Chapter 2

Motion in One Dimension (Cont.)

Outline

- Acceleration
  - Average acceleration
  - Instantaneous acceleration
- 1D kinematics equation for motion under constant acceleration
- Free fall

Average Acceleration

- **Accelerating**: When the velocity of a particle changes with time, we say the particle is accelerating.
- **Average Acceleration**: the rate of change of the velocity

$$\bar{a}_x = \frac{\Delta v_x}{\Delta t} = \frac{v_{xf} - v_{xi}}{\Delta t}$$

- Dimensions: L/T^2. SI units: m/s^2

Instantaneous Acceleration

- The instantaneous acceleration is the limit of the average acceleration as Δt approaches 0

$$a_x = \lim_{\Delta t \to 0} \frac{\Delta v_x}{\Delta t} = \frac{dv_x}{dt} = \frac{d^2 x}{dt^2}$$

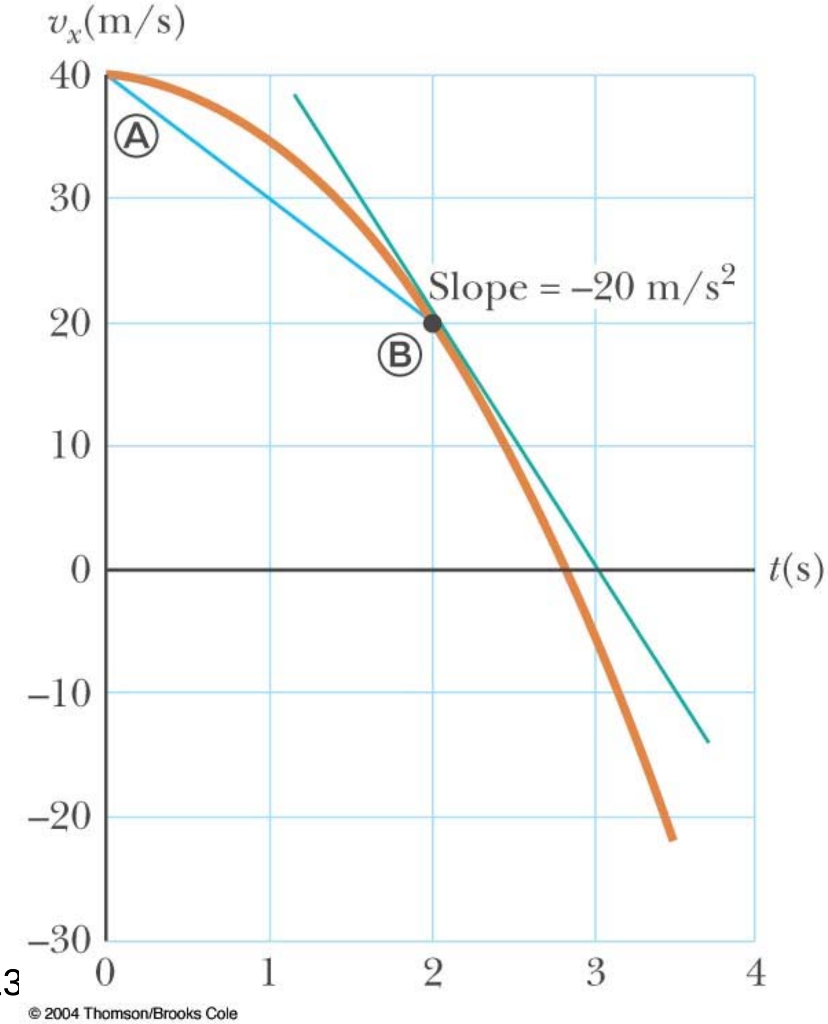
- For one-dimensional motions, use positive and negative signs to indicate the <u>direction</u> of the acceleration.
- When <u>acceleration is constant</u>, the instantaneous and average accelerations are the same.

Example: Average and Instantaneous Acceleration

- The velocity of a particle moving along the x axis varies in time according to the expression $v_x = (40 - 5t^2)$ m/s, where t is in seconds.
  - (A) Find the average acceleration in the time interval t = 0 to t = 2.0 s.
  - (B) Find the (instantaneous) acceleration at t = 2.0 s.

