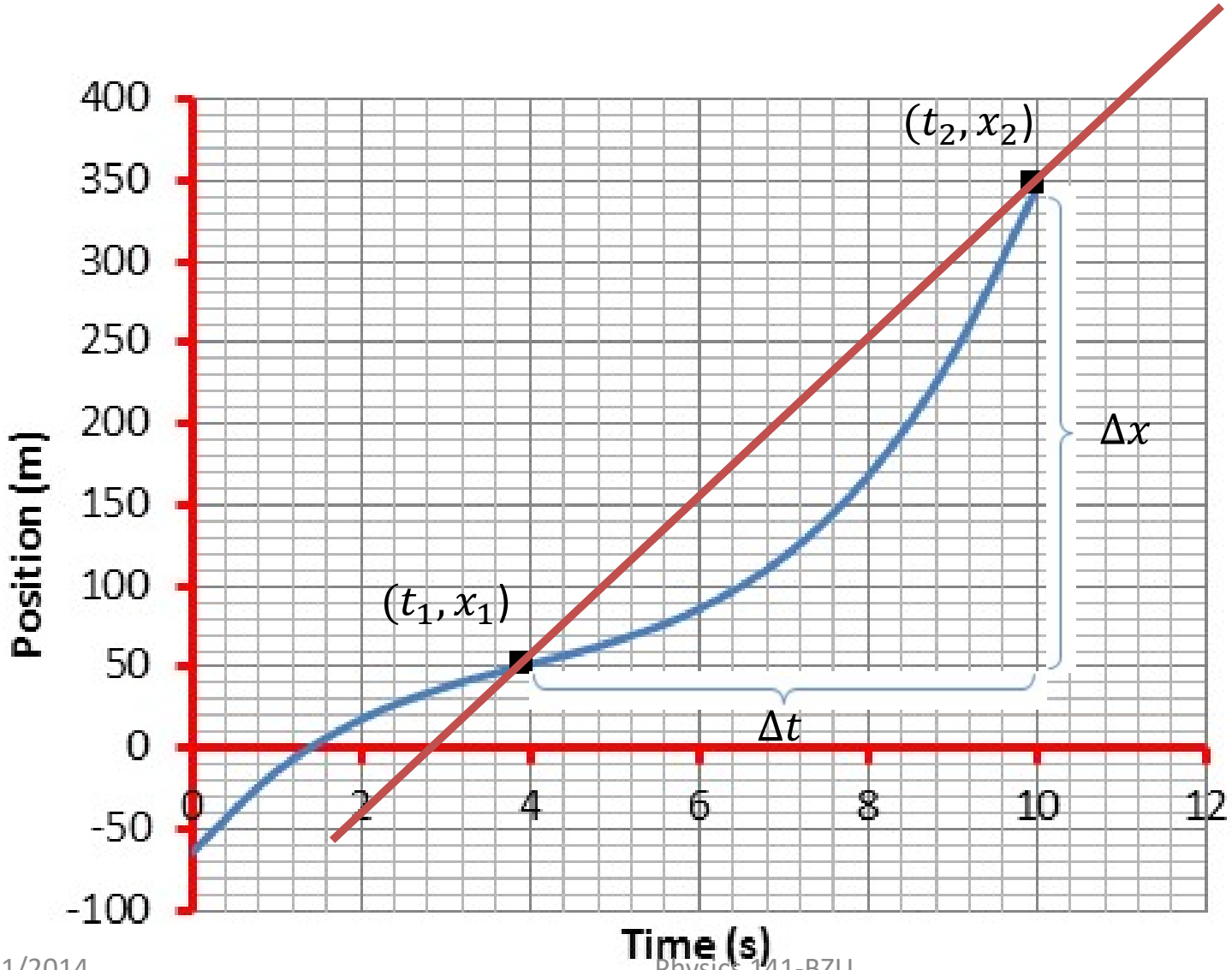


Units for velocity: m/s, MPH, kmPH.

