# Describing Motion: Kinematics in One Dimension

AP Physics

Chapter 2

# Describing Motion: Kinematics in One Dimension

AP Physics

Section 2-1 Reference Frames and Displacement

# Describing Motion: Kinematics in One Dimension

Mechanics – study of motion, force, energy

Kinematics – how objects move

Dynamics – why objects move

Translational Motion – move without rotation

# Describing Motion: Kinematics in One Dimension

Reference Frames (Frames of Reference)

Are we moving?

Compared to what?

Usually with “respect to the Earth”

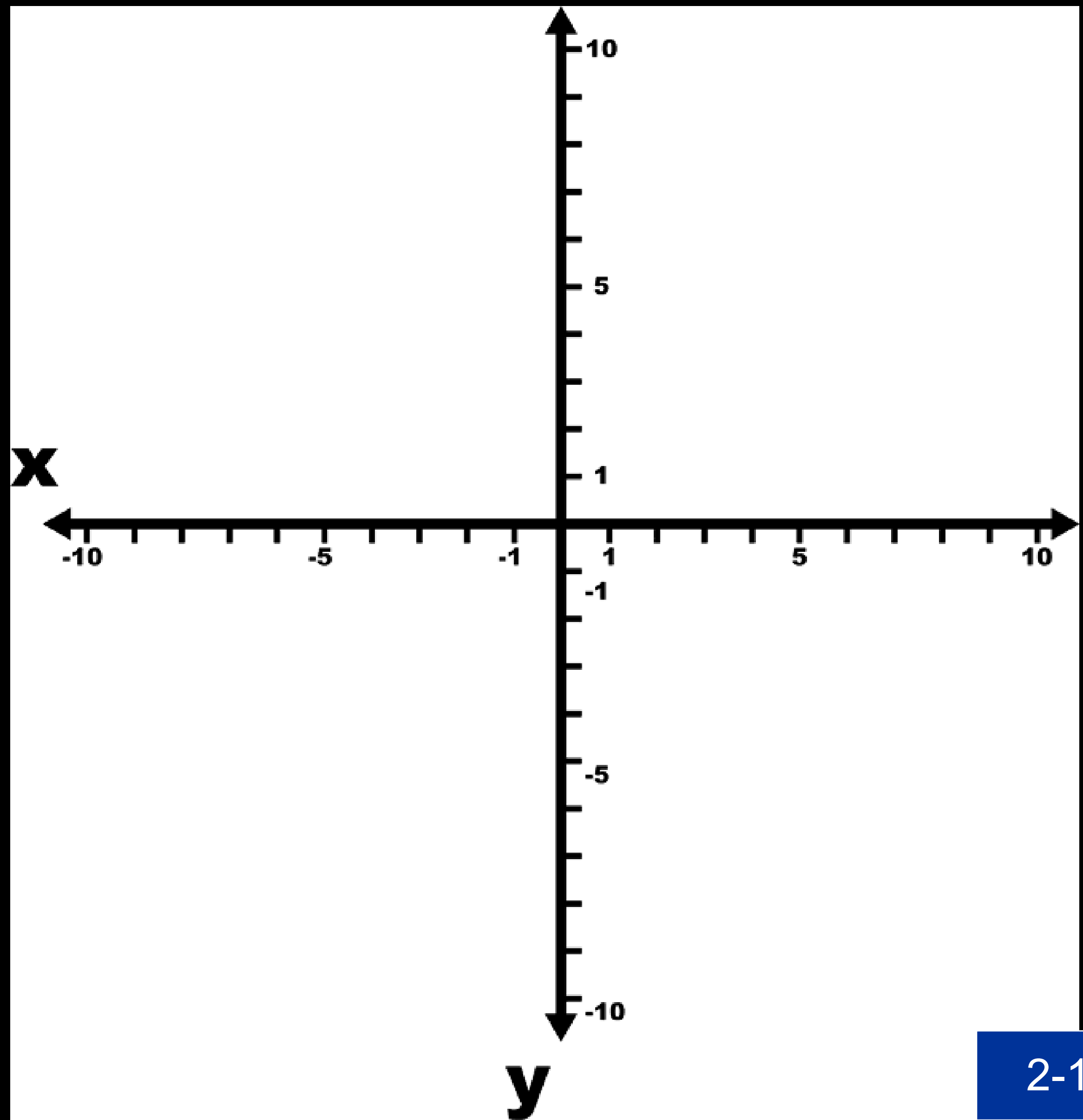
Unless otherwise specified

All other cases, must specify the frame of reference

Typically done with coordinate grid and x and y axis (only x or y for 1D motion)

