
**Lecture PowerPoints**

**Chapter 2**
***Physics: Principles with Applications, 7th edition***
**Giancoli**

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# Chapter 2
# Describing Motion: Kinematics in One Dimension

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## Dynamics

- The branch of physics involving the motion of an object and the relationship between that motion and other physics concepts
- ***Kinematics*** is a part of dynamics
  - In kinematics, you are interested in the *description* of motion
  - *Not* concerned with the cause of the motion

## Vector and Scalar Quantities

- Vector quantities need both magnitude (size) and direction to completely describe them
  - Generally denoted by boldfaced type and an arrow over the letter
  - + or – sign is sufficient for this chapter
- Scalar quantities are completely described by magnitude only

## Displacement Isn't Distance

- The displacement of an object is not the same as the distance it travels
  - Example: Throw a ball straight up and then catch it at the same point you released it
    - The distance is twice the height
    - The displacement is zero

## 2-1 Reference Frames and Displacement

Any measurement of position, distance, or speed must be made with respect to a reference frame.

For example, if you are sitting on a train and someone walks down the aisle, their speed with respect to the train is a few miles per hour, at most. Their speed with respect to the ground is much higher.

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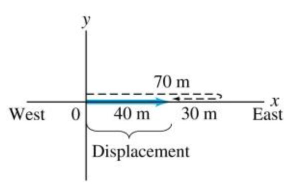
## 2-1 Reference Frames and Displacement

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.

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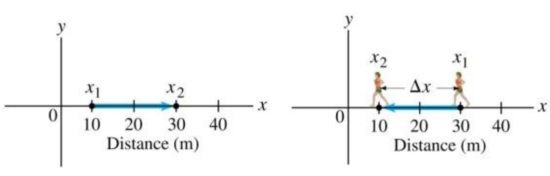
## 2-1 Reference Frames and Displacement

The displacement is written: $\Delta x = x_2 - x_1$

Left: Displacement is positive. Right: Displacement is negative.

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## 2-2 Average Velocity

Speed: how far an object travels in a given time interval

$$\text{average speed} = \frac{\text{distance traveled}}{\text{time elapsed}} \quad (2\text{-}1)$$

Velocity includes directional information:

$$\text{average velocity} = \frac{\text{displacement}}{\text{time elapsed}} = \frac{\text{final position} - \text{initial position}}{\text{time elapsed}}.$$

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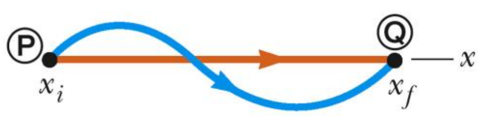
## Speed, cont

- Average speed totally ignores any variations in the object's actual motion during the trip
- The total distance and the total time are all that is important
- SI units are m/s

## Speed vs. Velocity



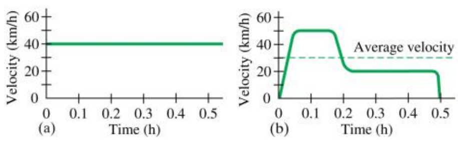

- Cars on both paths have the same average velocity since they had the same displacement in the same time interval
- The car on the blue path will have a greater average speed since the distance it traveled is larger

## 2-3 Instantaneous Velocity

The instantaneous velocity is the average velocity, in the limit as the time interval becomes infinitesimally short.

$$v = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t} \qquad \text{(2-3)}$$

These graphs show (a) constant velocity and (b) varying velocity.

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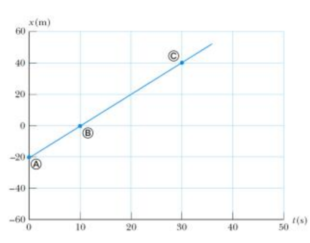
## Graphical Interpretation of Velocity

- Velocity can be determined from a position-time graph
- Average velocity equals the slope of the line joining the initial and final positions
- An object moving with a constant velocity will have a graph that is a straight line

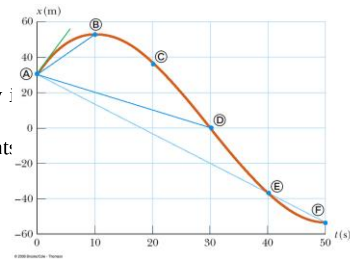
## Average Velocity, Constant

- The straight line indicates constant velocity
- The slope of the line is the value of the average velocity



**Average Velocity, Non Constant**

- The motion is non-constant velocity
- The average velocity i the slope of the blue line joining two point




**Instantaneous Velocity**

- The limit of the average velocity as the time interval becomes infinitesimally short, or as the time interval approaches zero

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

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

**Instantaneous Velocity on a Graph**

- The slope of the line tangent to the position-vs.-time graph is defined to be the instantaneous velocity at that time
  - The instantaneous speed is defined as the magnitude of the instantaneous velocity