Example (1):find average velocity

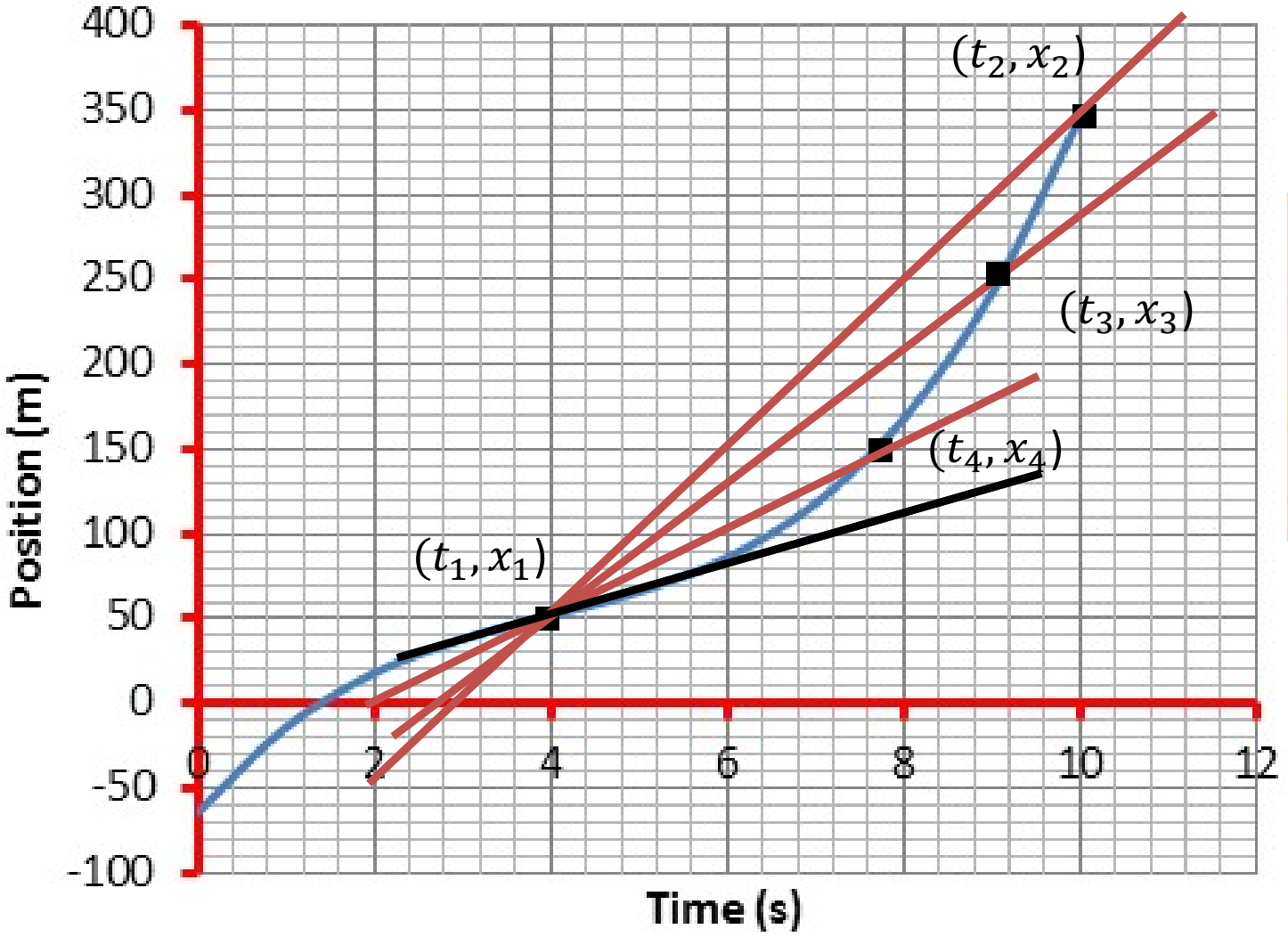
Graphical Representation of Motion

- Average velocity



$$\bar{v} = \frac{\Delta x}{\Delta t} = slope$$
$$= \frac{x_2 - x_1}{t_2 - t_1}$$
$$= \frac{350 - 50}{10 - 4}$$
$$= \frac{300\ m}{6\ s}$$
=50 m/s