Graphical Presentation of the Previous Example

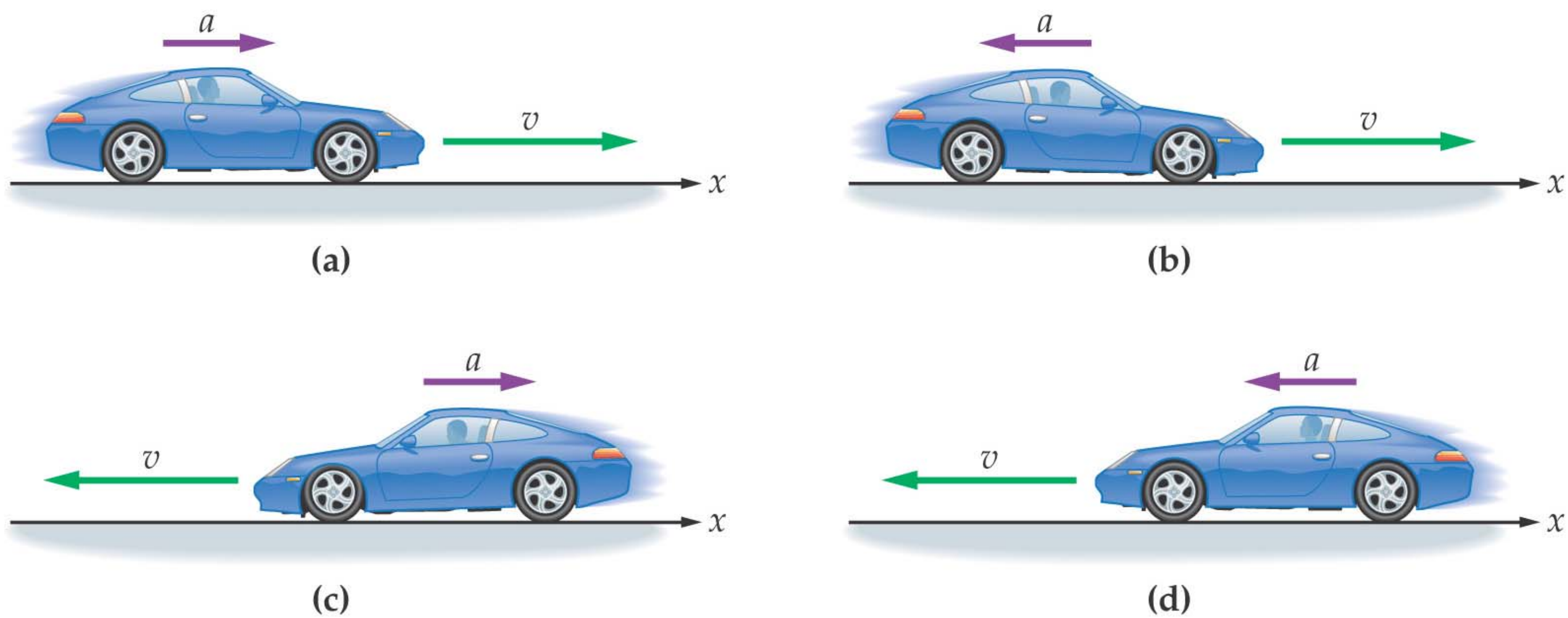
The red curve shows the graph (plot) of velocity vs. time corresponding to equation $v_x = (40 - 5t^2)$ m/s.



Directions of Acceleration and Velocity

- When an object's velocity and acceleration are in the same direction, the object is speeding up
- When an object's velocity and acceleration are in the opposite direction, the object is slowing down
- If the particle is moving with a constant velocity, acceleration is zero.

Speeding up or Slowing Down



(a) And (d): Car speeds up

(b) And (c): Car slows down

1D Kinematics Equations under Constant Acceleration

Important: Equations in Table 2.2 are valid for 1D motion under constant acceleration only.