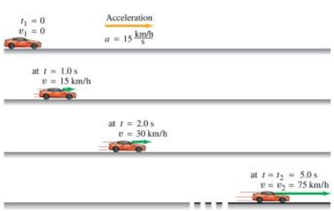
## Uniform Velocity

- Uniform velocity is constant velocity
- The instantaneous velocities are always the same
  - All the instantaneous velocities will also equal the average velocity

## 2-4 Acceleration

Acceleration is the rate of change of velocity.

$$\text{average acceleration} = \frac{\text{change of velocity}}{\text{time elapsed}}$$

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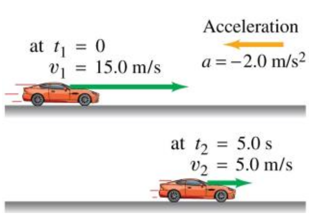
## 2-4 Acceleration

Acceleration is a vector, although in one-dimensional motion we only need the sign.

The previous image shows positive acceleration; here is negative acceleration:

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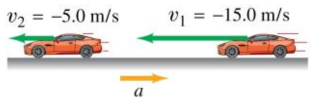
## 2-4 Acceleration

There is a difference between negative acceleration and deceleration:

Negative acceleration is acceleration in the negative direction as defined by the coordinate system.

Deceleration occurs when the acceleration is opposite in direction to the velocity.

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## 2-4 Acceleration

The instantaneous acceleration is the average acceleration, in the limit as the time interval becomes infinitesimally short.

$$a = \lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t} \qquad (2\text{-}5)$$

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## 2-5 Motion at Constant Acceleration

The average velocity of an object during a time interval $t$ is

$$\bar{v} = \frac{\Delta x}{\Delta t} = \frac{x - x_0}{t - t_0} = \frac{x - x_0}{t}$$

The acceleration, assumed constant, is $a = \dfrac{v - v_0}{t}$.

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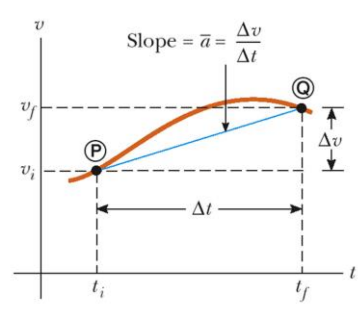
## Average Acceleration

- Vector quantity
- When the sign of the velocity and the acceleration are the same (either positive or negative), then the speed is increasing
- When the sign of the velocity and the acceleration are in the opposite directions, the speed is decreasing

## Graphical Interpretation of Acceleration

- Average acceleration is the slope of the line connecting the initial and final velocities on a velocity-time graph
- Instantaneous acceleration is the slope of the tangent to the curve of the velocity-time graph

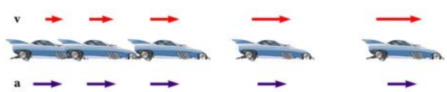
## Average Acceleration



## Relationship Between Acceleration and Velocity

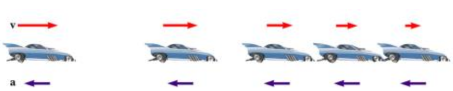

- Uniform velocity (shown by red arrows maintaining the same size)
- Acceleration equals zero

## Relationship Between Velocity and Acceleration




- Velocity and acceleration are in the same direction
- Acceleration is uniform (blue arrows maintain the same length)
- Velocity is increasing (red arrows are getting longer)
- Positive velocity and positive acceleration

## Relationship Between Velocity and Acceleration




- Acceleration and velocity are in opposite directions
- Acceleration is uniform (blue arrows maintain the same length)
- Velocity is decreasing (red arrows are getting shorter)
- Velocity is positive and acceleration is negative

## 2-5 Motion at Constant Acceleration

In addition, as the velocity is increasing at a constant rate, we know that

$$\bar{v} = \frac{v_0 + v}{2}. \qquad (2\text{-}8)$$

Combining these last three equations, we find:

$$\begin{aligned} x &= x_0 + \bar{v}t \\ &= x_0 + \left(\frac{v_0 + v}{2}\right)t \\ &= x_0 + \left(\frac{v_0 + v_0 + at}{2}\right)t \end{aligned}$$

or

$$x = x_0 + v_0 t + \tfrac{1}{2}at^2. \qquad (2\text{-}9)$$

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## 2-5 Motion at Constant Acceleration

We can also combine these equations so as to eliminate *t*:

$$v^2 = v_0^2 + 2a(x - x_0) \qquad (2\text{-}10)$$

We now have all the equations we need to solve constant-acceleration problems.

$$v = v_0 + at \qquad (2\text{-}11a)$$

$$v^2 = v_0^2 + 2a(x - x_0) \qquad (2\text{-}11c)$$

$$x = x_0 + v_0 t + \tfrac{1}{2}at^2 \qquad (2\text{-}11b)$$

$$\bar{v} = \frac{v + v_0}{2}. \qquad (2\text{-}11d)$$

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## 2-6 Solving Problems

1. Read the whole problem and make sure you understand it. Then read it again.
2. Decide on the objects under study and what the time interval is.
3. Draw a diagram and choose coordinate axes.
4. Write down the known (given) quantities, and then the unknown ones that you need to find.
5. What physics applies here? Plan an approach to a solution.