2.2 Instantaneous Velocity



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

$$= \frac{dx}{dt}$$

Instantaneous Velocity and Speed

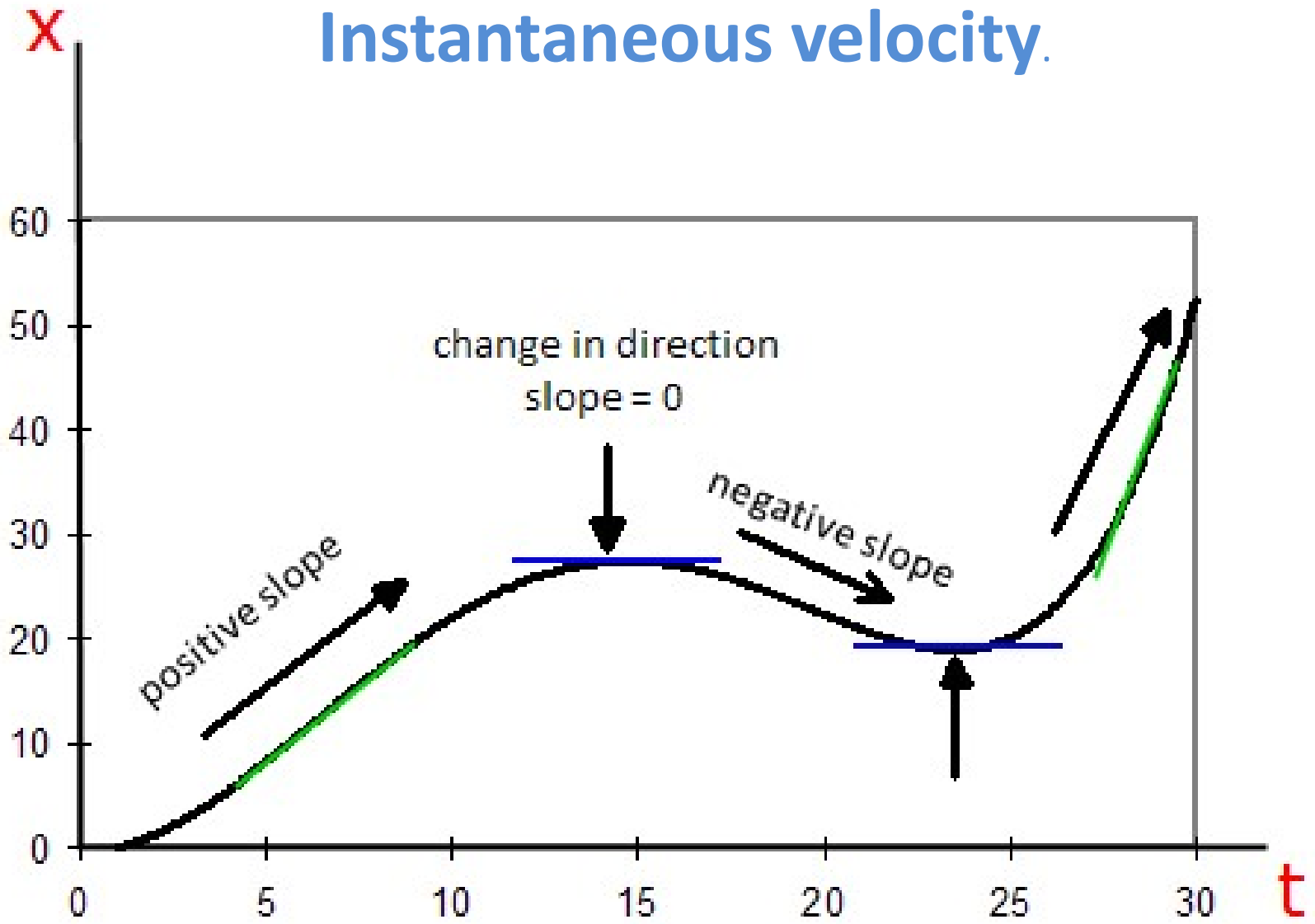
The ***instantaneous velocity*** **v** indicates how fast an object moves and the direction of the motion at each instant of time.