Table 2.2

Kinematic Equations for Motion of a Particle Under Constant Acceleration

Equation	Information Given by Equation
$v_{xf} = v_{xi} + a_x t$	Velocity as a function of time
$x_f = x_i + \frac{1}{2}(v_{xi} + v_{xf})t$	Position as a function of velocity and time
$x_f = x_i + v_{xi}t + \frac{1}{2}a_x t^2$	Position as a function of time
${v_{xf}}^2 = {v_{xi}}^2 + 2a_x(x_f - x_i)$	Velocity as a function of position

Note: Motion is along the x axis.

Example: 1D Kinematics with Constant Acceleration

- A jet lands on an aircraft carrier at 140 mi/h ($\approx$ 63 m/s). Assume constant acceleration,
  - (a) what is its acceleration if it stops in 2.0 s?
  - (b) what is the displacement of the plane while it is stopping?

Freely Falling Objects

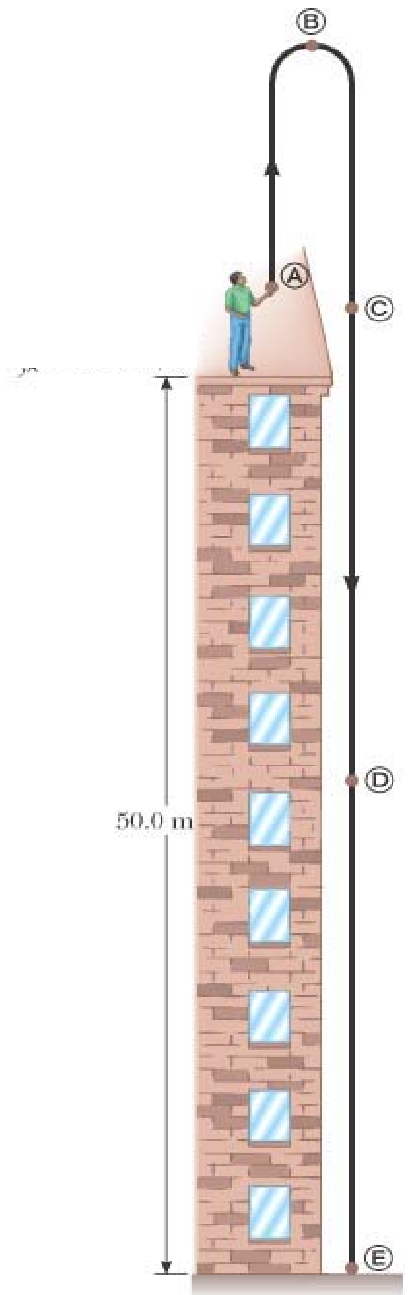
- A ***freely falling object*** is any object moving freely under the influence of gravity alone.
  - In real situations, when air resistance can be neglected, the motion can be approximated as a free fall.
- Free fall
  - Dropped (released) from rest
  - Thrown downward
  - Thrown upward

Acceleration of Freely Falling Object

- **Direction of the free fall acceleration**: The acceleration of an object in free fall is directed <u>downward</u>.
- **Magnitude of free fall acceleration**, g
  - g decreases with increasing altitude and g varies with latitude
  - 9.80 m/s^2 is the average at the Earth's surface
- Assuming the constant value of g=9.80 m/s^2 near the Earth surface, <u>free fall is a 1D motion with constant acceleration</u>
  - <u>Both the direction and magnitude do not change.</u>

Free Fall Example

- A stone thrown from the top of a building is given an initial velocity of 20.0 m/s straight upward. The building is 50.0 m high. Set $t_A=0$ as the time the stone leaves the thrower's had at position A, find
  - (A) the time when the stone reaches its maximum height.
  - (B) the maximum height
  - (C) the velocity and position of the stone at t=5.00 s.



Homework #1 (01/14/05)

- Chapter 2, P. 51, Problems: #15, 24, 30, 51.
- Hint: For #24, think about equation $v_{xf}^2 = v_{xi}^2 + 2a_x(x_f - x_i)$ in Table 2.2.