FUNDAMENTALS OF PHYSICS

10TH ED CHAPTER 2 "MOTION ALONG A STRAIGHT LINE"

BY

ENGR. HASSAN KHALID

CONTENT

- **Position, displacement and average velocity**
- **Instantaneous velocity and speed**
- **Acceleration**
- **Constant & free fall acceleration**
- **Graphical integration in motion analysis**

PHYSICS IN TERMS OF POSITION

- Our nature is full of fanatical behavior. Our purpose to study physics is to determine the position of objects
- Example
  - Geologists use this physics to measure tectonic-plate motion as they attempt to predict earthquakes
  - Medical researchers need this physics to map the blood flow through a patient when diagnosing a partially closed artery

MOTION

- The world and everything it has moves. Even though they look stationary such as road ways moves with Earth’s rotation. Same with the Sun, Milky Ways and galaxies
- Properties of motion
  - The motion is along a straight line only. The line may be vertical, horizontal, or slanted, but it must be straight
  - Forces (pushes and pulls) cause motion but will be discussed until Chapter 5
  - The moving object is either a particle (by which we mean a point-like object such as an electron) or an object that moves like a particle (such that every portion moves in the same direction and at the same rate)

POSITION & DISPLACEMENT

- In order to locate an object it is required to find its position relative to some reference
- A reference could be any point located on origin or arbitrary
- The direction of location can be positive or negative direction
- A displacement is a change of position from location x_1 to x_2
- Called displacement ($\Delta x = x_2 - x_1$)
- Displacement is a ________ quantity? Vector/Scaler