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

$$= \frac{dx}{dt}$$

The magnitude of the instantaneous velocity is called the ***instantaneous speed***, and it is the number (with units) indicated by the speedometer.

Instantaneous velocity.



Average velocity and Instantaneous velocity

- Average velocity
  - Average velocity in an interval of time
- Instantaneous velocity
  - Occurring at one instant in time
  - Like an automobile speedometer

Winner of the Men's 100 m at the 2004 Athens Olympics in 9.85 s

Average velocity = 100 m / 9.85 s

= 10.15 m/s

Example (2):

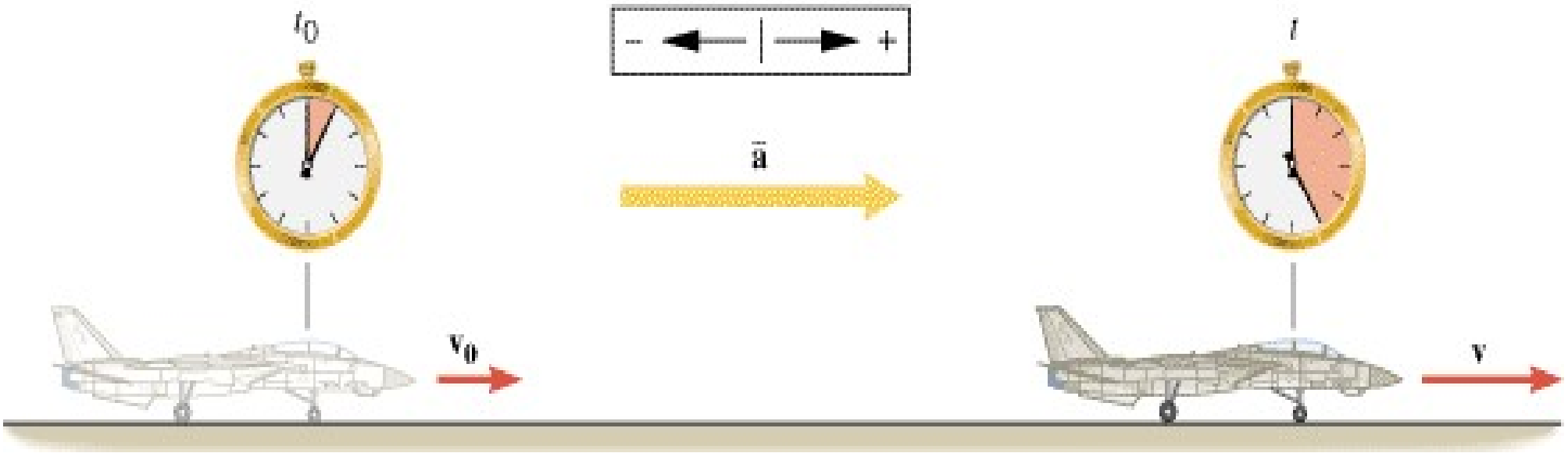
The position of a particle as a function of time is given by

$$x(t) = -2t^2 + 4t + 3,$$

where x is in meters and t is in seconds, find:

a) The average velocity during the first 4 seconds of motion.
b) The velocity at t= 2 seconds.
c) The maximum distance reached along the x-axis.

2.3 Acceleration



$$\textbf{Average Acceleration} = \frac{\textbf{Change in velocity}}{\textbf{Elapsed time}}$$

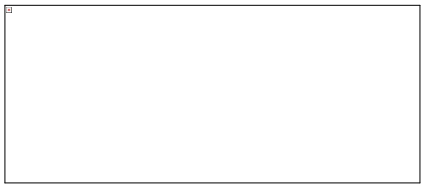
$$\bar{a} = \frac{v - v_0}{t - t_0}$$

Units: m/s^2

Instantaneous acceleration

Acceleration at a particular instant is called instantaneous acceleration.