# Describing Motion: Kinematics in One Dimension

- Positive – up and right
- Negative – down and left



# Describing Motion: Kinematics in One Dimension

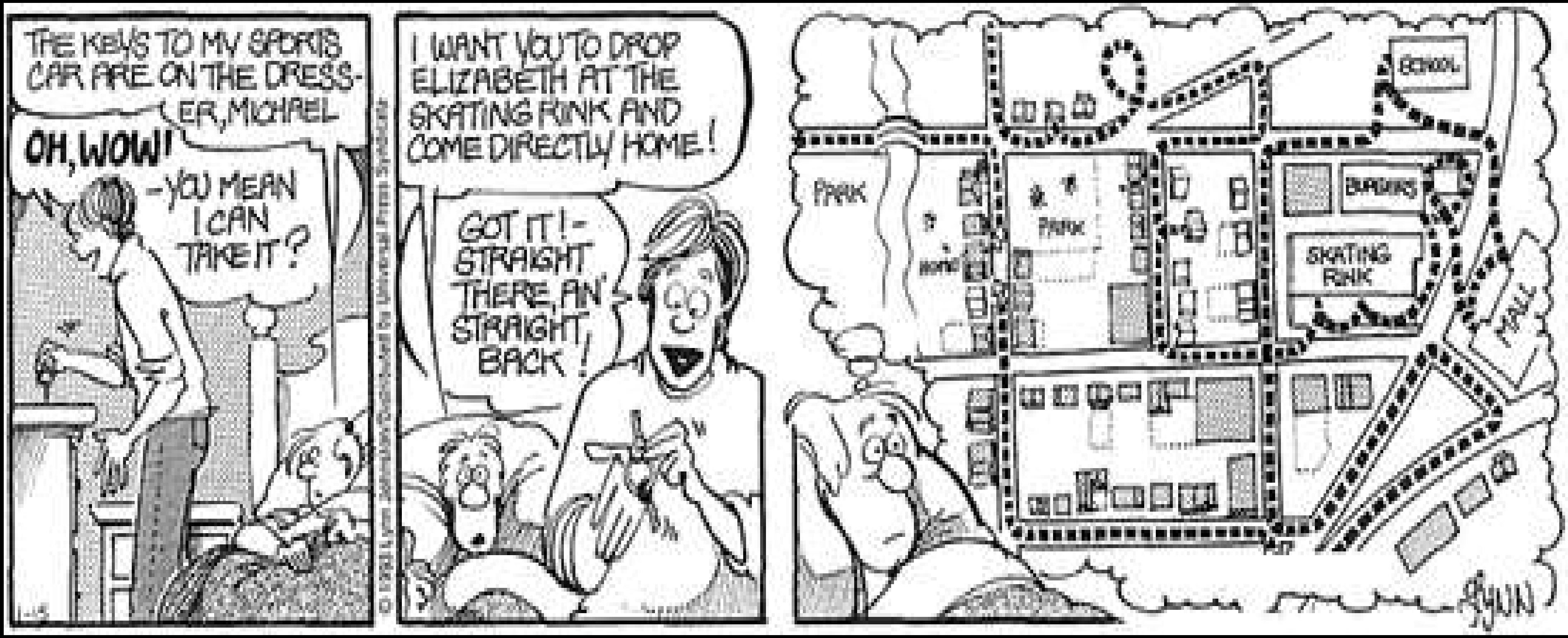
Defining Motion

Position – relative to frame of reference (x or y)

Displacement – change in position (meters)

$$\Delta x = x_2 - x_1$$

Not distance!!




# Distance vs. Displacement

# Describing Motion: Kinematics in One Dimension

1. Distance – scalar (magnitude)
2. Displacement – vector (magnitude and direction)

a. Must give a direction

For example East/West, up/down

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Section 2-2 Average Velocity

# Describing Motion: Kinematics in One Dimension

Average Speed – distance per unit time (scalar)

Average Velocity – displacement per unit time (vector)(meters/second)

$$\bar{v} = \frac{\Delta x}{\Delta t}$$

$\Delta$x = displacement

$\Delta$t = change in time

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Section 2-3 Instantaneous Velocity

Instantaneous Velocity – the average velocity during an infinitesimally short time interval

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

We will only calculate situations with constant velocity or constant acceleration