AVERAGE VELOCITY & SPEED

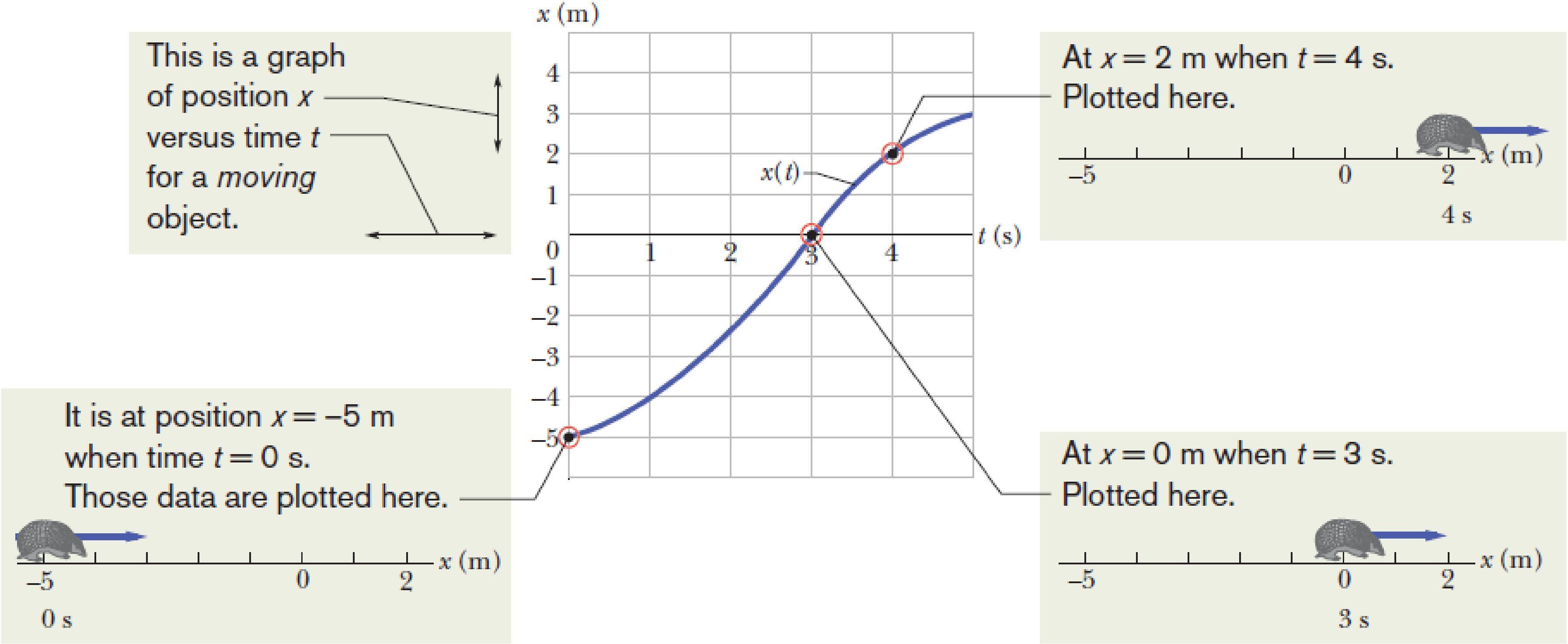
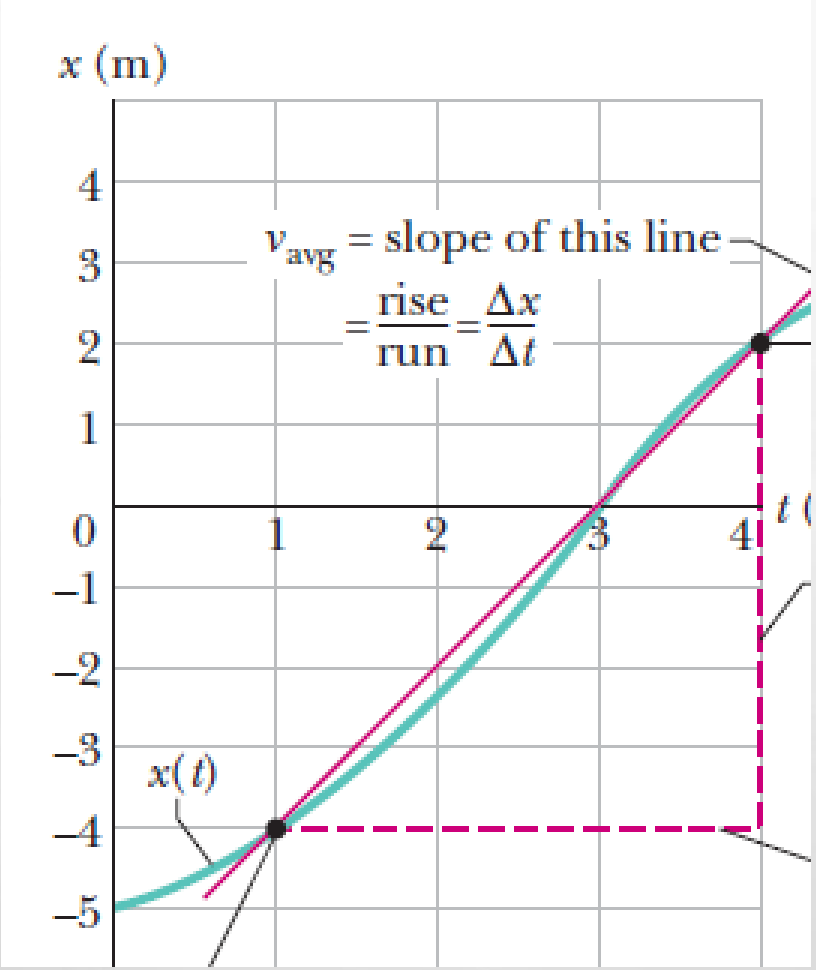


Figure 2-3 The graph of $x(t)$ for a moving armadillo. The path associated with the graph is also shown, at three times.

Average velocity is the ratio of displacement to the rate of change of time

$$v_{avg} = \frac{\Delta x}{\Delta t} = \frac{x_2 - x_1}{t_2 - t_1}.$$

Calculate V_{av} from 1sec to 4sec



- Average speed is different from average velocity as it describes “how fast”

$$s_{avg} = \frac{\text{total distance}}{\Delta t}.$$

Example

You drive a beat-up pickup truck along a straight road for 8.4 km at 70 km/h, at which point the truck runs out of gasoline and stops. Over the next 30 min, you walk another 2.0 km farther along the road to a gasoline station.

