3.2.3: Average Velocity

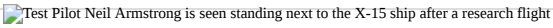

Figure 2.2.1

Test Pilot Neil Armstrong (later to become a famous astronaut) is seen here next to the X-15 ship after a research flight. The servo-actuated ball nose, seen at Armstrong's right hand, provided accurate measurement of air speed at hypersonic speeds. The X-15 was flown over a period of nearly 10 years, and set the world's unofficial speed record of 4,250 mph.

Average Velocity

In ordinary language, the words *speed* and *velocity* both refer to how fast an object is moving, and are often used interchangeably. In physics, however, they are fundamentally different. **Speed** is the magnitude of an object's motion, with no regard for the direction. **Velocity**, on the other hand, includes direction. It is a vector, and thus must have a magnitude and a direction.

Average speed is calculated by dividing the total distance traveled by the time interval. For example, someone who takes 40 minutes to drive 20 miles north and then 20 miles south (to end up at the same place), has an average speed of 40 miles divided by 40 minutes, or 1 mile per minute (60 mph). Average velocity, however, involves total displacement, instead of distance. It is calculated by dividing the total displacement by the time interval. In this example, the driver's displacement is zero (since they start and end at the same point), which makes the average velocity zero mph.

Neither average speed nor average velocity implies a constant rate of motion. That is to say, an object might travel at 10 m/s for 10 s and then travel at 20 m/s for 5 s and then travel at 100 m/s for 5 s. This motion would cover a distance of 700 m in 20 s and the average speed would be 35 m/s. We would report the average speed during this 20 s interval to be 35 m/s and yet at no time during the interval was the speed necessarily 35 m/s.

Constant velocity is very different from average velocity. If an object traveled at 35 m/s for 20 s, it would travel the same distance in the same time as the previous example but in the second case, the object's velocity would always be 35 m/s.

Example

Example 2.2.1

The position of a runner as a function of time is plotted as moving along the x-axis of a coordinate system. During a 3.00 s time interval, the runner's position changes from x_1=50.0 m to x_2=30.5 m. What was the runner's average velocity?

Solution

Displacement=30.5 m−50.0 m=−19.5 m (the object was traveling back toward zero)

Δt=3.00 s

v_{ave}=Δx/Δt=−19.5 m/3.00 s=−6.50 m/s

Example 3.2.3.1

Maria travels by car from Coalinga to Fresno, and back in 2 hours and 40 minutes (160 minutes). The distance between the cities is approximately 70 miles. What is (a) the average velocity of the car, and (b) the average speed of the car in m/s?

Solution

(a) The average velocity of the car is zero (0 m/s) because $x_f = x_i$; the car ends up at the same place it starts.

(b) The average speed of the car is calculated below. Note that the car travels 70 miles one way and 70 miles back, for a total distance of 140 miles.

$$v = \frac{x}{t} = \frac{140 \text{ miles}}{160 \text{ minutes}} \times \frac{1609 \text{ meters}}{1 \text{ mile}} \times \frac{1 \text{ minute}}{60 \text{ seconds}} = 24 \text{ m/s}$$

Observe the differences between constant velocity and average velocity in the simulation below where two silly robots, Irwin and Ruthie, are racing to the elevator:

Another important aspect of velocity is that it is always measured relative to something. We usually measure how fast a person walks or how fast a car drives relative to the ground. In Astronomy, we often measure the motion of the Earth relative to the Sun. A

reference frame is a fixed point and we measure directions relative to it.

Use the following simulation to explore what happens when two bikers approach each other at various velocities and be sure to click on different observers each time to observe their motion from different reference frames:

Summary

- Average speed is distance divided by time.
- Average velocity is displacement divided by time.

Review

1. On a one day vacation, Jane traveled 340 miles in 8.0 hours. What was her average speed?
2. An object on a number line moved from x = 12 m to x = 124 m and moved back to x = 98 m. The time interval for all the motion was 10 s. What was the average velocity of the object?
3. An object on a number line moved from x = 15 cm to x = 165 cm and then moved back to x = 25 cm, all in a time of 100 seconds.
    1. What was the average velocity of the object?
    2. What was the average speed of the object?
4. If you have spent much time driving, you probably have a good sense of speeds between about 10 and 70 miles per hour. But what are these in meters per second? What do we mean when we say that something is moving at 10 m/s? To get a better sense of what these values really mean, do some observations and calculations on your own:
    1. Calculate typical car speeds in meters per second
    2. Estimate jogging and walking speed by timing yourself; convert the measurements into both m/s and mi/h
    3. Determine the speed of an ant, snail, or falling leaf

Explore More

Use this resource to answer the question that follows.

1. What is the main difference between average speed and average velocity?

Additional Resources

PLIX: Play, Learn, Interact, eXplore: Velocity

Video:

Real World Application: How Fast Does A Gravitational Wave Travel?

Study Guide: Motion Study Guide