Calculus is required if acceleration is not constant

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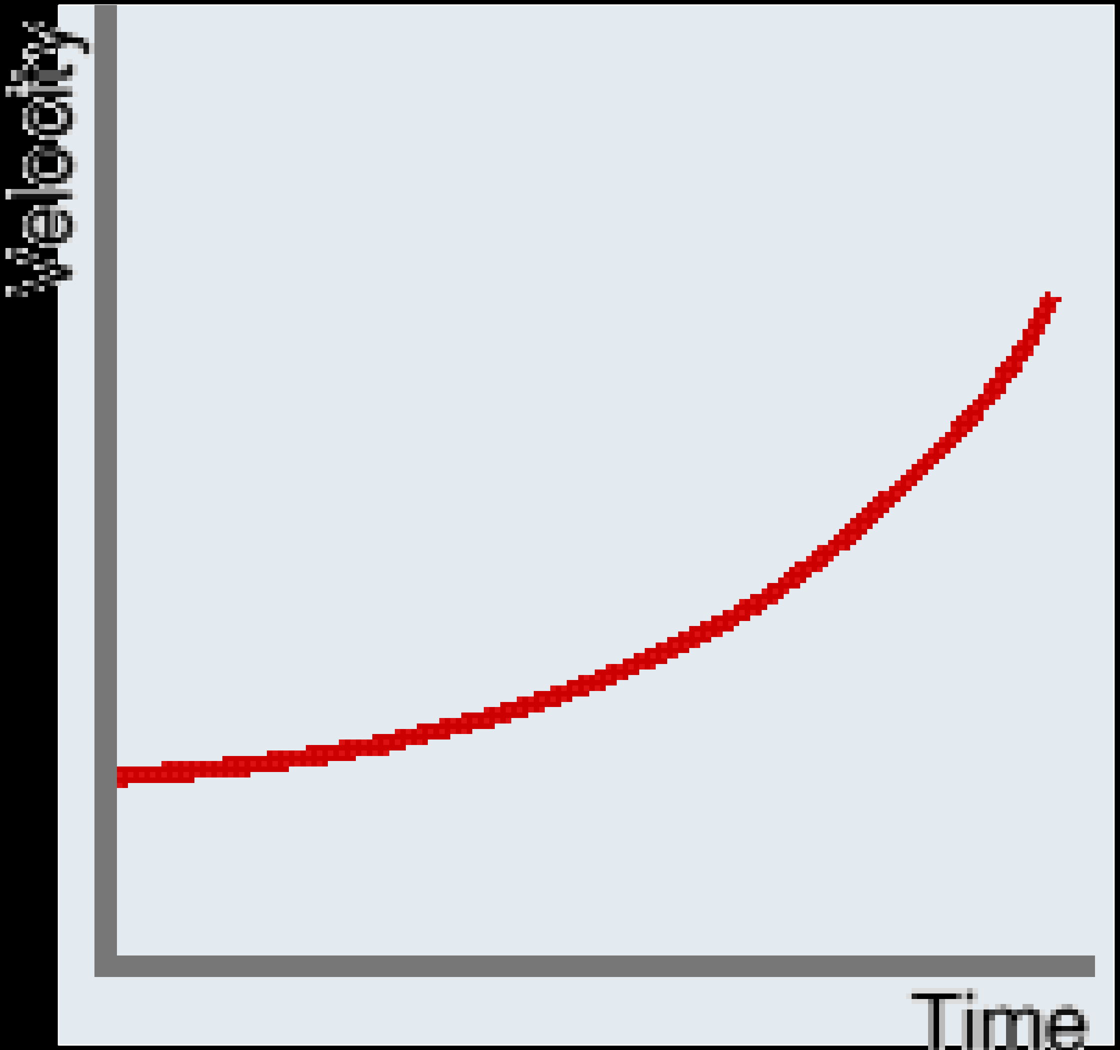
Slope of any displacement time graph is the instantaneous velocity



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Section 2-4 Acceleration

# Describing Motion: Kinematics in One Dimension

Average Acceleration – change in velocity per unit time (vector) (meters/second$^2$)

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

$v$ is final velocity

$v_0$ is initial velocity (or at time 0)

Sign of a indicates direction of vector

Deceleration is just negative acceleration

Acceleration is the slope of the velocity time graph

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Section 2-5 Motion at Constant Acceleration

# Describing Motion: Kinematics in One Dimension

We are limited to calculations when acceleration is a constant

We will use the mathematical definition of displacement, velocity, and acceleration to derive 4 Kinematic equations.

**Memorize these equations – you will use them a lot

# Describing Motion: Kinematics in One Dimension

Assume

$t_0 = 0$, it drops out of equations

We rework the definition of acceleration to get our first working equation

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

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

$$v = v_0 + at$$

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For the second equation we first rework the definition of average velocity to solve for displacement