(a) What is your overall displacement from the beginning of your drive to your arrival at the station?

(b) What is the time interval Δt from the beginning of your drive to your arrival at the station?

(c) What is your average velocity v_{avg} from the beginning of your drive to your arrival at the station? Find it both numerically and graphically.

(d) Suppose that to pump the gasoline, pay for it, and walk back to the truck takes you another 45 min. What is your average speed from the beginning of your drive to your return to the truck with the gasoline?

INSTANTANEOUS VELOCITY AND SPEED

- Till now we have described two ways to measure "how fast" an object can move.
  - Average velocity
  - Average speed
- Instantaneous velocity is a term used when to tell "how fast" an object moves at a given instant
- We shrink the interval by making it close to zero

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

CRITICAL QUESTION!

The following equations give the position $x(t)$ of a particle in four situations (in each equation, x is in meters, t is in seconds, and $t > 0$): (1) $x = 3t - 2$; (2) $x = -4t^2 - 2$; (3) $x = 2/t^2$; and (4) $x = -2$. (a) In which situation is the velocity v of the particle constant? (b) In which is v in the negative x direction?

ACCELERATION

- When a particle's velocity changes, the particle is said to undergo **acceleration** (or to accelerate). For motion along an axis, the **average acceleration**
- The sensations you would feel while riding in the cab. When the cab first accelerates, you feel as though you are pressed downward; when later the cab is braked to a stop, you seem to be stretched upward. In between, you feel nothing special.

$$a_{avg} = \frac{v_2 - v_1}{t_2 - t_1} = \frac{\Delta v}{\Delta t}$$

EXAMPLE 2.3

A particle's position on the x axis of Fig. 2-1 is given by

$$x = 4 - 27t + t^3,$$

with x in meters and t in seconds.

(a) Because position x depends on time t, the particle must be moving. Find the particle's velocity function $v(t)$ and acceleration function $a(t)$.

(b) Is there ever a time when $v = 0$?

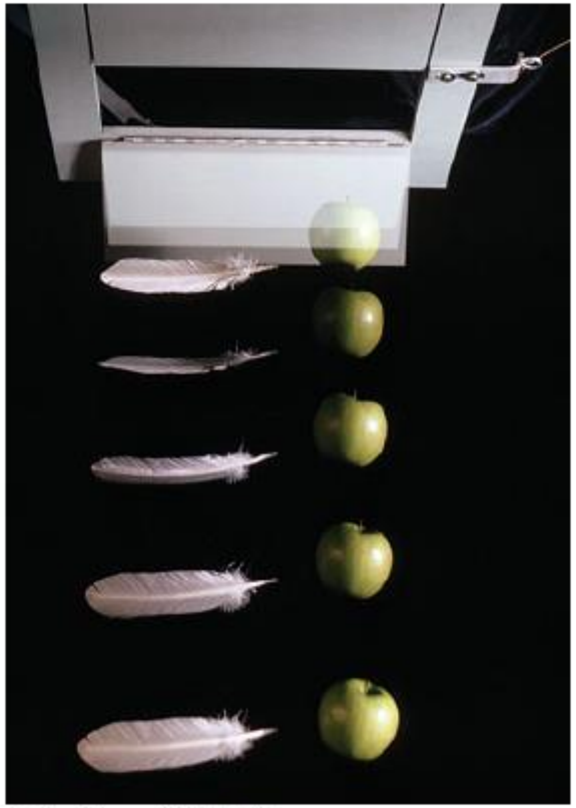
(c) Describe the particle's motion for $t \geq 0$.

STUDY YOUR SELF

- Constant acceleration
- Example 2.4

FREE FALL ACCELERATION

- The body that accelerates at certain constant rate either it moves up or down after eliminating effect of air is called free fall acceleration.
- The value of g varies slightly with latitude and with elevation. At sea level in Earth’s midlatitudes the value is 9.8 m/s2 (or 32 ft/s2), which is what you should use as an exact number for the problems in this book unless otherwise noted.



