

# Physics 221

## Sections 1 and 2

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### Motion in One Dimension

#### Part 1: Displacements, Velocity, and Speed

## Announcements

- Set 1 was due this morning on [WebAssign](#). We will discuss it briefly today.
- Set 2 is open and due next Wednesday. It contains problems 3, 5, 9, 13, 21, 23, 39, and 44 from Chapter 2.
- Read sections 6 and 7 in Chapter 2 by next time. The next class will emphasize acceleration, especially the special case of constant acceleration.
- We will skip section 8 in Chapter 2, since it uses integral calculus.

## Today's Homework

- The Chapter 1 problems are 2, 5, 9, and 10 in the text.
- Problem 2 is the basic definition of density – a simple “plug-in” problem.  $\rho = m/V$ . I rarely assign problems with black numbers (easy), but you may do them as practice.
- Problem 5 compares the size of two spheres with different mass. Note that

$$m_2/m_1 = V_2/V_1, \quad V_2/V_1 = r_2^3/r_1^3,$$
$$r_2/r_1 = \sqrt[3]{m_2/m_1}$$

## Today's Homework

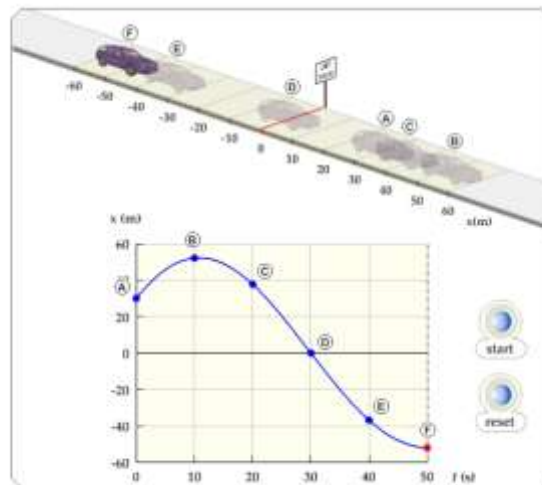
- Problem 9 is a multiple choice problem to select the correct units in Newton's Law of Universal Gravitation:  $F = GMm/r^2$ . Don't confuse  $m$  (mass) with  $m$  (meters).
- Problem 10 is a unit conversion problem. Convert 1/32 inches per day to nm/s.  
1 inch = 2.54 cm =  $2.54 \times 10^7$  nm.  
1 day = 24 x 60 x 60 sec.

## Chapter 2

- For today, you should have looked at the first 5 sections of chapter 2. The topic is Kinematics: how things move, without worrying about why.
- Main concepts:
  - Position
  - Velocity
  - Speed
  - Acceleration
  - Average vs Instantaneous Velocity & Acceleration

## Motion Diagram

A motion diagram shows the position  $x$  of an object as a function of time  $t$ .



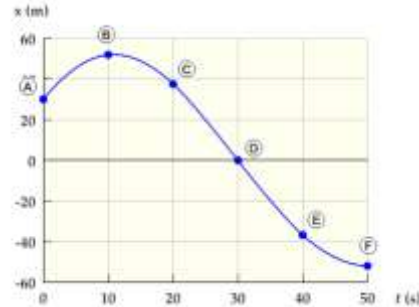
# Displacements

- The difference between two positions is called a **displacement**. Displacements are often denoted using the delta symbol  $\Delta$ .
- The displacement from point A to point B is

$$\Delta x = x_B - x_A.$$

What is this numerically?  $50 \text{ m} - 30 \text{ m} = 20 \text{ m}$ .

What is the displacement from A to F?  $-50 \text{ m} - 30 \text{ m} = -80 \text{ m}$ .