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

$$x = x_0 + \bar{v}t$$

## Describing Motion: Kinematics in One Dimension

We define average velocity as the average of the initial and final velocity (only possible with constant acceleration)

$$\bar{v} = \frac{v + v_0}{2}$$

Now we combine the last three equations

$$x = x_0 + \overline{v}t$$

$$x = x_0 + \left(\frac{v_0 + v}{2}\right)t$$

$$x = x_0 + \left(\frac{v_0 + v_0 + at}{2}\right)t$$

$$x = x_0 + v_0 t + \tfrac{1}{2}at^2$$

# Describing Motion: Kinematics in One Dimension

For the third equation we start by using a version of the definition of velocity

$$x = x_0 + \bar{v}t$$

Combine with our average velocity definition

$$x = x_0 + \bar{v}t$$

$$x = x_0 + \left(\frac{v_0 + v}{2}\right)t$$

Solve the definition of acceleration for time

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

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

Combine and you get

$$x = x_0 + \left( \frac{v_0 + v}{2} \right) t$$

$$x = x_0 + \left( \frac{v_0 + v}{2} \right) \left( \frac{v - v_0}{a} \right)$$

$$x = x_0 + \frac{v^2 - v_0^2}{2a}$$

Finally, solve for final velocity

$$x = x_0 + \frac{v^2 - v_0^2}{2a}$$

$$v^2 = v_0^2 + 2ax$$

# Describing Motion: Kinematics in One Dimension

The 4th equation is not found in your book, but is in most others

$$x = x_0 + \bar{v}t$$

$$x = x_0 + \left(\frac{v + v_0}{2}\right)t$$

$$x = x_0 + \tfrac{1}{2}(v + v_0)t$$

# Describing Motion: Kinematics in One Dimension

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Section 2-6 Solving Problems

# Describing Motion: Kinematics in One Dimension

- Determine what the object is your are solving for.
- Draw a diagram.  Determine the positive and negative direction for motion.
- Write down any known quantities.
- Think about "The Physics" of the problem.
- Determine what equation, or combination of equations will work under theses Physics conditions.

- Make your calculations.
- See if your answer is reasonable.
- Determine what units belong with the number, and what the direction should be if it is a vector.

A car slows down uniformly from a speed of 21.0 m/s to rest in 6.00s. How far did it travel in this time?

- Object – car
- Diagram

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- Object – car
- Diagram
- Know

$v_0$=21.0m/s

$v$=0m/s

t=6.00s

A car slows down uniformly from a speed of 21.0 m/s to rest in 6.00s. How far did it travel in this time?

- Physics – car is going through negative acceleration in 1D, acceleration is constant
- Equation – needs $v_0$, $v$, t, x (define $x_0$=0)

So

$$x = x_0 + \frac{1}{2}(v + v_0)t$$

A car slows down uniformly from a speed of 21.0 m/s to rest in 6.00s. How far did it travel in this time?

- Physics – car is going through negative acceleration in 1D, acceleration is constant
- Equation – needs $v_0$, $v$, t, x (define $x_0=0$)

Solve

$$x = \tfrac{1}{2}(0 + 21m/s)(6s) = 63m$$

A car is behind a truck going 25m/s on the highway. The car's driver looks for an opportunity to pass, guessing that his car can accelerate at 1.0m/s$^2$. He gauges that he has to cover the 20 m length of the truck, plus 10 m clear room at the rear of the truck and 10 m more at the front of it. In the oncoming lane, he sees a car approaching, probably also traveling at 25 m/s. He estimates that the car is about 400 m away. Should he attempt to pass?

# Describing Motion: Kinematics in One Dimension

- Object – car
- Diagram

- Object – car
- Diagram
- Known quantities

Car relative truckCar relative to App. CarApp. Car

$v_0$=0m/s25m/s25m/s

a=1m/$s^2$ 1m/$s^2$ 0m/$s^2$

x=40m 360m (why?)

4. Physics – car must travel 40 m to pass truck, approaching car can travel maximum of 400-40 m in that same period of time, or their paths overlap

5. Time for car to pass

$$x = x_0 + v_0 t + \tfrac{1}{2} a t^2$$

$$x = \tfrac{1}{2} a t^2$$

$$t = \sqrt{\frac{2x}{a}} = \sqrt{\frac{2(40m)}{1m/s^2}}$$

$$t = 8.94s$$

5. How far did the other car get in that time?

$$t = 8.94s$$

$$x = vt$$

$$x = (25m/s)(8.94)$$

$$x = 223.5m$$

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Section 2-7 Falling Objects (the y-dimension)

We will ignore air friction

We will learn the why later.

Acceleration due to gravity at earths surface is 9.80 $m/s^2$ directed downward (-9.80$m/s^2$)

Symbol g represents acceleration due to gravity

Still use motion equations but

x is replaced with y

a is replaced with g

Two common problems

- Acceleration and velocity are always in the same direction

a. No, as an object is thrown upward, velocity is +y, acceleration is –y

- Acceleration is zero at the highest point.

a. No, at the highest point, the velocity is zero, but acceleration is always $-9.80 m/s^2$

b. The object changes velocity, it must have an acceleration