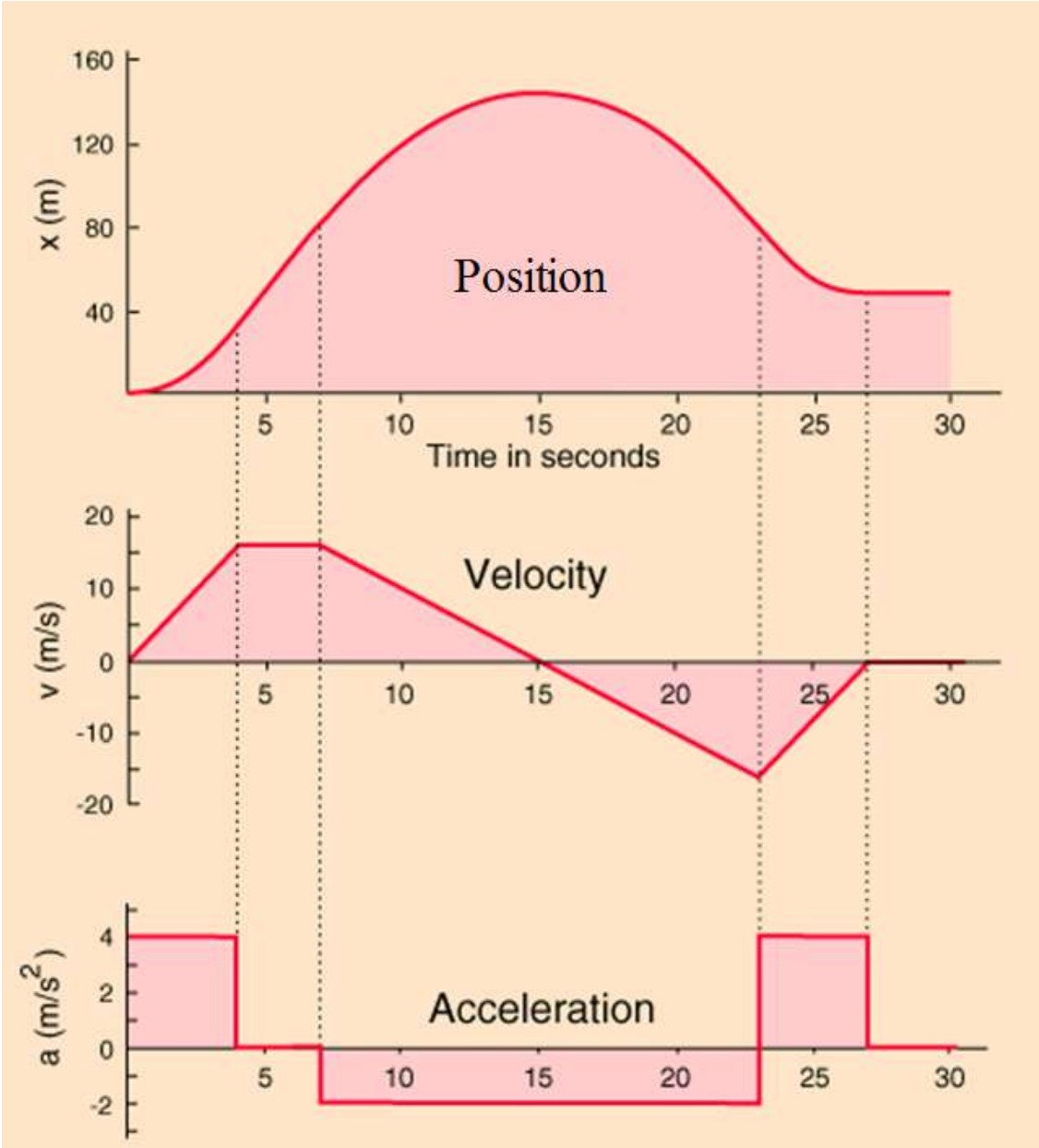
$$a = \lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t} = \frac{dv}{dt}$$