# Average Velocity

- **Average velocity** is defined to be the displacement divided by the time:

$$v_x^{\text{avg}} = \frac{\Delta x}{\Delta t}$$

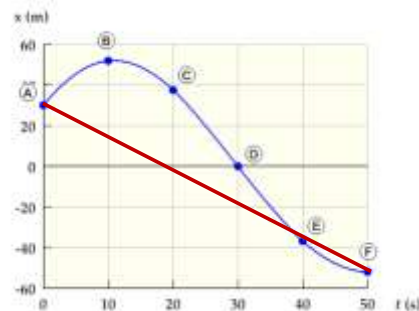
- What is the average velocity for the entire trip?

$\Delta x = -80 \text{ m}$ ,  $\Delta t = 50 \text{ s}$ .

$v_x^{\text{avg}} = -80/50 \text{ m/s} = -1.6 \text{ m/s}$ .

Note the sign!

This is the slope of a line segment from A to F.



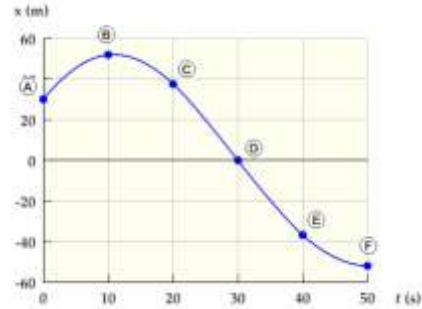
# Average Speed

- Average speed is defined to be the total distance traveled divided by the time:

$$v_{\text{avg}} = \frac{s}{t}$$

where the distance  $s$  is always measured along the direction of motion.

- What is the average speed for the entire trip?



Yes, I used the same symbol  $v$  for speed as for velocity: but note that speed doesn't have a subscript  $x$ : Speed has no direction.

# Average Speed

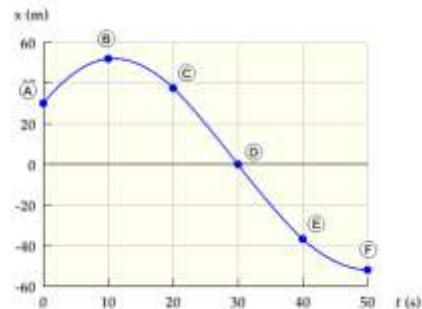
The total distance traveled is

$$\begin{aligned} s &= |x_B - x_A| + |x_F - x_B| \\ &= 20 \text{ m} + 100 \text{ m} = 120 \text{ m}. \end{aligned}$$

The average speed is

$$v_{\text{avg}} = \frac{s}{t} = 120 \text{ m} / 50 \text{ s} = 2.4 \text{ m/s}.$$

Speed is always positive.



## Average Speed

- Two cars go from Dallas to Austin and back. Car 1 goes 70 mph both ways. Car 2 pulls a trailer to Austin and can only go 60 mph, but drops it off and drives 80 mph back to Dallas.
- Which car had the greater average velocity for the entire trip?
- Remember the definition: the net displacement was zero for both cars, since they returned to their starting point. Both had average velocity **zero**.

## Average Speed

- Which car had the greater average **speed** for the entire trip?
- Car 2 spends more time going 60 than going 80, since the distances are equal each way.
- The average speed is a time average, so the 60 mph speed is weighted more than the 80 mph speed, giving an average a little closer to 60 mph.
- What, exactly, is the average speed for car 2?

## Average Speed: Car 2

We need  $v_{\text{avg}} = \text{total distance} / \text{total time}$

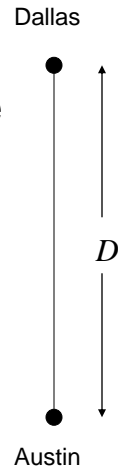
$$= \frac{2D}{t_1 + t_2}.$$

We know:  $t_1 = D/v_1$ ,  $t_2 = D/v_2$

Combine:

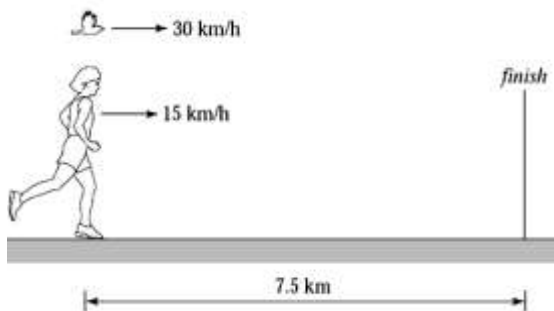
$$t_1 + t_2 = \frac{D}{v_1} + \frac{D}{v_2} = D \left( \frac{v_1 + v_2}{v_1 v_2} \right).$$

$$v_{\text{avg}} = \frac{2D}{t_1 + t_2} = \frac{2v_1 v_2}{v_1 + v_2} = \frac{2 \times 60 \times 80}{140} \text{ mph} = 68.6 \text{ mph}$$



## Runner and Bird

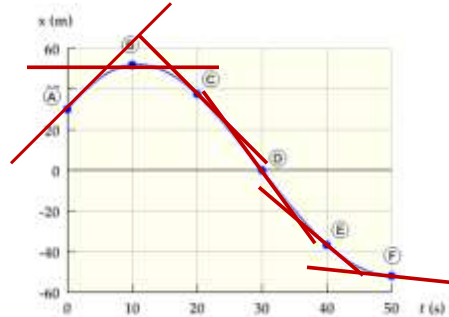
A runner runs at a steady pace of 15 km/hr. When she is 7.5 km from the finish, a bird begins flying from the runner to the finish at 30 km/hr. Every time the bird reaches the finish line, it turns around and flies back to the runner, repeating until the runner reaches the finish line. How far does the bird travel?



$$\begin{aligned} D_{\text{bird}} &= v_{\text{bird}} t_{\text{runner}} \\ &= v_{\text{bird}} \left( \frac{D_{\text{runner}}}{v_{\text{runner}}} \right) \\ &= \frac{30 \times 7.5}{15} \text{ km} \\ &= 15 \text{ km.} \end{aligned}$$

# Instantaneous Velocity

- The speed of the car keeps changing, and so does its direction. It is not enough to just describe average velocities. We also need to talk about **instantaneous velocity**.



This is  $v_x = \Delta x / \Delta t$  for a **very short** time  $\Delta t$ . Graphically, it is the slope of the curve at a point.

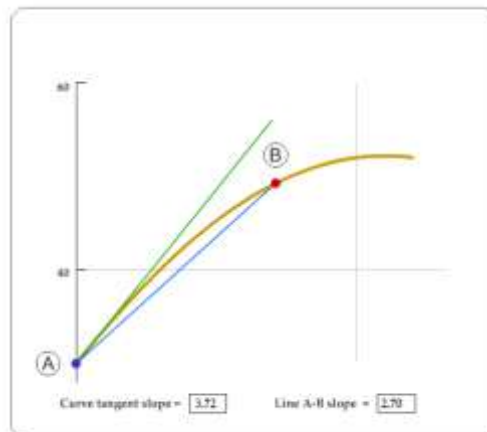
# Instantaneous Velocity

Taking the limit of  $\Delta x / \Delta t$  for  $\Delta t \rightarrow 0$  gives the slope of a line tangent to the curve.

This is called the **derivative** of  $x$  with respect to  $t$ , written  $dx/dt$ .

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

**Instantaneous velocity** = derivative of position with respect to time.



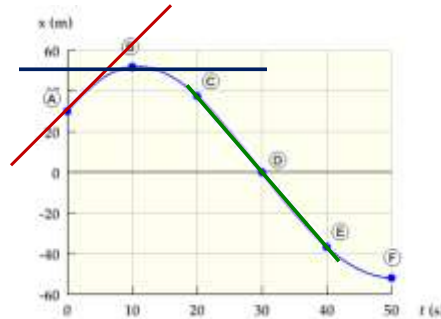
# Instantaneous Velocity

Where is the instantaneous velocity the greatest?

[remember the sign]

Where the slope is greatest and positive: point A.

The minimum velocity occurs where the slope is most negative: point D.



The velocity is zero at a turning point (B), where the slope is zero.