Sample Problem 2.05 Time for full up-down flight, baseball toss

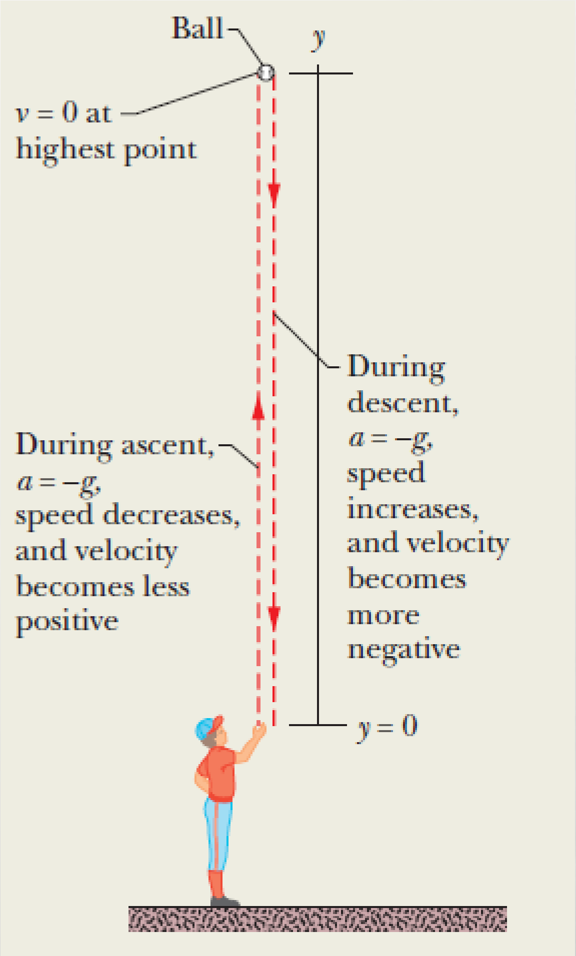
In Fig. 2-13, a pitcher tosses a baseball up along a y axis, with an initial speed of 12 m/s.

(a) How long does the ball take to reach its maximum height?

(1) Once the ball leaves the pitcher and before it returns to his hand, its acceleration is the free-fall acceleration $a = -g$. Because this is constant, Table 2-1 applies to the motion. (2) The velocity v at the maximum height must be 0.

Calculation: Knowing v, a, and the initial velocity $v_0 = 12$ m/s, and seeking t, we solve Eq. 2-11, which contains those four variables. This yields

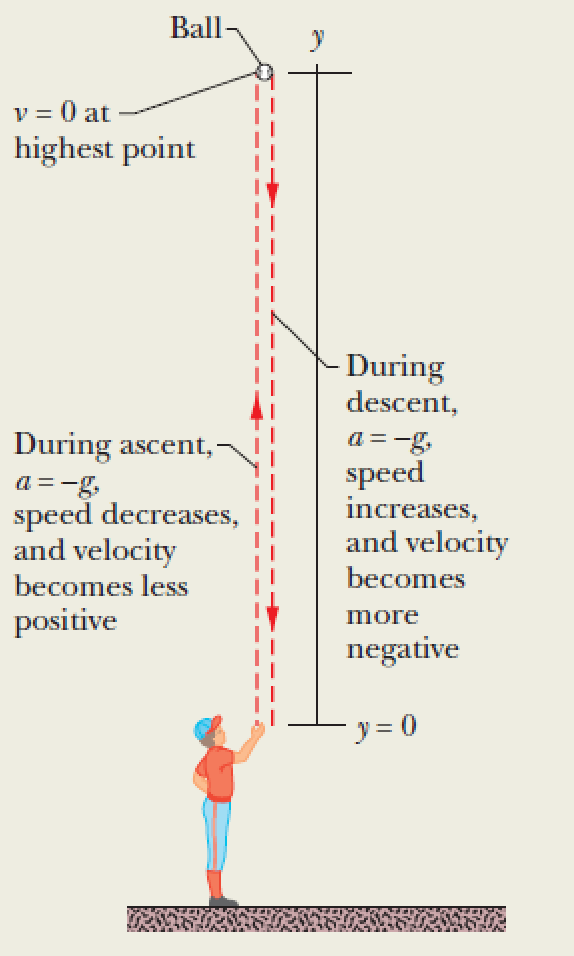
$$t = \frac{v - v_0}{a} = \frac{0 - 12\text{ m/s}}{-9.8\text{ m/s}^2} = 1.2\text{ s.} \qquad \text{(Answer)}$$