Position x

Velocity = $\frac{dx}{dt}$

Acceleration = $\frac{dv}{dt}$

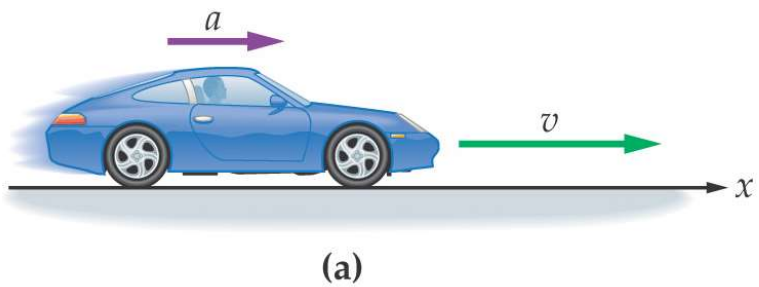


Acceleration & Deceleration

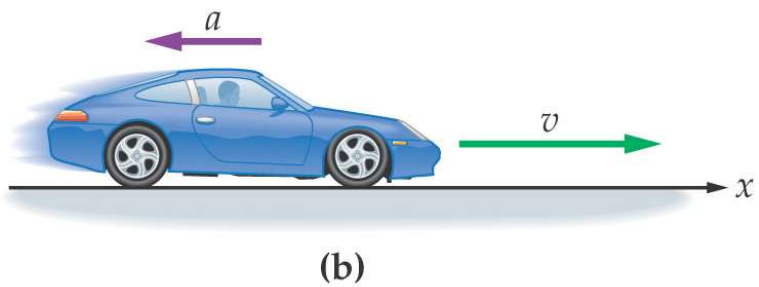
- Acceleration (increasing speed) and deceleration (decreasing speed) should not be confused with the directions of velocity and acceleration:
- In 1-D velocities & accelerations can be “+” or “-” depending on whether they point in the “+” or “-” direction of the coordinate system
- Leads to two conclusion
  - When the velocity & acceleration have the same sign the speed of the object increases (in this case the velocity & acceleration point in the same direction)
  - When the velocity & acceleration have opposite signs, the speed of the object decreases (in this case the velocity & acceleration point in opposite directions

Acceleration and Deceleration

Acceleration	Velocity	Speed	Motion
+	+	Increases	Accelerating
-	+	Decreases	Decelerating
+	-	Decreases	Decelerating
-	-	Increases	Accelerating



(a)



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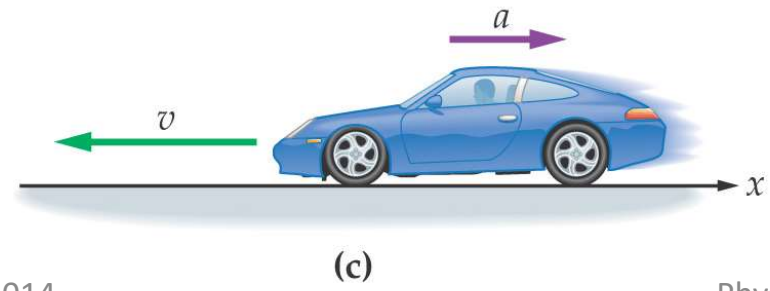

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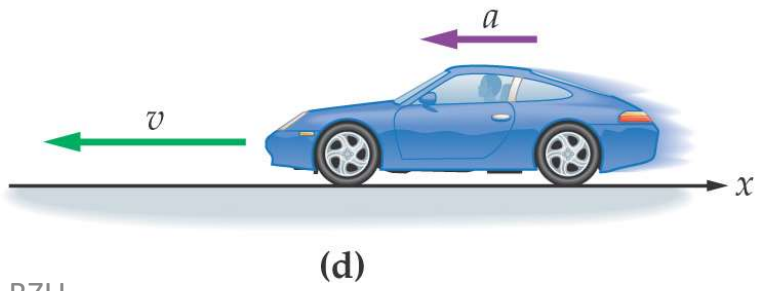

(d)

Summary of Lecture 2

- Kinematics is the description of how objects move with respect to a defined reference frame.
- Displacement is the change in position of an object.
- Average speed is the distance traveled divided by the elapsed time; average velocity is the displacement divided by the elapsed time.
- Instantaneous velocity is the limit of the average velocity as the time becomes infinitesimally short.
- Average acceleration is the rate of change of velocity with respect to time.
- Acceleration is the limit of the average acceleration as the time interval becomes infinitesimally small.