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## 2-6 Solving Problems

6. Which equations relate the known and unknown quantities? Are they valid in this situation? Solve algebraically for the unknown quantities, and check that your result is sensible (correct dimensions).
7. Calculate the solution and round it to the appropriate number of significant figures.
8. Look at the result—is it reasonable? Does it agree with a rough estimate?
9. Check the units again.

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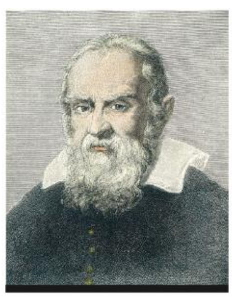
## Galileo Galilei

- 1564 - 1642
- Galileo formulated the laws that govern the motion of objects in free fall
- Also looked at:
  - Inclined planes
  - Relative motion
  - Thermometers
  - Pendulum



## Free Fall

- All objects moving under the influence of gravity only are said to be in free fall
  - Free fall does not depend on the object's original motion
- All objects falling near the earth's surface fall with a constant acceleration
- The acceleration is called the acceleration due to gravity, and indicated by *g*

## Acceleration due to Gravity

- Symbolized by $g$
- $g = 9.80\ \mathrm{m/s^2}$
  - When estimating, use $g \approx 10\ \mathrm{m/s^2}$
- $g$ is always directed downward
  - toward the center of the earth
- Ignoring air resistance and assuming $g$ doesn't vary with altitude over short vertical distances, free fall is constantly accelerated motion

## 2-7 Freely Falling Objects

Near the surface of the Earth, all objects experience approximately the same acceleration due to gravity.

This is one of the most common examples of motion with constant acceleration.

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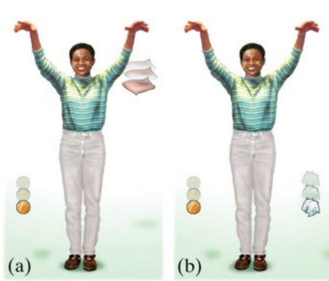
## 2-7 Freely Falling Objects




In the absence of air resistance, all objects fall with the same acceleration, although this may be hard to tell by testing in an environment where there is air resistance.

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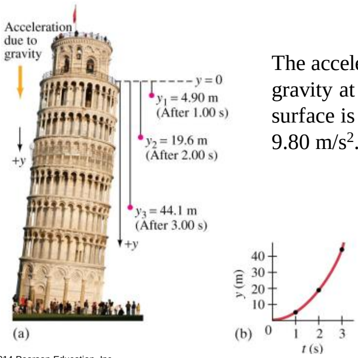
## 2-7 Freely Falling Objects

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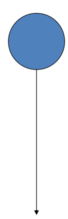
The acceleration due to gravity at the Earth's surface is approximately 9.80 m/s$^2$.

## Free Fall – an object dropped

- Initial velocity is zero
- Let up be positive
- Use the kinematic equations
  – Generally use y instead of x since vertical
- Acceleration is $g$ = -9.80 m/s$^2$

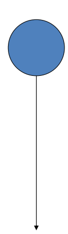


$v_o$= 0

a = g

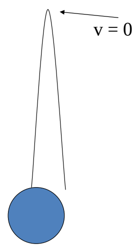
## Free Fall – an object thrown downward

- a = $g$ = -9.80 m/s$^2$
- Initial velocity ≠ 0
  – With upward being positive, initial velocity will be negative



## Free Fall -- object thrown upward

- Initial velocity is upward, so positive
- The instantaneous velocity at the maximum height is zero
- a = *g* = -9.80 m/s$^2$ everywhere in the motion

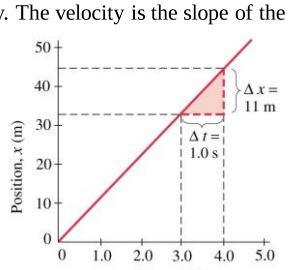



## Thrown upward, cont.

- The motion may be symmetrical
  - Then $t_{up} = t_{down}$
  - Then $v = -v_o$
- The motion may not be symmetrical
  - Break the motion into various parts
    - Generally up and down

## 2-8 Graphical Analysis of Linear Motion

This is a graph of *x* vs. *t* for an object moving with constant velocity. The velocity is the slope of the *x*-*t* curve.

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## Summary of Chapter 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 time it took; average velocity is the displacement divided by the time.
- Instantaneous velocity is the limit as the time becomes infinitesimally short.

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