(b) What is the ball's maximum height above its release point?

Calculation: We can take the ball's release point to be $y_0 = 0$. We can then write Eq. 2-16 in y notation, set $y - y_0 = y$ and $v = 0$ (at the maximum height), and solve for y. We get

$$y = \frac{v^2 - v_0^2}{2a} = \frac{0 - (12\ \text{m/s})^2}{2(-9.8\ \text{m/s}^2)} = 7.3\ \text{m}. \qquad \text{(Answer)}$$



(c) How long does the ball take to reach a point 5.0 m above its release point?

Calculations: We know v_0, $a = -g$, and displacement $y - y_0 = 5.0$ m, and we want t, so we choose Eq. 2-15. Rewriting it for y and setting $y_0 = 0$ give us

$$y = v_0 t - \tfrac{1}{2} g t^2,$$

or $$5.0\text{ m} = (12\text{ m/s})t - (\tfrac{1}{2})(9.8\text{ m/s}^2)t^2.$$

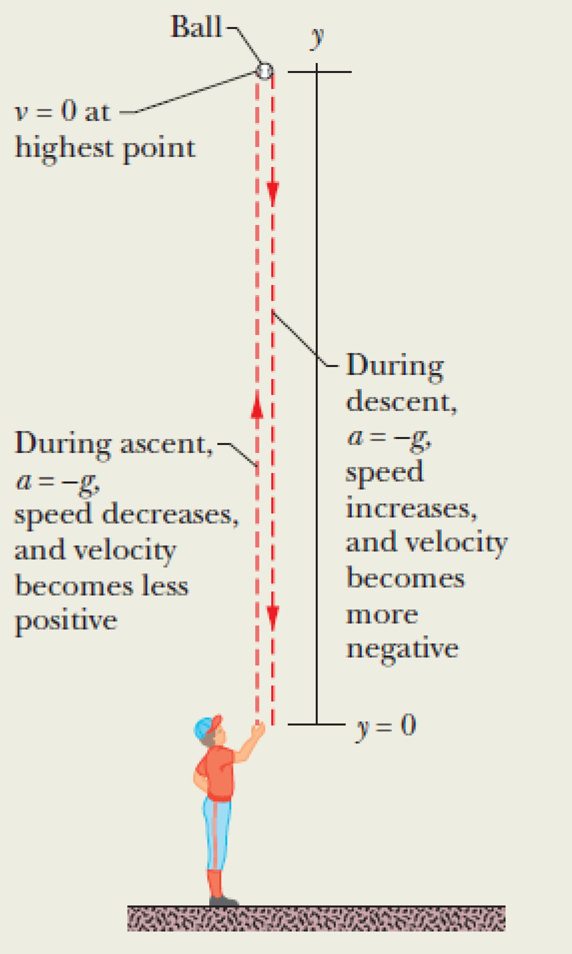
If we temporarily omit the units (having noted that they are consistent), we can rewrite this as

$$4.9t^2 - 12t + 5.0 = 0.$$

Solving this quadratic equation for t yields

$$t = 0.53\text{ s} \quad \text{and} \quad t = 1.9\text{ s}. \qquad \text{(Answer)}$$

There are two such times! This is not really surprising because the ball passes twice through $y = 5.0$ m, once on the way up and once on the way down.



BEST OF LUCK

- Do related problems from exercise by your self